DEA SUPPORTED ANN APPROACH TO OPERATIONAL EFFICIENCY ASSESSMENT OF SMEs

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Abstract:
This study addresses to classify Turkish Small Medium Enterprises (SMEs) in terms of their efficiency scores by developing a DEA supported Neural Network classification model. For this purpose, 744 manufacturing companies from ten different industries are taken into consideration. First, by considering the input and output values of the firms, efficiency scores of the companies are calculated with Data Envelopment Analysis (DEA). Then, to perform the Artificial Neural Network (ANN) classification analysis, same inputs variables are used while the efficiency scores from the DEA model are used as target values. This DEA supported ANN model provides a powerful efficiency estimation of SMEs with 96.4% performance efficiency when their output measures (i.e. market share, profit margin etc.) are not available.

Keywords: operational efficiency, DEA, neural network, classification, SMEs

1 INTRODUCTION

The importance of SMEs has increased to considerable levels with highly increasing of production, export, value added and share of investments. SMEs compromise of 99.8% of Turkish companies and built 78% employment rate in Turkey. Investments made by SMEs have reached up to 50% and added value is 55% regarding total number of investments and added values. SMEs have share of 59% of the total export rate and total bank loan is less than 24% in all sector. (SME Strategy and Action Plan, 2011-2013)

SMEs have limited resources and it is challenging to develop any specific competitive concept for SMEs (Brophey & Brown, 2009). Since manufacturing industry are working with limited resource and low technology, value added products are not at the satisfactory level. To change this, enterprises need to use their resources effectively and should be instructed to use high technology for producing high value added products.

In recent years, artificial neural networks are used extensively in areas like; finance, healthcare, manufacturing and marketing. In marketing, artificial neural networks are used to market research, for example market segmentation, and market response, forecasting, consumer choice prediction and supplier evaluation (Paliwal & Kumar, 2009).

In this study, a neural network classification model is developed by linking up the DEA results to perform the classification and analyze it in order to figure out whether the model is working properly in a way of finding efficient SMEs. A new neural network model which is developed to classify SMEs into groups with respect to their efficiency scores provides us advantages over DEA model. By the new model, a new added decision making unit can be evaluated directly without any need of output variables unlike the DEA model, which needs both input and output variables. Since there is no need to start the model from the beginning, consistency of results can be provided by merely running the model at a current level and which in turn saves cost and time.

2 LITERATURE REVIEW

2.1 Small and Medium Enterprises

SMEs definitions in Turkey were somewhat harmonized with the EU definition under a new law enacted on 18 November 2005 (European Commission, 2014). Relying on the EU definition for its member companies, SMEs are enterprises that employ less than 250 employees and have less amount of $50 million. Based on OECD, 99.8% of businesses are SMEs, with a total employment of 61.1% and 27.3% to value added in the manufacturing industry. The contribution to total value added was around 27% for all sectors and 38% of investment was attributable to SMEs (European Commission, 2014).

For Turkish SMEs most of the policies address the lack of productivity of 95% of the SME which are micro enterprises, and also the medium durable companies that only satisfies the local market demand and overseas. For improving the efficiency of SME policies in Turkey, there is a need to focus on innovation and efficiency driven economy. They need a broader publicity of innovation, a higher level of education, the growth of clusters and innovation network, the improvement to credit access and capital and tax-related issues. Even though, there has been a lot of initiatives taken by the Turkish officials, there is still far more steps to complete. According to the European Turkish Business Centers Network (2010), the issues such as innovation, technology development, new business models, smart networks and a new business ethos but also a young and growing workforce forms important pillars for competitiveness (Enis Bulak & Turkyilmaz, 2014).

2.2 Data Envelopment Analysis (DEA)

Data envelopment analysis is a linear programming technique that provides dynamic collective comparative results for evaluation the productivity of organizations based on multiple inputs and outputs. DEA technique was firstly introduced by Charnes et al. (1978) upon the seminal work by Farrell (1957) relied on the measurement of productive efficiency, and called as CCR model in the literature (Charnes, Cooper, & Rhodes, 1979; Farrell, 1957). In that model, the objective function was to maximize the output values to inputs for the organizations called as decision making units (DMUs) in DEA terminology. DEA is a methodology that measures relative efficiency of DMUs that has been paid attention by many scholars compared to traditional methods due to the advantages. DEA provides an efficiency score for each unit that accommodates comparison between by using the obtained scores. It is relied on peer group comparison that efficient elements will yield the efficient frontier and inefficient elements will be enveloped with their reference sets of frontiers. DEA can provide productivity analysis by multiple inputs and outputs with different units of measurement for each input/output variable.

