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The application of multivariate analysis approaches to designing NSBM model considering undesirable variable and shared resources

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Abstract. Due to the competitiveness of the banking industry and the increasing bargaining power of customers, evaluating the performance of banks is crucial to better serve classified customers in a universal system. In this paper, by dividing the customers into personal and business ones, methods such as Confirmatory Factor Analysis (CFA) and Structural Equation Model (SEM) were used for selecting appropriate variables of the Network Data Envelopment Analysis (NDEA) model based on the network slacks-based measure while considering undesirable variables and shared resources. The SEM model was used to establish a proper connection between different dimensions of the NDEA model, and the CFA model was used to identify the importance of each dimension. Moreover, the proposed model was used to evaluate the operational and decomposed universal efficiency of one of the Iranian bank branches (Bank Day). The results showed that the extracted model provided managers with a suitable perspective for adopting appropriate policies to promote banking performance in the different sectors including deposit attraction, financial serving personal and business banking customers, and profit generation and, also, to compare them based on different dimensions of the model.

1. Introduction

In the current competitive environment of industry, efficiency measurement plays a crucial role in achieving and facilitating sustainable development [1]. Charnes, Cooper and Rhodes were the first who proposed the data envelopment analysis with the CCR approach for measuring the relative efficiency of Decision-Making Units (DMUs). In this model, relative efficiency is given through the ratio of inputs to outputs [2]. In traditional models, the DMUs behave like black boxes to which inputs are inserted and outputs exit irrespective of the inner distances [3].

However, given that some production systems have a network-like structure and the output of one stage becomes the input of the next stage [4], unlike the classical Data Envelopment Analysis (DEA), Network Data Envelopment Analysis (NDEA) helps not only model the organization, but also measure the efficiency of the model components [3,5–7].

NDEA has a strong potential to be widely applica-

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ble in the real world and provides managers with valuable information [8]. A bank's production system has a two-stage structure for producing resources: attracting deposits and allocating facilities to customers [9]. Considering the benefits and generalizability of the model, the banking industry, like other industries, is no stranger to the application of the NDEA model for measuring the efficiency of different sectors [10]. In recent years, the efficiency of some banks has been evaluated through NDEA in terms of customer segmentation (personal and business groups). Using a three-stage model with two independent parallel stages (personal banking and business banking) merged in the last stage, Ebrahimnejad et al. evaluated the efficiency of 49 bank branches [11].

One of the important issues concerning Network Slacks-Based Measure (NSBM) and Slacks-Based Measure (SBM) models is the existence of undesirable variables such as non-current facilities of the banks. Huang et al. proposed the application of the US-SBM model, which is the integration of super-efficiency model based on slack variables and undesirable inputs/outputs [12]. Fukuyama and Weber also studied the NSBM model that considers undesirable variables [4]. Huang et al. developed a super-efficiency NSBM model while considering the undesirable variables of the US-NSBM model and applied it to the efficiency measurement of Chinese Banks [13]. For the first time, Tavassoli et al. proposed a new super-efficiency model for ranking DMUs in the presence of both zero data and undesirable outputs simultaneously. The proposed model may have a good chance to work fine when input or output data are zero [14]. Using the results of the paper by Olfat et al. [15], the NSBM model was studied while taking desirable and undesirable variables in the universal banking system into account.

The other issue concerning the NDEA model is the shared resource flows in the network processes. Zha and Liang presented an approach to the study of shared flows in a two-stage production process in series. Their approach is based on the assumption that shared inputs can be freely allocated among different stages [16]. Wu et al. set different proportions of each shared resource for different DMUs to evaluate the efficiency of a parallel transportation system [17]. Zegordi and Omid introduced a new approach to assess the partial effectiveness of each sub-process and the overall efficiency of the hand-made carpet industry in the form of a multi-stage system with extra inputs, undesired outputs, and shared variables [18]. Tavassoli et al. [19] proposed a novel slacks-based measure network data envelopment analysis (SBM-NDEA) approach to measure both technical efficiency and service effectiveness of airlines. By using the results obtained by Tavassoli et al. and Zha and Liang [16], the NSBM model was studied while considering shared resources.

One of the problems in developing the DEA-based efficiency evaluation methods is to assess the model validity, given a wide range of input and output indicators [20,21]. It should be pointed out that DEA models are sufficiently valid if their inputs and outputs are identified properly. This identification has a significant role in model validation [22]. The evaluation of DMUs with a wrong model would lead to misidentifying appropriate efficient frontiers and, consequently, inaccurate recognition and correct segregation of the model components. Hence, to measure the efficiency of each DMU, selecting the inputs and outputs of each system and ensuring the quality of the correct models are very important [23].

In practice, many variables can be considered as indicators that affect efficiency. Each variable has to be defined as the input or output of the unit. There are different approaches to identifying inputs and outputs of the banks; however, the major ones are intermediate and production approaches. In the intermediate approach, banks use labor, capital, and deposits to create financial obligations and, mainly, create loans and different financing facilities. However, in the production approach, loan and deposit are also considered as outputs and only labor and capital as inputs [24]. A large number of input and output variables require more dimensions of the problem-solving space that reduces the accuracy of the analysis [21]. Further, a large number of variables in the analysis can reduce the difference between the efficiency scores of the units, in which eventually more units are considered to be efficient [25].

A number of studies have investigated the improvement of validity through efficiency analysis [26–29]. For example, Adler and Yazhemsky (2010) investigated the application of Principal Component Analysis (PCA) and Variable Reduction (VR) methods to the process of efficiency estimation, and the results showed more strength and greater stability of the PCA method [28]. Independent component analysis (ICA) is also a method based on the characteristic selection and the developed version of PCA used in identifying the independent components of the observed data [30]. ICA attempts to eliminate a part of the observed data information that features little or no improvement in the efficiency of the units [29]. In this regard, the NSBM model, as proposed by Lin, based on the production, serving consumer and corporate customers, and profitability and by the use of the ICA, managed to identify the primary source of inefficiency by revealing the latent variables that consist of independent components and are considered as input, intermediate or new output in the network model [31]. Ebrahimpour et al. designed the NDEA model based on supply chain. With the application of PCA and the contribution of 115 experts and specialists, their proposed model was configured with four factors (latent variables) including financial, responsiveness, collaborative, and knowledge-based factors; then, the model was applied to pharmaceutical companies [32].

Recent studies have largely neglected the application of multivariate analysis approaches to selecting appropriate indicators in NDEA and creating significant models in the relationship between NDEA in the banking industry and customer segmentation approach. To cover this identified gap, this research aims to incorporate the NDEA model and multivariate analysis methods in order to select appropriate and significant variables and create a significant network model based on the path analysis of the Structural Equation Modeling (SEM). The selected variables are applied to the NDEA model and, finally, the efficiency of the banks is evaluated in four respects: production, finance, serving personal and business customers, and profit generation. The solution of the proposed model that considers undesirable intermediate variables, such as Non-Performing Loans (NPLs), helps managers better identify the inefficient sources and, eventually, make strategic decisions to improve the quality level of customer services.

In all of the mentioned studies concerning the application of the NSBM model, the weights of model components were equally considered. Thus, according to the identified gap, in this paper, along with the use of Confirmatory Factor Analysis (CFA), the weight of each component is identified by the experts in the banking industry.

The rest of the paper is organized as follows: Section 2 presents the literature of the NDEA, some examples, and related problems and the application of the multivariate analysis methods for selecting appropriate indicators in efficiency measurement models. Then, in the research methodology section, SEM, CFA, and the proposed NSBM model while considering undesirable variables and shared resources in the universal banking system are presented. In Section 4, the proposed model is applied to one of the Iranian bank branches and the results are discussed. Finally, conclusion and future research ideas are given.

2. Literature review

Efficiency is one of the most important criteria in the performance evaluation of the organizations, especially in financial institutions like banks. The first step in the efficiency improvement process is efficiency measurement and evaluation. In recent years, given the economic growth in developing countries and market-oriented banking based on customer needs, valuable experiences have been gained and much research on the banks' efficiency has been conducted in the developing countries, including Iran [33–43]. These studies show that successful banks have segmented their customers in order to achieve a better understanding of their short-term and long-term needs. In this segmentation, some of the real or legal customers have been identified as special customers with different needs. Thus, to provide more specialized services, personal and business banking has been considered to serve real and legal customers, respectively [11,31].

In the following, studies about the network DEA models that have been applied to the banking industry and those on different methods of selecting appropriate indicators in DEA models are reviewed.

2.1. *Review of NDEA, some examples, and related problems*

In the model presented by Charnes et al. [2], DMUs are seen as black boxes, i.e., their internal structures are not considered. Castelli, Pesenti and Ukovich reviewed those models that consider internal structures of DMUs. The main rationale for the classification is driven by the realization that the three groups of models are different generalizations of the same elementary formulation. In particular, shared flow models are applied when it is possible to partition a DMU as a collection of components whose inputs and/or outputs compete with other components of the same DMU. Multi-level models are used when some inputs (or outputs) of a DMU are also inputs (or outputs) of its subunits and some other inputs (or outputs) are not. Furthermore, network models are introduced when intermediate flows among the subunits are taken into account [44]. NDEA is used to compute the partially efficient performance and overall performance within an integrated framework. The network structure that connects different stages of the inputs and intermediate outputs of a set of processes was introduced by Fare in 1991 and developed later on [45-50]. Since the original DEA formulation representing DMUs as black boxes in a constant returns to the scale environment, many authors have proposed more sophisticated or alternative approaches that include the non-radial measuring of efficiency, value judgment, and the economic measuring of efficiency. So far, these extensions have received insignificant attention when DMUs have an identifiable internal structure, especially in the case of multi-level and network models [44].

Network DEA allows an analyst to look into the DMU and provides a penetrating insight into the sources of organizational inefficiency. In the network DEA, each DMU comprises two or more sub-DMUs. Each resource consumed by a sub-DMU either enters the DMU from outside (input to the DMU) or is produced by another sub-DMU (intermediate product). Each product produced by a sub-DMU either exits the DMU (output of the DMU) or is consumed by another

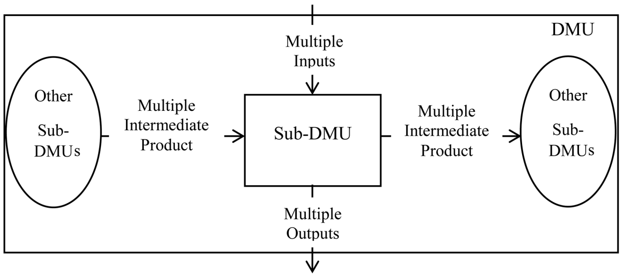

Figure 1. A typical network DEA DMU.

sub-DMU (intermediate product). A typical network DEA DMU is presented in Figure 1 [51].

Based on the two basic ideas of efficiency measurement, i.e., distance measure and output-input ratio, nine categories of Network DEA models are classified as follows: 1- independent, 2- system distance measure, 3- process distance measure, 4- factor distance measure, 5- SBM, 6- ratio-form system efficiency, 7- ratio-form process efficiency, 8- game-theoretic, and 9- value-based. Model structures are categorized as follows: basic two-stage, general two-stage, series, parallel, mixed, hierarchical, and dynamic. Distance measure models, especially process-based ones, are one of the key focuses of network DEA studies, to be developed and continued for sure. SBM models are relatively new, which appear to gain growing interest [52].

Supply chains are examples of complex multi-stage systems with temporal and causal interrelations that involve multi-input and multi-output production and services by using fixed and variable resources. Given the lack of a systematic view, the need to identify system-wide and individual effects and incorporate a coherent set of performance metrics, the recent literature points to reports of an increasing, yet limited, number of applications of frontier analysis models (e.g., DEA) for the performance assessment of supply chains or networks. The relevant models in this respect are multi-stage models with various assumptions on the intermediate outputs and inputs, enabling the derivation of metrics for assessing technical and cost efficiencies of a system and the autonomous links. The analysis shows several open problems in the application of DEA to supply chain performance measurement. First, the existing models demonstrate the limitations and rigidity of the model specification process. Second, most models lack a clear economic or technical motivation for the intermediate measures. Third, the existing literature largely neglects the explicit modeling of the power or governing structures within a supply chain. Fourth, the relevant literature mostly takes into account the predominance of multiplicative models [53].

Koronakos et al. revisited the basic and some recently introduced network DEA models to reformulate them in a common modeling framework. They showed that the leader-follower approach, the multiplicative and additive decomposition methods, the recently introduced min-max method, and the "weak-link" approach could all be modeled in a multi-objective programming framework; these methods differ only in terms of the definition of the overall system efficiency and the adopted solution procedure. The proposed common modeling framework permits a straightforward comparison between different methodologies. This enables the analyst to comprehend the specific characteristics of each methodology and the way each methodology approaches the performance assessment task so as to select an appropriate model to employ in assessment exercise [54].

Pitfalls in the network DEA were discussed by Chen et al. with respect to the determination of divisional efficiency, frontier type, and projections. They demonstrated that, under general network structures, the multiplier and envelopment network DEA models were two different approaches. The divisional efficiency obtained from the multiplier network DEA model could be infeasible in the envelopment network DEA model. This indicated that these two types of network DEA models applied different concepts of efficiency. It was demonstrated that the divisional efficiency scores based on the envelopment model did not necessarily represent divisional efficiencies and might actually be the overall efficiency. This indicates that caution needs to be exercised when developing a network DEA model using production possibility sets [55].

The fundamental approaches to two-stage NDEA include the multiplicative and additive efficiency decomposition approaches. They differ in the definition of the overall system efficiency and the way they conceptualize the decomposition of the overall efficiency to the efficiencies of the individual stages. Despotis et al. first showed that the efficiency estimates obtained by the additive decomposition method were biased by unduly favoring one stage over the other, while those obtained by the multiplicative method were not unique. They presented a novel approach to estimate unique and unbiased efficiency scores for the individual stages, which were then composed to determine the efficiency of the overall system [56].

A usual assumption shared amount most researchers is the tendency to modeling the weights of the multi-stage model (i.e., decomposition weights), implicitly reflecting the relative significance of different stages in a DMU as variables and assuming that the weights have a specific structure, such that the original problem can be converted to an equivalent LP. Specifically, Ang and Chen found that the decomposition weights could not initiate an increase from the first to the last stage in certain multi-stage DEA models, implying that the model always assigns a higher (or not lower) priority to the upstream stages in efficiency decomposition. As an alternative to the models with endogenous weights, the additive DEA model was investigated in which weights were pre-determined by the evaluator based on his/her perception of different production stages. Since weights are set to be constant in this model, the problem due to endogenous weights is circumvented. They illustrated that the standard multi-stage model might generate spurious weights and efficiency scores when the importance of different production stages in the model could be articulated [57].

A successful efficiency evaluation protocol should satisfy the dominance property at the divisional efficiency level. To be specific, there should not be any other feasible solution in the assessment model (sub-optimal in terms of optimality criterion) that provides stage efficiency scores at least as high as the assessed ones and higher than the assessed ones for at least one stage. Sotiros et al. investigated the dominance property of different methods for the two-stage series processes of various complexities. They proved that the additive efficiency decomposition method and the relational model provided non-dominated divisional efficiencies when applied to elementary two-stage processes, where nothing but the external inputs to the first stage can be added to the system and nothing but the external outputs of the second stage leave the system [58].

2.2. NSBM of efficiency

NDEA models based on radial performance models should be implemented with the assumption of Constant Return to Scale (CRS). For example, models based on BCC and CCR models are based on a basic methodology and a production possibility set. CRS reflects the fact that output varies by the same proportion as inputs do. In this study, weighted NSBM is carried out considering Variable Returns-to-Scale (VRS) and non-orientation. In the application of DEA, the SBM by Tone [59] has gradually become the non-radial model of choices. VRS is more desirable because it processes information on returns to scale of operations for each DMU while avoiding inappropriate utilization of performance [60].

VRS is particularly suitable in NDEA and attempts to capture the interactions among multiple divisions within each DMU and for different scales of operations found in business organizations. Essentially, VRS modeling purges efficiency estimates of the impact of scale of operations. Non-directional and non-radial models are used in a larger number of studies and are more widely applied in the business world and reality. For example, non-oriented models consider simultaneous input reductions and output expansions [61]. Similarly, non-radial models deal with slacks of each input/output individually and independently and integrate them into an efficiency measure [59].

Lothgren and Tombour [62] applied a network DEA model to a sample of Swedish pharmacies with organizational objectives that necessitated the monitoring of efficiency, productivity, and customer satisfaction. They compared the results of network DEA models with those of traditional DEA models. Tone and Tsutsui [7] developed this model using an SBM called the NSBM. The NSBM approach is a non-radial method and is suitable for measuring efficiencies when inputs and outputs may change non-proportionally [63].

Eqs. (1) to (7) define the DMU level network efficiency estimated based on NSBM. If weighted summation in Eq. (1) is equal to 1, all divisions of a branch must also be efficient.

$$(NSBM)\,\theta_0 =$$

$$\min \frac{\sum_{k=1}^{K} w^k \left[1 - \frac{1}{m_k}\left(\sum_{i=1}^{m_k} \frac{s_i^{k-}}{x_{io}^{K}}\right)\right]}{\sum_{k=1}^{K} w^k \left[1 + \frac{1}{r_k}\left(\sum_{r=1}^{r_k} \frac{s_r^{k+}}{y_{ro}^{K}}\right)\right]}, \tag{1}$$

$$\text{s.t.}\quad X_o^k = X^k\lambda^k + S^{k-}\,(k = 1, \ldots, K)\,, \tag{2}$$

$$Y_o^k = Y^k\lambda^k - S^{k+}\,(k = 1, \ldots, K)\,, \tag{3}$$

$$e\lambda^k = 1 \ \text{ Constraints relating to Variable Return to Scale (VRS)}, \tag{4}$$

$$Z_o^{(k,h)} = Z^{(k,h)}\lambda^h \forall\,(k,h)\,, \tag{5}$$

$$Z_o^{(k,h)} = Z^{(k,h)}\lambda^k \forall\,(k,h)\,, \tag{6}$$

$$\lambda^k, s^{k-}, s^{k+}, w^k \geq 0 \text{ The last general constraints}, \tag{7}$$

where:

o	Observed DMU, $o = 1, ..., N$
N	Number of DMUs
k	Number of divisions
m	Number of inputs
r	Number of outputs
s_i^{k-}	Input slacks
s_i^{k+}	Outputs slacks
λ^k	Intensity
$Z^{(k,h)}$	Intermediate product link between division j and division h
$\{X_j^k \in R_+^{m_k}\}$	Input matrix for division k, $(j = 1, \ldots, n : k = 1, \ldots, K)$
$\{y_j^k \in R_-^{r_k}\}$	Output matrix for division k, $(j = 1, \ldots, n : k = 1, \ldots,)$
$\sum_{k=1}^{K} w^k = 1$	The relative weight of division k determined exogenously

2.3. A review of the efficiency measurement indicators

Regarding the bank deposits, there are two basic approaches to the efficiency measurement of the banks: the production approach and the intermediate approach. In the production approach, deposits are treated as the bank output because they are actually considered as a service provided by the banks [64-66]. In the financial intermediary approach, the bank becomes active as an intermediary who uses the deposits and dedicates facilities to customers, in which the deposits are treated as inputs [67–74]. One of the advantages of the NDEA is that it considers the deposits as intermediate variables and in the position of the input and output [9].

In this paper, the indicators of the NDEA model have been previously examined from different perspectives. Thus, according to the available literature, the indicators of the efficiency measurement model for the bank branches are classified into six categories, as shown in Table 1.

2.4. The indicator selection methods for the DEA model

Table 2 shows the studies that have applied statistical methods and multivariate analysis to the selection of appropriate indicators for the DEA models.

3. The research methodology

The procedure of this research is implemented as the flowchart of Figure 2, described in detail in the following.