DEA has been implemented in a wide range of research areas. literature about use of DEA in performance assessment can be found in (Enis Bulak & Turkyilmaz, 2014) and (Lao & Liu, 2009)

In common form of efficiency ratio is determined as follows:

$$Efficiency = \frac{Valueofouputs}{Valueofinputs}$$

In the literature, an efficiency score of any specific unit cannot be greater than 1; hence, it must be less than or equal to 1.

$$\frac{Valueofoutputs}{Valueofinputs} \leq 1$$

It should also be remarked that the traditional DEA models are divided into two groups, an input oriented and output oriented. An input oriented model leads to the proportional reduction of inputs while conserving the current level of output for an inefficient organization to become efficient. Unlike, an output oriented model guides to how much increase of output of an inefficient firm is necessary while conserving the current level of inputs for it to become efficient.

2.3 Artificial Neural Networks

Artificial Neural Networks (ANN's) is a method based on the biological systems which study the human brain to understand the neurons and their relationships. Like brain, ANN's are able to learn from experience. Currently, ANNs are being used for a wide range of tasks in many different scopes of science, industry and business (Rumelhart, Widrow, & Lehr, 1994).

ANN's are developed to imitate basic biological neural systems. That is why ANN's are formed as a part of an interconnected network, which is connected by nodes, in other words, neurons. Each node receives an input signal from other nodes or external stimulus, processes it locally through an activation or transfer function and produces a transformed output signal to other nodes or external outputs. Even if each individual neuron implements its task slowly, a collective network of neurons can perform a surprising number of tasks quite efficiently (Reilly and Cooper, 1990). To make an ANN operational, there must be input and output data to construct an ANN model. Input data are called independent variables or predictor variables, and output data are called dependent variables or predicted variables. In a basic ANN model, input, hidden and output neurons are connected together as a network (Stalinski and Tuluca, 2006), (Hill & Lewicki, 2007).

2.3.1 Classification using Neural Networks

Many problems in business, science, industry, and medicine can be treated as classification problems. Examples include bankruptcy prediction, credit scoring, medical diagnosis, quality control, handwritten character recognition, and speech recognition and etc (Zhang, 2000).Since classification is such an important subject, a lot of studies were performed and several methods are developed by researchers. Some of these methods are: (Mitchell, 2012; Statnikov, Aliferis, & Tsamardinos, 2005)

- Nearest-Neighbor Classifiers
- Decision trees and oblique decision trees
- Neural Networks
- Support Vector Machine based classification methods
- Logistic Regression
- Statistical Classifications

Traditional classification procedures are based on the Bayesian decision theory. In these procedures, in order to make a classification, some assumptions are made and this is their downside because they must satisfy assumptions. Because of these reason, the effectiveness of these methods largely depends on how they satisfy these assumptions and in which way they are developed. For this reason, users experience and expertise are very important for a successful application. On the other hand, neural networks have emerged as an important tool for classification (Zhang, 2000).

The advantages of using neural networks for classification are:

- At Neural networks the focus point is data and with respect to this data, neural networks use self-adaptive methods in order to adjust themselves to the data without any explicit specification of functional or distributional form for the underlying model.
- Neural Networks are universal functional approximators and with this they have the ability to approximate any functions.
- Neural networks are nonlinear models, so it is easier to apply them to real world non-linear models.
- Neural networks can estimate the hidden probabilities, which give them the ability to establish classification rules and perform statistical analysis (Zhang, 2000).

In order to classify with neural networks, data with two parts is used. First part is called input data, which includes attributes that is used for classification. Second part is called target data. Target data gives the real classification results of the samples as binary values. Target values are compared with signals that come from the input and by using the back propagation method; neural networks train themselves and find the best weights.

3 METHODOLOGY

3.1 DEA supported Artificial Neural Network

Below figure illustrates the flow of the application process that starts with data collection and selection, continues with DEA analysis and finishes by ANN classification of SMEs' efficiency.