3.1. SEM to create a significant model of efficiency measurement of the bank branches

Structural path modeling (an approach based on the variance-based SEM or Partial Least Squares SEM (SEM-PLS)) and structural equation model (a covariance-based approach) originate in the main complex data structure and multivariate data analysis methods whose principal feature is the analysis of multiple independent or dependent variables [97]. The PLS method has been developed as the second generation of structural equation models; this model is superior to the covariance-based method due to a number of advantages including the use of normal or abnormal data, predictability and development of a new model, and insensitivity to the sample size [98,99,100]. In this stage, through the distribution of questionnaires among 60 experts in the banking industry, the importance of every input and output indicators has been investigated by means of a five-scale Likert in each of the resource attraction processes in terms of serving real and legal customers, profitability, and the results shown in Table 3. Then, by applying the SEM-PLS modeling using SmartPLS V3 software, a significant model for selecting appropriate input, intermediate, and output indicators in each dimension of the model has been extracted.

After the implementation of the model, factor

Table 1. The literature review of the efficiency measurement model for the bank branches.

Factors	Indicators	References
Branch cost	**Non-operating cost:** General cost, depression cost, rent cost, value equipment cost	[11,13,75]
	Operating Cost: Saving deposit cost	[8,11,31]
Characteristics and potential branch	Location potential	[76,77,78,79,80]
	Number of documents (workload)	[78,79,81]
Deposits	Saving deposits, investment deposit, Checking deposits	[11,31,75,82,83,84]
Satisfaction	Satisfy customers	[79,85,86]
Banking Service	Current loans	[31,75,83,87]
	Non-Performing Loans (NPLs)-bad loans	[11,31,84,87]
Profitability	Interest income	[11,31,82,84,88,89]
	Non-interest income (of loans) (Fee loan- commission loan, interest loan)	[11,31,84]
	Fee banking service	[82,83,90]

Table 2. The literature review of the statistical methods and multivariate analysis in the selection of appropriate indicators for the Data Envelopment Analysis (DEA) models.

Author(s), Year	Method	Results
Chen, P. and Liu, C.Z., 2007	SEM, DEA	By performing the analysis of the DEA model and according to the Structural Equation Model (SEM), productivity in the housing market was studied. The impact of the exogenous criteria on the indicators in the SEM was demonstrated. Then, the efficiency of 31 different areas was estimated by the DEA model. The results showed that the two diverse trends in the housing market and in the 31 different areas of China, without any internal ordering, were explainable [91].
Wagner, J.M. and Daniel, G.S., 2007	Stepwise selection-DEA	In this study, a backward stepwise approach was used for variable selection that involves sequentially maximizing (or minimizing) the average change in the efficiencies under the removal or addition of the variables from the analysis. This method considers all the possible variables involved in the DEA model. In each step, a variable was eliminated by analyzing the efficiency scores of the decision-making units. From a theoretical point of view, this method can proceed to the extent that we have only one input variable and one output variable. From a practical point of view, the stopping rules can be incorporated into the model using the decision criterion. The obtained model was applied to Tokyo's hotels and, from six input variables, three variables with no significant impact on the efficiency were excluded [92].
Nataraja, N.R., Johnson, A.L., 2011	ECM, PCA, regression-based test, bootstrapping, DEA	In the studies that were conducted at Texas University in 2011, named as "guidelines for using variable selection techniques in data envelopment analysis", four common approaches were used: Efficiency Contribution Measure (ECM), Principal Component Analysis (PCA), regression-based test, and bootstrapping. By using Monte Carlo simulations, the results of the four methods for a three-input, one-output production process showed that, for highly correlated inputs (greater than 0.8) and even for small datasets (less than 300 observations), PCA-DEA performs well; for a low correlation (less than 0.2) and relatively larger datasets (at least 300 observations), the regression and ECM approaches perform well. Bootstrapping performs relatively poorly and its computational time is greater than the three other methods [93].
Aslan, N., Shahrivar A.A., Abdollahi, H., 2012	GEA-DEA	Investigation of the combined approach with the two-stage DEA to predict the financial failure and integrated super-efficiency DEA (SE-DEA) approach with Grey Relational Analysis (GRA) was done for the selection of indicators. In this paper, to apply the two-stage DEA, it is required to select the related indicators from a set of candidate indicators. Thus, the integration model of SE-DEA model and GRA was used to select financial indicators that have a significant correlation with the financial state of the organization [94].
Lin, T.Y., Chiu, S.H, 2013	ICA_NSBM	This model has been developed with four dimensions of performance including production, corporate banking, consumer banking, and profitability for the efficiency measurement of Taiwan's banks. In this model, the Independent Component Analysis (ICA) was applied to select new input, intermediate, and output variables, which are unrelated to Independent Components (ICs), and create new latent variables. The results showed that the proposed ICA-NSBM model had a significant relationship with the NSBM model and was capable to predict the inefficiency of each dimension of the model with higher accuracy [31].

Table 2. The literature review of the statistical methods and multivariate analysis in the selection of appropriate indicators for the Data Envelopment Analysis (DEA) models (continued).

Author(s), Year	**Method**	**Results**
Qin, Z., Song, I, 2014	ECM, RB, Lasso, DEA	In this study, a data-based variables group selection method for DEA, a non-parametric linear programming approach for estimating production frontiers, was developed. This study developed a new least absolute shrinkage and selection operator (Lasso), which is from the variables group selection tools in the linear regression model, and applied it to DEA models. In particular, a particular constrained version of the group Lasso with the loss function, which is suited for variable selection in DEA models, is derived and solved by a new algorithm based on the Alternating Direction Method of Multipliers (ADMM). By carrying out Monte Carlo simulations, the performance of the proposed method was evaluated against the Efficiency Contribution Measure (ECM) method and the Regression-Based (RB) test, and covariance structure of inputs, sample size, the importance of inputs, and the dimensionality of the production space were estimated. The simulation results showed that this method exhibited an acceptable performance [95].
Ebrahimpour, M. Olfat, L., Amiri, M. et al., 2013	NDEA-EFA	The network DEA was developed based on the supply chain. Through explanatory factor analysis and the contribution of 115 experts and specialists, the data were classified into financial, responsive, collaborative, and knowledge-based factors. This model was applied to pharmaceutical companies [32].
Chao, H., Chong, D. Miao, G., 2015	SE-DEA and GCA	Identifying the grey relational degrees considered as the quantity of the similarity and relationships of the discrete data, the GRA method identifies the ranking of the indicators. In this study, the objective of the GRA is to calculate the GRD between the financial state and financial indicators and, accordingly, to select the key effective indicators. The empirical analysis results of the Chinese companies showed the superiority of the two-stage DEA model and integrated the models of SE-DEA and CGA into the CCR and BCC models [96].

Table 3. The validation results of the final structural equation model.

	AVE (> 0.5)	**Composite reliability (> 0.7)**	**R-square 0.33 average and 0.67 noticeable**	**Cronbach's alpha (> 0.7)**
Dimension/ statistical indicators	Average variance Extracted convergent validity	Measurement of the internal correlation of the observed variables of each latent variable	Coefficient determination, estimating the amount of changes in the endogenous variable by the exogenous variable	Internal measurement of the variable observed for each latent variable
Cost	0.580	0.803	–	0.743
Deposits	0.745	0.854	0.370	0.732
Business banking service	0.710	0.831	0.491	0.856
Personal banking service	0.735	0.847	0.482	0.836
Profitability	0.643	0.876	0.418	0.812

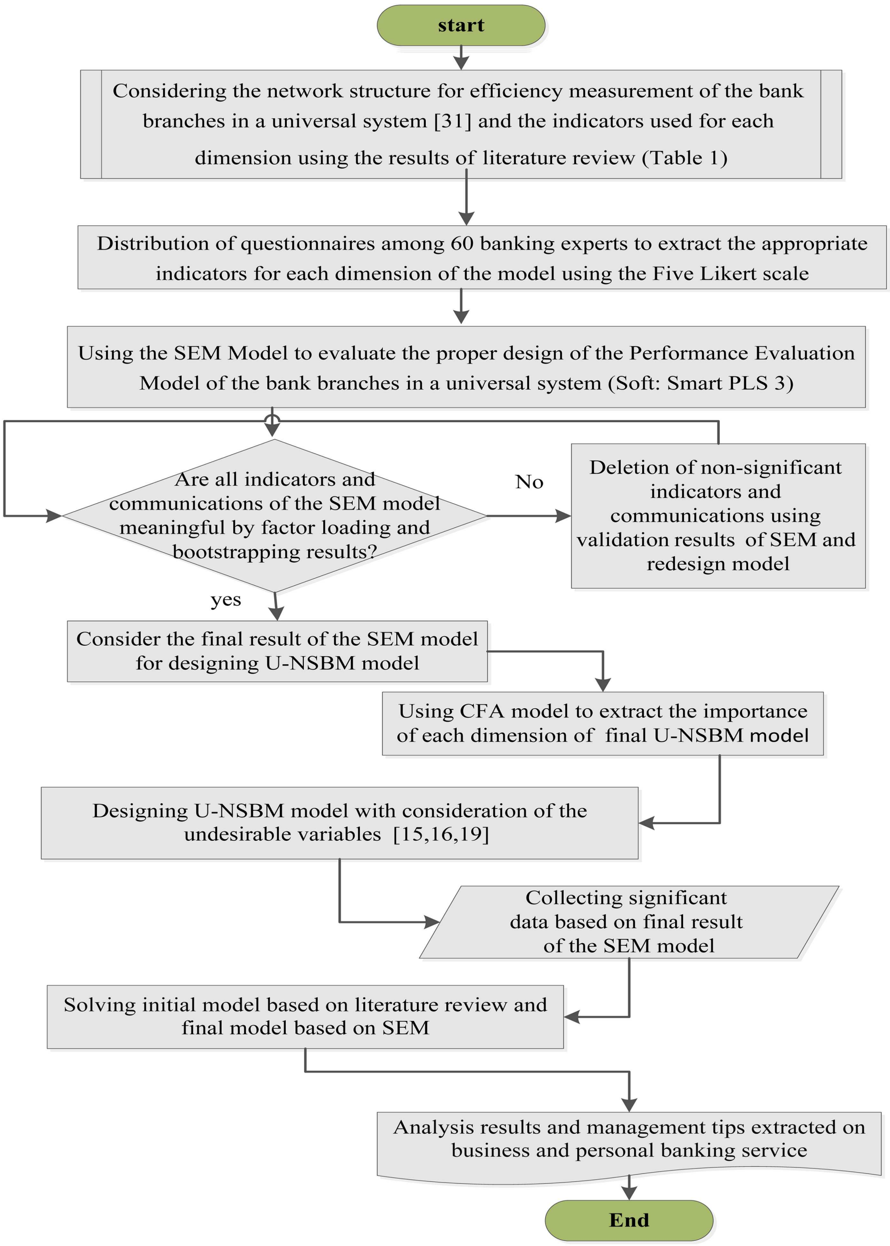

Figure 2. Process of designing NSBM model by multivariate analysis approaches.

loadings and the criteria for assessing the structural part of the model are summarized in Figure 3. The factor loadings are obtained by calculating the correlations between the measures and their respective constructs. If these values are greater than or equal to 0.4 with the significance values (bootstrap results) at a significance level of 0.95 with a value less than 1.96, then the validity of the relationship between the measures and constructs is shown. Therefore, according to Figure 3, measures of no significance are removed from the model and, after the re-running, a significant model is extracted as shown in Figure 4.

The validation results of the final model show the significance of the final model in Table 3.

3.2. Using CFA model to extract the weights of each dimension of the NSBM model

In this stage, to determine the weights of each dimension of the original NSBM model, using the provided questionnaire distributed among 60 banking industry experts, the importance of the final selected indicators in the factor analysis model is related to the four factors (deposits attraction, serving personal customers, serving business customers, and profitability) and, finally, four secondary factors construct the efficiency. The results of the implemented model along with bootstrapping are shown in Figure 5. Factor loadings and bootstrapping results at a significance

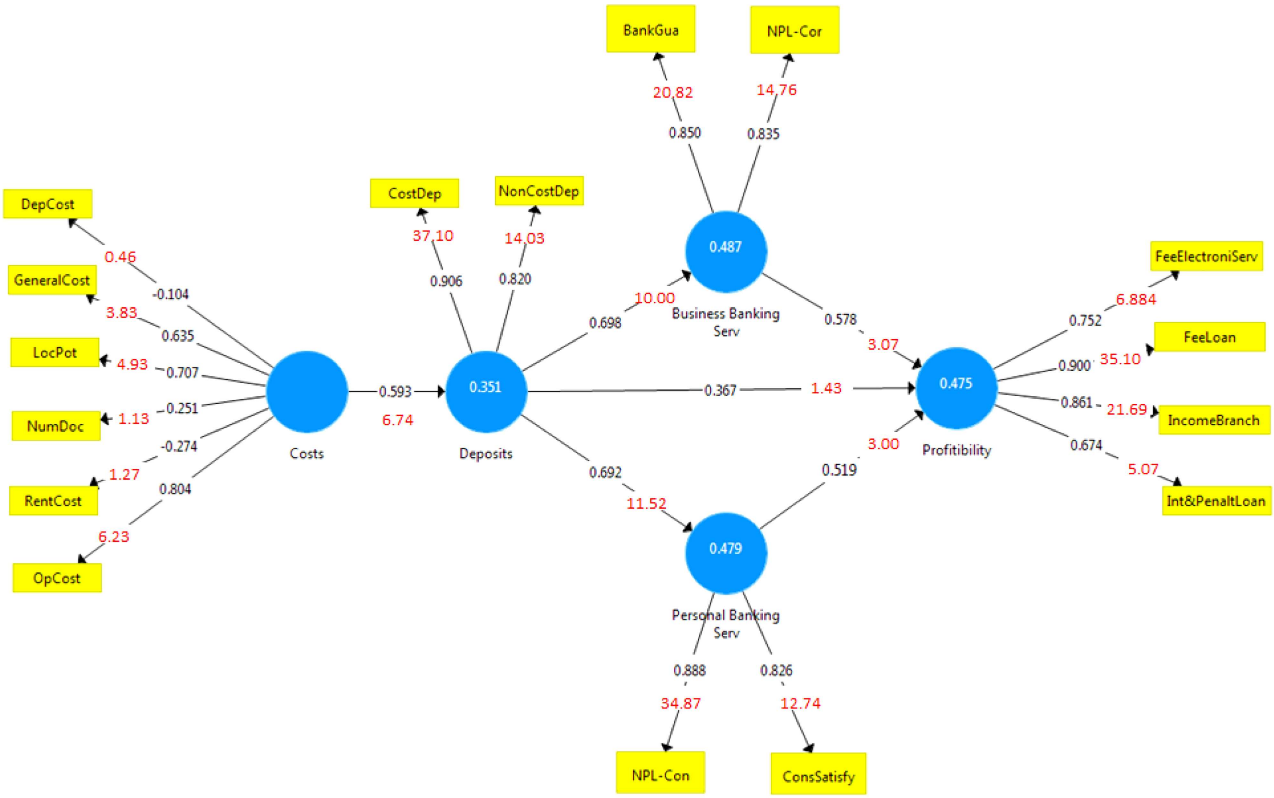

Figure 3. The initiative structural equation model to construct the significant model for efficiency measurement of the bank branches in a universal banking system.

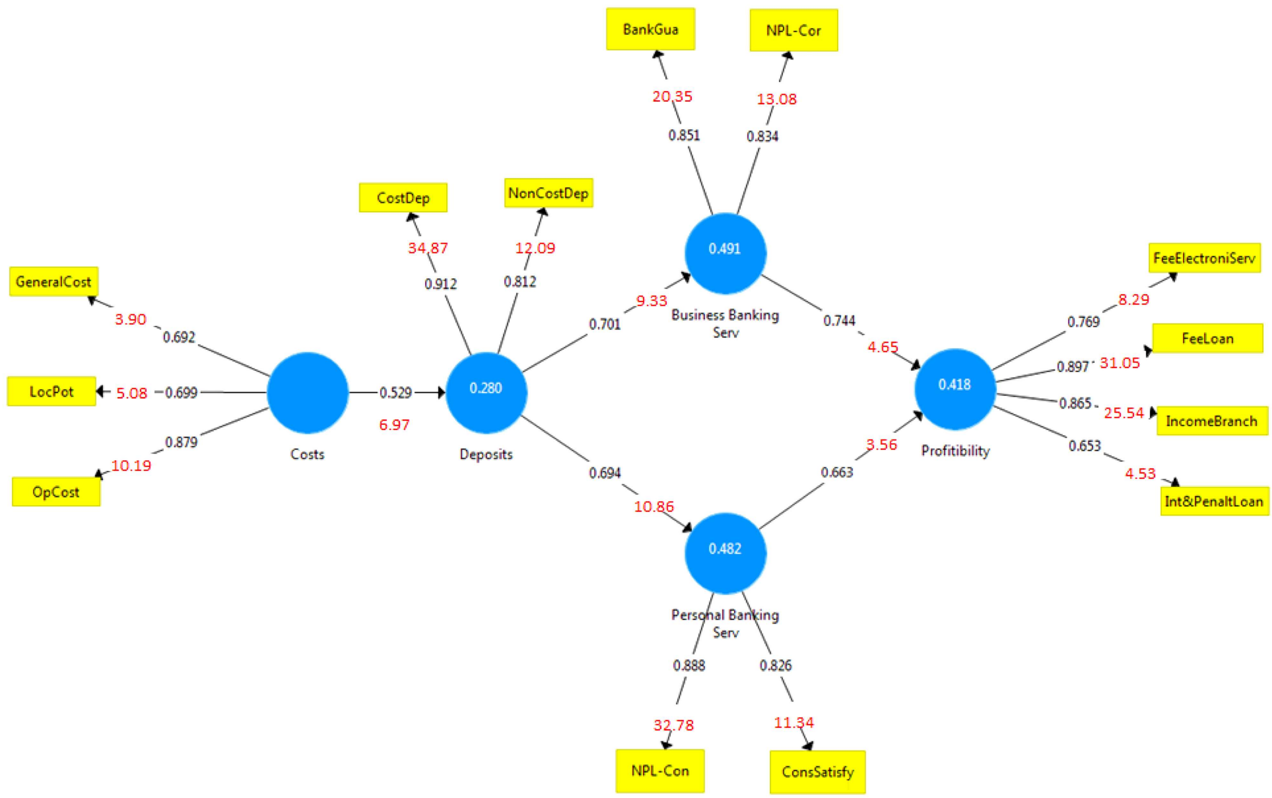

Figure 4. The final structural equation model to construct a significant model for efficiency measurement of the bank branches in a universal banking system.