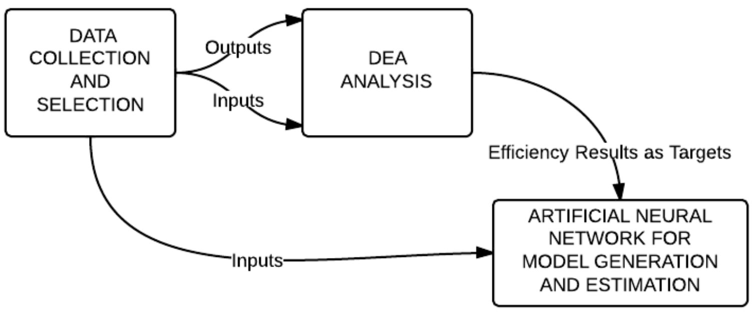


Figure 1: Flowchart of the application

3.2 Data Collection

For this study, data is gathered from 744 manufacturing SMEs from 10 different industries via online survey filled by companies' top managers. Survey questions are written according to proposed model based on a 5 point Likert Scale (1 = very weak to 5 = very strong) except one output called profit margin.

In the proposed model; output oriented CCR model is used, since the objective is to increase efficiency by increasing output levels. The main goal of the proposed model is to figure out whether or not a SME is efficient if the value of the objective function equals 1 or if it is less than 1, it is inefficient.

Input variables are proximity to market with respect to competitors, ability to control costs, potential labor force, product quality, prompt advantage, certification, product assortment, distribution channel, pricing policy, service, capital and machinery-equipment track and output variables are profit margin and market share. All data from 744 companies used in the DEA analysis. In the result of efficiency analysis, there are 94 companies obtained comparatively efficient best practice SMEs (score=1) and 650 inefficient companies (score<1) observed and reference set for each inefficient units are identified.

3.3 Artificial Neural Network Analysis

In this study, SMEs are classified as efficient or not efficient with respect to ANN classification analysis. Data is provided by KOSGEB. The following attributes determined by the DEA application are used as inputs in neural network:

- Proximity to market with respect to competitors
- Ability to control costs
- Potential Labor Force
- Product Quality
- Prompt Advantage Prompt
- Certification
- Product Assortment
- Distribution Channel Power
- Pricing Policy
- Service
- Capital
- Machinery-Equipment Track

The classification results found by the DEA are used as target values. The SMEs data are used in the analysis and it has 744 samples. MATLAB software's Neural Network toolbox is utilized to do the analysis.

12 attributes will enter this model from the input nodes. From there they will flow through the hidden neurons. The number of hidden neurons is 10 as a default in MATLAB, and changing the size of hidden layer size to lower and higher numbers resulted in worse solutions. So, default numbers of hidden layers are used. As an output, the inputs samples will leave the network as either 1 (efficient) or 0 (non-efficient). Generally, sample data are divided into three parts by MATLAB; 70% training, 15% validation and 15% testing. So randomly selected 520 data are used for training the network, 112 data are used for validation and 112 data are used for testing this newly formed network.

When the inputs and targets are entered to the MATLAB's neural network toolbox, the following results are found.

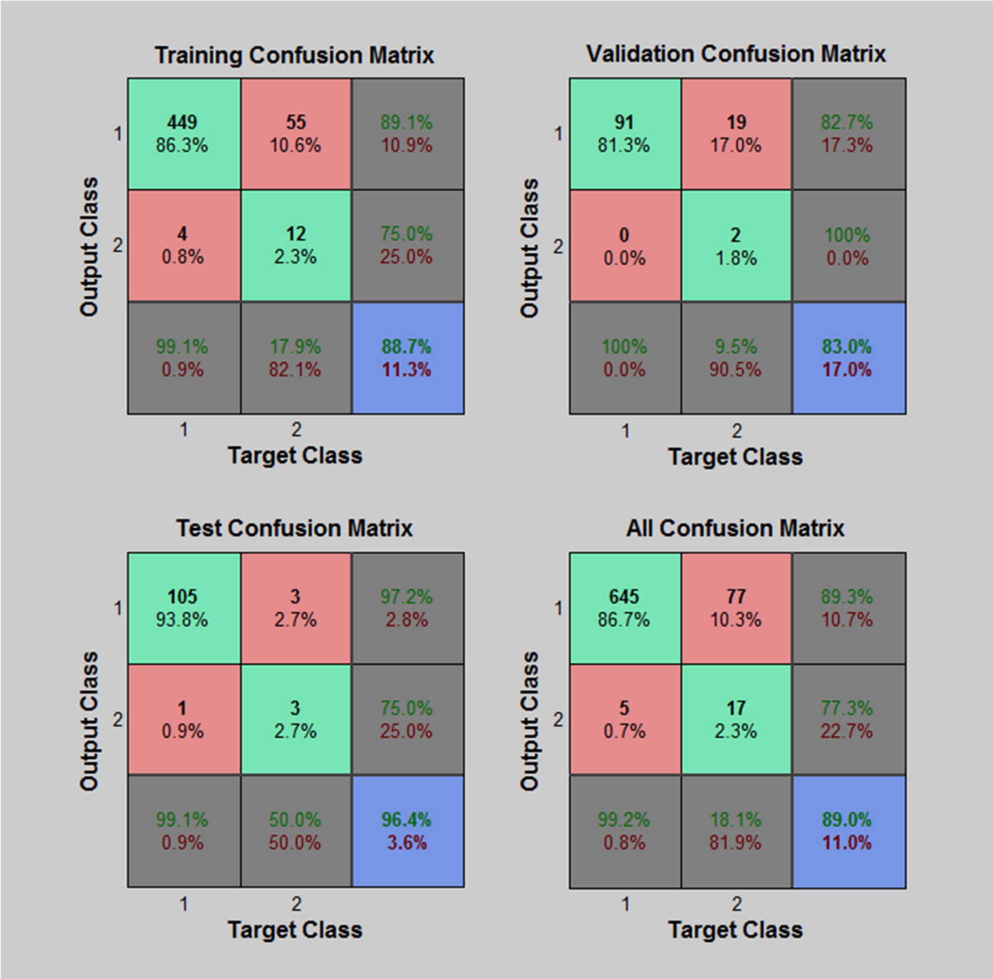
Figure 2: Error Values of Classification