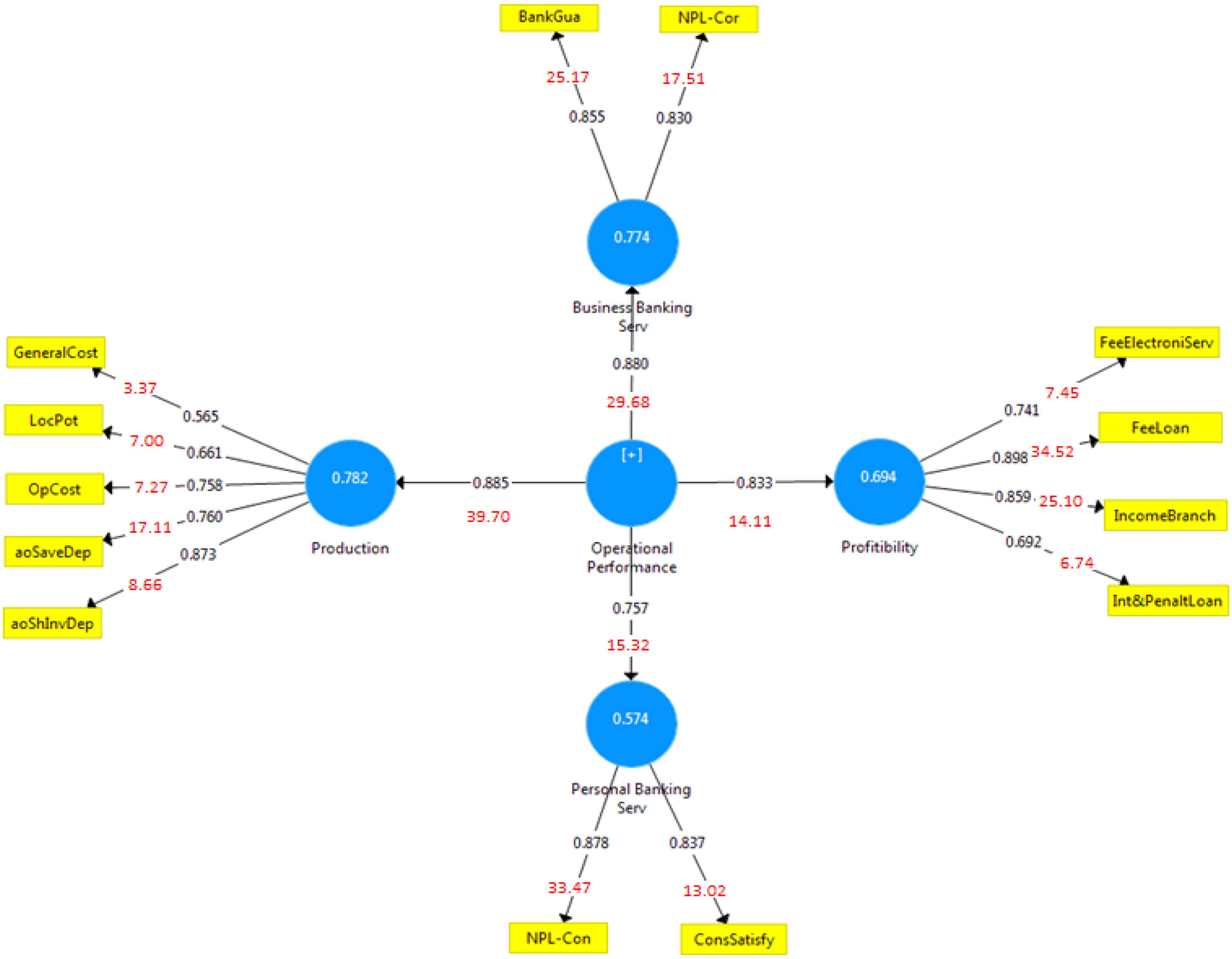

Figure 5. The Confirmatory Factor Analysis (CFA) model to extract weights of each dimension of the NSBM model.

Table 4. The validation results of the CFA model.

	AVE (> 0.5)	Composite reliability (> 0.7)	R-square	Loading factor	Cronbach's alpha (> 0.7)
Production	0.634	0.822	0.806	0.885	0.736
Business banking service	0.710	0.831	0.779	0.880	0.856
Personal banking service	0.736	0.848	0.617	0.757	0.831
Profitability	0.643	0.877	0.691	0.833	0.812
Operational performance	0.602	0.907	—	—	0.887

level of 0.95 show that all indicators have been correctly selected.

The validation results of Table 4 identify the significance of the CFA model of Figure 5.

3.3. The proposed NSBM model considering the undesirable variables and shared resources

Considering the extracted significant model that is in accordance with the results of Figure 4, the three-stage network structure including two serving stages that operate in parallel (shown in Figure 6) is proposed to measure the efficiency of the bank branches in a universal banking system that serves personal and business customer groups.

The proposed NSBM model considers undesirable variables and shared resources and based on the integrated results (of Olfat, Amiri, Soufi et al., and Tavassoli, Faramarzi, Farzipoor Saen, and Lin and Chiu) is defined as follows [15,19,31]. All the indices,

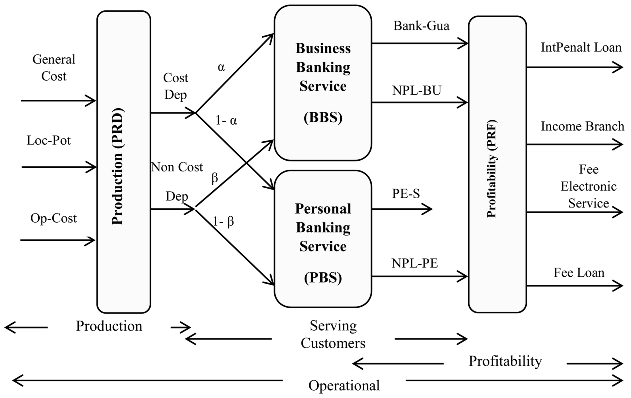

Figure 6. The network structure for efficiency measurement of the bank branches in a universal banking system.

parameters, and decision variables used in the proposed NSBM model are summarized in Table 5.

$$\rho_o^* =$$

$$\min w^{PRD}\left[1-\frac{1}{3}\left(\frac{s_1^{PRD-}}{x_{1o}^{PRD}}+\frac{s_2^{PRD-}}{x_{2o}^{PRD}}+\frac{s_3^{PRD-}}{x_{3o}^{PRD}}\right)\right]$$

$$+w^{BBS}\left[1-\left(\frac{s_1^{BBS-}}{x_{1o}^{BBS}}\right)\right]+w^{PBS}\left[1-\left(\frac{s_1^{PBS-}}{x_{1o}^{PBS}}\right)\right]$$

$$+w^{PRF}\left[1-\frac{1}{3}\left(\sum_{i=1}^{3}\frac{s_1^{PRF-}}{x_{1o}^{PRF}}+\frac{s_2^{PRF-}}{x_{2o}^{PRF}}+\frac{s_3^{PRF-}}{x_{3o}^{PRF}}\right)\right]$$

$$/w^{PRD}\left[1+\frac{1}{2}\left(\frac{s_1^{PRD+}}{y_{1o}^{PRD}}+\frac{s_2^{PRD+}}{y_{2o}^{PRD}}\right)\right]$$

$$+w^{\mathrm{BBS}}\left[1+\frac{1}{3}\left(\frac{s_1^{BBS+}}{y_{1o}^{BBS}}+\frac{s_{r2}^{BBS+}}{y_{2o}^{BBS}}+\frac{s_3^{BBS+}}{y_{3o}^{BBS}}\right)\right]$$

$$+w^{\mathrm{PBS}}\left[1+\frac{1}{3}\left(\frac{s_1^{PBS+}}{y_{1o}^{PBS}}+\frac{s_2^{PBS+}}{y_{2o}^{PBS}}+\frac{s_3^{PBS+}}{y_{3o}^{PBS}}\right)\right]$$

$$+w^{\mathrm{PRF}}\left[1+\frac{1}{5}\left(\frac{s_1^{PRF+}}{y_{1o}^{PRF}}+\frac{s_2^{PRF+}}{y_{2o}^{PRF}}+\frac{s_3^{PRF+}}{y_{3o}^{PRF}}\right.\right.$$

$$\left.\left.+\frac{s_4^{PRF+}}{y_{4o}^{PRF}}+\frac{s_5^{PRF+}}{y_{5o}^{PRF}}\right)\right]. \tag{8}$$

S.t:

- **Inputs and outputs of PRD node considering their desirability**
  General cost- desirable input:

$$\sum_{j=1}^{54} x_{1j}^{PRD}\lambda_j^{PRD}+s_1^{PRD-}=x_{1o}^{PRD}, \tag{9}$$

Loc-pot (the average rent and the purchase price)- desirable input:

$$\sum_{j=1}^{54} x_{2j}^{PRD}\lambda_j^{PRD}+s_2^{PRD-}=x_{2o}^{PRD}, \tag{10}$$

Op-cost- desirable input:

$$\sum_{j=1}^{54} x_{3j}^{PRD}\lambda_j^{PRD}+s_3^{PRD-}=x_{3o}^{PRD}, \tag{11}$$

Cost dep- desirable output:

$$\sum_{j=1}^{54} y_{1j}^{PRD}\lambda_j^{PRD}-s_1^{PRD+}=y_{1o}^{PRD}, \tag{12}$$

Noncost dep-desirable output:

$$\sum_{j=1}^{54} y_{2j}^{PRD}\lambda_j^{PRD}-s_2^{PRD+}=y_{2o}^{PRD}. \tag{13}$$

- **Inputs and outputs of BBS node considering their desirability**
  NPL-BU (non-performing loan of business banking)- undesirable output:

$$\sum_{j=1}^{54} x_{1j}^{BBS}\lambda_j^{BBS}+s_1^{BBS-}=x_{1o}^{BBS}, \tag{14}$$

Bank-gua (banking guarantee of business banking)- desirable output:

$$\sum_{j=1}^{54} y_{1j}^{BBS}\lambda_j^{BBS}-s_1^{BBS+}=y_{1o}^{BBS}, \tag{15}$$

Cost dep-undesirable input:

$$\sum_{j=1}^{54} \alpha_j y_{2j}^{BBS}\lambda_j^{BBS}-s_2^{BBS+}=\alpha_o y_{2o}^{BBS}, \tag{16}$$

NonCost dep- undesirable input:

$$\sum_{j=1}^{54} \beta_j y_{3j}^{BBS}\lambda_j^{BBS}-s_3^{BBS+}=\beta_o y_{3o}^{BBS}. \tag{17}$$

- **Inputs and outputs of PBS node considering their desirability**
  NPL-PE (non-performing loan of personal banking)- undesirable output:

$$\sum_{j=1}^{54} x_{1j}^{PBS}\lambda_j^{PBS}+s_1^{PBS-}=x_{1o}^{PBS}, \tag{18}$$

PE-S (satisfy of personal banking)- desirable output:

Table 5. The notations used in the proposed NSBM model with definitions and explanations.

Stage	**Definitions and explanations**
PRD	Production: In the dimension of production, a bank utilizes a set of resources to provide financial products and services that will attract customers with deposit acquirement and loan lending as intermediate outputs [34].
BBS	Business banking service dimension measures the ability to recover loans in business banking departments [34].
PBS	Personal banking service dimension measures the ability to recover loans in personal banking departments and personal customer satisfaction [34].
PRF	Profitability: In the profitability dimension, the input-output variables used to assess profitability efficiency reflect the managerial objective to maximize the bank's profit, which refers to the profit contribution made by lending services from business and customer-banking departments [34].
Indices	**Definition and explanation**
j	The number of DMUs
K	The indices of dimensions, $K =$ PRD, BBS, PBS, PRO
M_k	Sum of desirable inputs and undesirable outputs at K dimension
R_k	Sum of undesirable inputs and desirable outputs at K dimension
i	The number of desirable inputs and undesirable outputs at K dimension
r	The number of undesirable inputs and desirable outputs at K dimension

Parameters in the figure and formula		**Definitions and explanations**
General cost	x_{1j}^{PRD}	General cost: Expense incurred by an organization that does not relate to its main activity. Examples of the general cost include building rent, consultant fees, and depreciation on office equipment, insurance, supplies, subscriptions, utilities, and salary staff.
Loc pot	x_{2j}^{PRD}	Location-potential: The average purchase and rental price per square meter in residential and commercial areas.
Op cost	x_{3j}^{PRD}	Operational-cost: Expenses related to the operation of a business or to the operation of the banking process such as costs considered to give profits to depositor customers.
Cost dep	$y_{1j}^{PRD}, y_{2j}^{BBS}, y_{2j}^{PBS}$, $Z_{link1j}^{PRD-BBS}, Z_{link1j}^{PRD-PBS}$	Cost deposit: Short-term and long-term investment deposits that the bank is required to pay interest to the depositor.
Non CostDep	$y_{2j}^{PRD}, y_{3j}^{BBS}, y_{3j}^{PBS}$, $Z_{link2j}^{PRD-BBS}, Z_{link2j}^{PRD-PBS}$	NonCost deposit: Deposits of Qarz al-Hassaneh that the owner does not give to the bank for profit but to their owners for the purpose of spiritual reward and using a variety of banking services and expediting the transfer of their funds to the bank.
Bank gua	$y_{1j}^{BBS}, y_{5j}^{PRF}, Z_{link2j}^{BBS-PRF}$,	Banking guarantee: A bank guarantee is a guarantee from a lending institution, ensuring that the liabilities of a debtor will be met. In other words, if the debtor fails to settle a debt, the bank covers it. A bank guarantee enables the customer, or debtor, to acquire goods, buy equipment or draw down loans, and thereby expand business activity.
NPL BU	$x_{1j}^{BBS}, x_{1j}^{PRF}, Z_{link1j}^{BBS-PRF}$,	Non-performing loans of business banking customer.
PE-S	y_{1j}^{PBS}	Satisfaction of personal banking customer.
NPL PE	$x_{1j}^{PBS}, x_{2j}^{PRF}, Z_{link1j}^{PBS-PRF}$,	Non-performing loans of personal banking customer

Table 5. The notations used in the proposed NSBM model with definitions and explanations (continued).

Parameters in the figure and formula		Definitions and explanations
Int penalt loan	y_{1j}^{PRF}	Interest and penalty of loan: If an installment is not received according to the repayment terms, sometimes if not received by the end of the month, the borrower/buyer is charged penalty interest on the delayed installment/payment
Income branch	y_{2j}^{PRF}	The residual income of a branch after adding total revenue and gains and subtracting all expenses and losses for the reporting period.
Fee electronic service	y_{3j}^{PRF}	The amount of money the bank receives from its customers for providing electronic services such as the transactions of ATM, POS, internet banking, mobile banking, and so on.
Fee loan	y_{4j}^{PRF}	A loan application fee is one type of fees a borrower may be charged for obtaining a loan. Different from other types of loan fees, the loan application fee is an upfront charge that a borrower is required to pay when they submit a loan application.

Decision variables	Definitions and explanations
$s_1^{PRD-}, s_2^{PRD-}, s_3^{PRD-}$	Slack variable of desirable input resource at PRD dimension
s_1^{PRD+}, s_2^{PRD+}	Surplus variable of desirable output product at PRD dimension
s_1^{BBS-}	Slack variable of desirable input resource at BBS dimension
$s_1^{BBS+}, s_2^{BBS+}, s_3^{BBS+}$	Surplus variable of desirable output and undesirable input at BBS dimension
s_1^{PBS-}	Slack variable of undesirable output resource at PBS dimension
$s_1^{PBS+}, s_2^{PBS+}, s_3^{PBS+}$	Surplus variable of desirable output and undesirable input at PBS dimension
s_1^{PRF-}, s_2^{PRF-}	Slack variable of desirable input resource at PRF dimension
$s_1^{PRF+}, s_2^{PRF+}, s_3^{PRF+} s_4^{PRD+}, s_5^{PRF+}$	Surplus variable of desirable output and undesirable input at PRF dimension
λ_j^k	Intensity vector of Kth dimension in DMU_j
w^k	Weight of the Kth dimension
α_o, β_0	Proportionality variables of the shared resource (CostDep and NonCostDep) under DMU evaluation
α_j, β_j	Proportionality variables of the shared resource (CostDep and NonCostDep)
ρ_k	efficiency of the Kth dimension
ρ_o	Overall efficiency (operational efficiency)

$$\sum_{j=1}^{54} y_{1j}^{PBS} \lambda_j^{PBS} - s_1^{PBS+} = y_{1o}^{PBS}, \tag{19}$$

Cost dep- undesirable input:

$$\sum_{j=1}^{54} (1-\alpha_j)\, y_{2j}^{PBS} \lambda_j^{PBS} - s_2^{PBS+} = (1-\alpha_o)\, y_{2o}^{PBS}, \tag{20}$$

NonCost dep- undesirable input:

$$\sum_{j=1}^{54} (1-\beta_j)\, y_{3j}^{PBS} \lambda_j^{PBS} - s_3^{PBS+} = (1-\beta_o)\, y_{3o}^{PBS}. \tag{21}$$

- **Inputs and outputs of PRF node considering their desirability**

  NPL-BU- desirable input:

$$\sum_{j=1}^{54} x_{1j}^{PRF} \lambda_j^{PRF} + s_1^{PRF-} = x_{1o}^{PRF}, \tag{22}$$

NPL-PE-desirable input:

$$\sum_{j=1}^{54} x_{2j}^{PRF} \lambda_j^{PRF} + s_2^{PRF-} = x_{2o}^{PRF}, \tag{23}$$

IntPenalt loan (interest and penalty of loan) - desirable output:

$$\sum_{j=1}^{54} y_{1j}^{PRF}\lambda_j^{PRF} - s_1^{PRF+} = y_{1o}^{PRF}, \tag{24}$$

Income branch-desirable output:

$$\sum_{j=1}^{54} y_{2j}^{PRF}\lambda_j^{PRF} - s_2^{PRF+} = y_{2o}^{PRF}, \tag{25}$$

Fee electronic service- desirable output:

$$\sum_{j=1}^{54} y_{3j}^{PRF}\lambda_j^{PRF} - s_3^{PRF+} = y_{3o}^{PRF}, \tag{26}$$

Fee loan- desirable output:

$$\sum_{j=1}^{54} y_{4j}^{PRF}\lambda_j^{PRF} - s_4^{PRF+} = y_{4o}^{PRF}, \tag{27}$$

Bank-gua- undesirable output:

$$\sum_{j=1}^{54} y_{5j}^{PRF}\lambda_j^{PRF} - s_5^{PRF+} = y_5^{PRF}. \tag{28}$$

- **Link between PRD node and BBS node**
  Cost dep:

$$\sum_{j=1}^{54} \alpha_j Z_{link1j}^{PRD-BBS}\lambda_j^{PRD} = \sum_{j=1}^{54} \alpha_j Z_{link1j}^{PRD-BBS}\lambda_j^{BBS}, \tag{29}$$

NonCost dep:

$$\sum_{j=1}^{54} \beta_j Z_{link2j}^{PRD-BBS}\lambda_j^{PRD} = \sum_{j=1}^{54} \beta_j Z_{link2j}^{PRD-BBS}\lambda_j^{BBS}. \tag{30}$$

- **Link between PRD node and PBS node**
  Cost dep:

$$\sum_{j=1}^{54}(1-\alpha_j) Z_{link1j}^{PRD-PBS}\lambda_j^{PRD} = \sum_{j=1}^{54}(1-\alpha_j) Z_{link1j}^{PRD-PBS}\lambda_j^{PBS}. \tag{31}$$

NonCost dep:

$$\sum_{j=1}^{54}(1-\beta_j) Z_{link2j}^{PRD-PBS}\lambda_j^{PRD} = \sum_{j=1}^{54}(1-\beta_j) Z_{link2j}^{PRD-PBS}\lambda_j^{PBS}. \tag{32}$$

- **Link between BBS node and PRF node**
  NPL-BU:

$$\sum_{j=1}^{54} Z_{link1j}^{BBS-PRF}\lambda_j^{BBS} = \sum_{j=1}^{54} Z_{link1j}^{BBS-PRF}\lambda_j^{PRF}, \tag{33}$$

Bank-gua:

$$\sum_{j=1}^{54} Z_{link2j}^{BBS-PRF}\lambda_j^{BBS} = \sum_{j=1}^{54} Z_{link2j}^{BBS-PRF}\lambda_j^{PRF}. \tag{34}$$

- **Link between PBS node and PRF node**
  NPL-PE:

$$\sum_{j=1}^{54} Z_{link1j}^{PBS-PRF}\lambda_j^{BBS} = \sum_{j=1}^{54} Z_{link1j}^{PBS-PRF}\lambda_j^{PRF}. \tag{35}$$

- **General Constraint**
  Constraint related to Variable Return to Scale (VRS):

$$\sum_{j=1}^{n} \lambda_j^k = 1. \tag{36}$$

The importance of each dimension in the operational activity of the bank:

$$\sum_{k=1}^{K} w^k = 1. \tag{37}$$

The importance of each dimension - result of the CFA model:

$$w^k = \frac{loading\ factor_k}{\sum_{k=1}^{K} loading\ factor_k}. \tag{38}$$

General constraint:

$$\lambda^k, s^{k-}, s^{k+}, w^k \geq 0, \tag{39}$$

proportionality variables of the shared resources:

$$0 \leq \alpha_o, \quad \beta_0 \leq 1. \tag{40}$$

To measure the efficiency of each dimension of the model, the following equation is used, where s_i^{k-*} and s_r^{k+*} are the optimal input and output slacks for Eq. (8) [7]:

$$\rho_k = \frac{\left[1 - \frac{1}{M_k}\left(\sum_{i=1}^{M_k} \frac{s_i^{k-*}}{x_{io}^K}\right)\right]}{\left[1 + \frac{1}{R_k}\left(\sum_{i=1}^{R_k} \frac{s_r^{k+*}}{y_{ro}^K}\right)\right]} k = PRD, BBS, PBS, PRD. \tag{41}$$

The efficiency of the production dimension is calculated based on the constraints related to its input and outputs and the link related to the production dimension and dimension of the personal and business banking. Similarly, the efficiency of the other dimensions is also calculated and, finally, the operational efficiency of the branches is calculated considering the objective function (Eq. (8)) and its constraints (Eqs. (9) to (40)). In this model, α_o and β_0 are variables, ranging between zero and one. Herein, these variables range from 0.2 to 0.8 ($0.2 < \alpha_o$, $\beta_o < 0.8$). These values were given by Iranian banking experts.

4. Results and analysis

4.1. Collecting the values of significant indicators extracted from the SEM model according to validation results

According to what was reported in the literature review and the results of Table 1 and those of the final structural equation model (Figure 4), the following indicators have been extracted, whose samples are obtained from 54 branches of one of the Iranian banks. In Table 6, the Pierson correlation coefficients of the data are given. The results of Table 6 show that all correlations of the intended data are less than 0.6 and are weak and intermediate correlations, and there is no redundant variable in the model that brings the inefficient units to lie in the efficiency frontiers [101].

4.2. Solving the initial and final NSBM models

First, the initial NSBM model was implemented without multivariate analysis methods and with regard to the equal weights of different dimensions of the model. The results are summarized in Table 7.

It is worth noting that in order to extract the weights of the dimensions, the extracted factor loadings in Table 4 were used and the total sum of the weights was considered to be one, as can be seen in Table 8. Through this approach, there is no requirement for using Eq. (37).

Then, after collecting the model's indicators, the nonlinear final NSBM model was transformed to a linear one [102], and the results shown in Table 9 were obtained using the GAMS 24.1.2 software.

The results in Table 9 show that the operational efficiency of the bank branches varies from 0.0063 to 1 with an average of 0.3296, and six branches of 54 banks are efficient based on all dimensions of the model.

Table 6. The correlation coefficients between the parameters.

Variables	Variables												
	General cost	**Loc pot**	**Op cost**	**Cost dep**	**Non cost dep**	**Bank gua**	**NPL BU**	**PE-S**	**NPL PE**	**Int penalt loan**	**Income branch**	**Fee loan**	**Fee electronic service**
General cost	1												
Loc pot	0.039	1											
Op cost	0.275*	0.345*	1										
Cost dep	0.326*	0.281*	0.456**	1									
Non CostDep	0.281*	0.113	0.391**	0.078**	1								
Bank gua	0.235	0.153	0.165**	0.153	0.514**	1							
NPL BU	–0.190	–0.267	–0.304*	–0.272*	–0.298*	–0.061	1						
PE-S	–0.049	–0.589	–0.294*	–0.255	0.049	–0.163	0.106	1					
NPL PE	–0.167	0.137	0.007	–0.032	–0.066	0.113	0.148**	–0.156	1				
Int penalt loan	0.196	0.266	0.280**	0.35	0.087**	0.311**	–0.125	–0.209	0.138	1			
Income branch	0.248	0.240	0.116**	0.172**	0.247**	0.023**	–0.190	–0.192	0.070	0.277**	1		
Fee loan	0.174	0.255	0.066**	0.252	0.054**	0.169**	–0.140	–0.074	0.060	0.093*	0.320**	1	
Fee electronic service	0.124	–0.243	0.055	0.077	–0.019	–0.053	0.029	–0.062	0.074	0.014	0.010	–0.158	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 7. The efficiency of the bank branches in a universal banking system obtained from the initial NSBM model.

	Production	**Business banking service**	**Personal banking service**	**Profitability**	**Operational performance**
Mean	0.9075	0.9526	0.9526	0.9526	0.9005
Std Dev	0.2641	0.2926	0.3043	0.2923	0.3087
Max	1.0000	1.0000	1.0000	1.0000	1.0000
Min	0.0230	0.0088	0.0050	0.0126	0.0656
Efficient DMU	15	19	19	19	17
Percentage of efficient	27.78%	35.19%	35.19%	35.19%	31.48%

Table 8. The weights of the dimensions.

Dimension	Production	Business banking service	Personal banking service	Profitability
Weight	0.2638	0.2623	0.2256	0.2483

Thus, suitable programs have to be provided for the progress and promotion of a considerable portion of the branches. The results show that the production dimension has a greater average than others and, therefore, the branches have been successful in attracting deposits; however, only 7.41% of the branches have been efficient in this dimension and a large number of the branches are still far from reaching the efficient frontier.

Regarding the efficiency of the universal banking system in serving different customer groups, it can be noted that the average efficiencies of serving personal and business customers are respectively equal to 0.3 and 0.3219 and, also, there are only 6 efficient branches, implying their equal performance in serving personal and business customers. However, considering the immaturity of the universal banking system in Iran, there is a long way to go before reaching the ideal point in each dimension. Due to the influence of these branches on the profitability and operational efficiencies, efficiency in these two dimensions is very important. Similar to the personal and business banking, 11.11% of the branches are efficient in the profitability sector. Variables α_o and β_0 also represent the share of common parameters of costly and non-cost deposits in the business customers. According to Table 9, the average share of the costly deposit in the BBS is 0.7240 and 0.2760 in the PBS section; in addition to these, the average share of the non-cost deposits in the BBS is 0.4434 and 0.5566 in the PBS section, illustrating the use of shared resources in each part of serving business and personal customers.

Therefore, according to the output of Figure 7, it is possible to schematically compare the efficiency of the branches in serving the customer groups of the universal banking system (personal and business customers) and making management decisions for improving the inefficient branches in each section.

Moreover, as can be seen in Tables 7 and 9, the standard deviation results show better diversity of the efficiency values of the final NSBM model and the correct selection of DMU as an efficient DMU, compared to the initial NSBM model.

Therefore, it can be mentioned that using the proposed model and selecting the appropriate model through scientific structural equation methods and factor analysis in the selection of appropriate indicators and their relationships for model development can help the banking industry managers to measure the efficiency of the branches in different sectors. Considering the macro strategies, managers can make appropriate policies for designing suitable and attractive tools to attract deposit attraction and convert resources to facilities for the customer groups with high attractiveness, high liquidity, and low risk and bring NPL ratio to the minimum possible value. In this light, managers can make encouragement and punishment policies to involve staff in serving customers in the best manner.

5. Conclusions and future research

5.1. Comparison of this study with other related studies and extraction of managerial tips (insights/visions)

Considering the growing number of studies on the application of the DEA models in the banking industry along with the competitiveness of the banking industry and the increasing bargaining power of the customers, banks should better provide customized services to personal and business customers in a universal banking

Table 9. The efficiency of the bank branches in a universal banking system obtained from the final Network Slackes-Based Measure (NSBM) model.

DMU	Production	Business banking service	Personal banking service	Profitability	Operational performance	Model stat	α_o	β_0
1	0.9373	0.9373	0.9373	0.9373	0.9373	1.0000	0.654	0.800
2	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.800	0.200
3	0.1581	0.1413	0.1186	0.1393	0.1393	1.0000	0.446	0.200
4	0.3006	0.4697	0.4697	0.4697	0.4697	1.0000	0.800	0.714
5	0.2619	0.2752	0.2752	0.2752	0.2752	1.0000	0.800	0.283
6	0.7147	0.9268	0.9268	0.9268	0.9268	1.0000	0.800	0.721
7	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.200	0.200
8	0.2873	0.1110	0.0321	0.1619	0.1619	1.0000	0.800	0.444
9	0.9132	1.0000	1.0000	1.0000	1.0000	1.0000	0.800	0.200
10	0.0426	0.0235	0.0101	0.0289	0.0289	1.0000	0.800	0.200
11	0.5164	0.0869	0.2451	0.2828	0.2828	1.0000	0.800	0.200
12	0.3390	0.1922	0.0346	0.1784	0.1784	1.0000	0.800	0.800
13	0.0198	0.0006	0.0052	0.0090	0.0090	1.0000	0.800	0.200
14	0.0341	0.0161	0.0167	0.0269	0.0269	1.0000	0.800	0.200
15	0.0292	0.0047	0.0151	0.0230	0.0230	1.0000	0.800	0.200
16	0.9268	0.9268	0.9268	0.9268	0.9268	1.0000	0.800	0.800
17	0.0102	0.0011	0.0030	0.0063	0.0063	1.0000	0.200	0.200
18	0.1167	0.0389	0.0401	0.0800	0.0800	1.0000	0.800	0.200
19	0.0424	0.0119	0.0072	0.0228	0.0228	1.0000	0.800	0.200
20	0.3825	0.4002	0.0396	0.2800	0.2800	1.0000	0.800	0.200
21	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.800	0.654
22	0.0344	0.0299	0.0099	0.0290	0.0290	1.0000	0.800	0.800
23	0.4886	0.4886	0.4137	0.4637	0.4637	1.0000	0.225	0.800
24	0.0367	0.0274	0.0417	0.0369	0.0369	1.0000	0.772	0.200
25	0.0222	0.0113	0.0030	0.0147	0.0147	1.0000	0.800	0.800
26	0.6449	0.6928	0.5523	0.6459	0.6459	1.0000	0.800	0.200
27	0.5589	0.6823	0.6823	0.6823	0.6823	1.0000	0.800	0.200
28	0.0723	0.0048	0.0059	0.0318	0.0318	1.0000	0.800	0.200
29	0.9523	0.9523	0.9523	0.9523	0.9523	1.0000	0.800	0.800
30	0.1107	0.0313	0.1506	0.1108	0.1108	1.0000	0.800	0.200
31	0.0312	0.0044	0.0277	0.0312	0.0312	1.0000	0.800	0.200
32	0.2461	0.2985	0.2985	0.2985	0.2985	1.0000	0.200	0.200
33	0.1573	0.0516	0.2517	0.1850	0.1850	1.0000	0.800	0.200
34	0.1521	0.0011	0.0194	0.0498	0.0498	1.0000	0.200	0.800
35	0.0557	0.0346	0.0176	0.0391	0.0391	1.0000	0.800	0.800
36	0.0359	0.0358	0.0286	0.0362	0.0362	1.0000	0.800	0.800
37	0.0636	0.0172	0.0197	0.0345	0.0345	1.0000	0.800	0.200
38	0.7524	0.6423	0.1631	0.5150	0.5150	1.0000	0.800	0.800
39	0.0528	0.0283	0.0580	0.0481	0.0481	1.0000	0.800	0.800
40	0.1553	0.1668	0.1460	0.1717	0.1717	1.0000	0.800	0.200
41	0.1971	0.4184	0.0309	0.2893	0.2893	1.0000	0.800	0.200
42	0.6351	1.0000	1.0000	1.0000	1.0000	1.0000	0.800	0.200
43	0.0699	0.0398	0.0237	0.0445	0.0445	1.0000	0.800	0.800
44	0.0263	0.0059	0.0289	0.0212	0.0212	1.0000	0.800	0.200
45	0.0563	0.0164	0.0749	0.0554	0.0554	1.0000	0.800	0.800
46	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.200	0.200
47	0.0639	0.0069	0.0375	0.0554	0.0554	1.0000	0.800	0.200
48	0.1081	0.1461	0.0331	0.1084	0.1084	1.0000	0.800	0.200
49	0.9268	0.9268	0.9268	0.9268	0.9268	1.0000	0.800	0.800
50	0.0142	0.0007	0.0051	0.0100	0.0100	1.0000	0.800	0.200
51	0.0978	0.0374	0.0320	0.0598	0.0598	1.0000	0.800	0.800
52	0.0690	0.0232	0.0216	0.0379	0.0379	1.0000	0.800	0.800
53	0.9568	0.9568	0.9568	0.9568	0.9568	1.0000	0.800	0.730
54	0.1157	0.0397	0.0832	0.0796	0.0796	1.0000	0.800	0.800
Mean	0.3332	0.3219	0.3000	0.3296	0.3296	1.0000	0.7240	0.4434
Std Sev	0.3542	0.3883	0.3846	0.3754	0.3754	0.0000	0.1908	0.2844
Max	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.8000	0.8000
Min	0.0102	0.0006	0.0030	0.0063	0.0063	1.0000	0.2000	0.2000
Efficient DMU	4	6	6	6	6	—	—	—
Percentage of efficient	7.41%	11.11%	11.11%	11.11%	11.11%	—	—	—

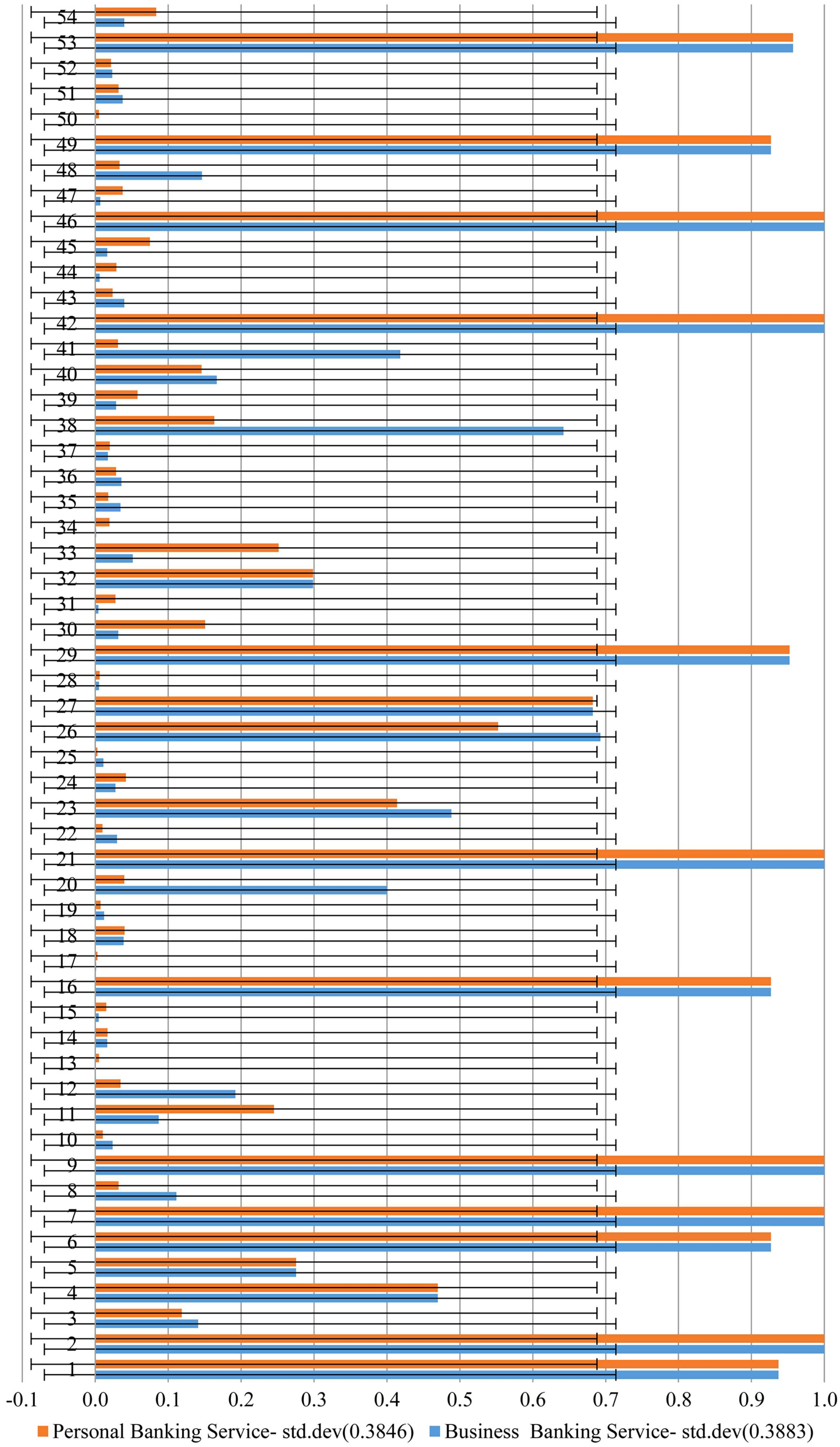

Figure 7. Comparison efficiency of the business and personal banking service dimension with standard deviation.

approach. Hence, the efficiency measurement of the bank branches is a crucial activity to acquire a better understanding of the short-term and long-term needs of customers.

The important issue in the efficiency measurement and the application of the NDEA model is to properly select input, intermediate, and output variables and relate different dimensions to create a significant model.

In this paper, the application of the multivariate data analysis approaches was considered to select appropriate indicators of the DEA models and create a significant model in the network relationships of the NDEA in the banking industry via a customer group-based approach. The appropriate efficiency measurement indicators were categorized into six panels: the branch costs (operational and non-operational costs), the potential of the branch's location, deposits, customer satisfaction, customer servicing, and profitability. Then, to implement the structural equation model, questionnaires were distributed among 60 banking industry experts to identify the importance of the mentioned indicators. The structural equation model was developed to correctly select the variables and establish proper relationships between the different dimensions of the banking process such as generating and attracting deposits, serving personal and business customers, and profitability; finally, the NSBM model considering the undesirable variables and shared resources was extracted.

It is worth noting that, in all of the aforementioned papers, the weights of different dimensions of the NSBM model were equally considered. Thus, in this paper, along with the use of Confirmatory Factor Analysis (CFA) methods, the weight of each dimension was obtained by the experts of the universal banking system. The factor analysis results showed that to measure the efficiency of bank branches, deposit attraction, serving business customers, profitability, and serving personal customers were important.

The designed model was applied to the efficiency measurement of 54 branches of one Iranian bank (Day Bank), and the results showed that the modified final model based on the multivariate analysis methods had a higher standard deviation, which identified the diversity of the efficiency values and the correct selection of efficient DMUs.

The average efficiency degrees of deposit attraction, serving personal and business customers, and profitability were 0.3332, 0.3, 0.3219, and 0.3296, respectively. However, considering the immaturity of the universal banking in Iran, the efficiency values implied that the managers should design special programs for deposit attraction, design special products and services that convert resources to facilities with minimum possible risk, increase the non-interest and fee income, and finally ensure profitability. Here, the rationale for providing credit-based products is related to the production of the customer-oriented products, which is a normal trend for the top banks in the world that attend to personal and business customer orders.

Solving the proposed model helps managers better identify the dimensions and inefficient resources and, finally, make strategic decisions in order to improve the quality and promote the performance of the branches in providing services for various groups of customers.

5.2. Limitations and future research

One of the limitations of this research is the lack of sufficient data on various sectors of personal, commercial, and corporate banking due to the lack of maturity and the growth of universal banking in Iran. After reaching a universal banking system in maturity and sufficient data, the NSBM model can be solved by considering three personal, commercial, and corporate customers. In this research, a number of internal banking systems were used; however, there were some limitations concerning the use of some indicators such as commercial-corporate customers' satisfaction. Therefore, in the future research studies, some important indicators specific to each customer group should be added to the model, and there should be no limitations on collecting and dispreading them. After the validation and hypothesis testing of the multivariate based-analysis methods, the proposed model should be used in the case of other banks and organizations that operate in other industries. Therefore, the obtained results can be used for the segmentation of the bank branches and, accordingly, for the branches that lie in the adjacent clusters, appropriate encouragement and punishment policies should be made to promote the performance and efficiency of the branches. Solving the model through the dimension of time, considering it as a dynamic model to investigate the progress or deterioration of the DMUs over time, and applying obtained results to the staff payment systems of the organization can be another research idea.

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