Results

	Samples	MSE	%E
Training:	520	8.90280e-2	11.34615e-0
Validation:	112	1.28008e-1	16.96428e-0
Testing:	112	4.42177e-2	3.57142e-0

When Figure 2 is examined, MSE results and percentages from the classifications can be observed. Neural networks are adjusted with training data, and validation data are used for stopping training before over-fitting. The testing data are independent from both of them and used to measure the performance of the network. Because of that, we will focus of results of the testing data. Error values from the testing of the neural network results the lowest values, which means the neural network is working with an error ratio of is 3.6% and can be interpreted as a well performing model.

Figure 3: Confusion Matrix of Classification



When the confusion matrices in figure 3 are examined, correct, false positive and false negative classifications can be seen clearly. In this figure, the part that needs attention is the classification results of testing. As said before, the testing data is completely independent on training and validation, and shows the real performance of neural network. The detailed explanation of this matrix is in analysis section.

4 RESULTS

From the test confusion matrix classification analysis, all units are observed as efficient and non-efficient. The main evaluation criterion in this model is the performance of the neural network.

Table 1: Test Results of Classification of SME's

	Efficient		Non-Efficient		Total	
Number of SMEs	3	1	105	3	108	4
Performance	75%		97.20%		96.40%	
	False Negative: 25%		False Positive: 2.8%			

In Table 1, in "Number of SMEs" row, the amount on the left side for each column shows the correct classification, and the amount on the right side for each column shows the incorrect classification according to DEA results. The “Performance” row shows the efficiency performance percentages of these classifications.

By examining the efficiency results, some patterns are easily recognized. For efficiency results, neural network model is better in classification of the non-efficient SMEs. The imbalance between number of efficient and non-efficient SME’s causes this pattern. For all data the efficient and non-efficient ratio is 0.145 and because of that neural network model’s false positive and false negative ratios are different. The false negative is the situation in which efficient SMEs are considered non-efficient and false positive is the situation in which non-efficient SMEs are considered efficient. In the model, from the results, it is clearly seen that false positive ratio is smaller than the false negative ratio. In a sense, this is a good result, because this means that the neural network does not classify the non-efficient SMEs as efficient SMEs. Because, if an SME is classified as non-efficient even if it is efficient, it can improve itself to be more efficient, but if a non-efficient SME is classified as efficient, this can result in big damages for the SME.

So to conclude, neural network is trained more at non-efficient results. In future, if new efficient SMEs data is added, then the neural network can be trained to make better efficiency classification.

5 MANAGERIAL IMPLICATIONS AND CONCLUSION

The importance of this study comes from the fact that in real world some outputs are difficult to obtain, especially output values like total sales and market share. Because, these values can be manipulated and take a lot of time and effort to calculate. That is why, a model which only uses easy to find inputs without relying the outputs can be effective in many ways. Also, it consumes less resource and can be applied quickly.

DEA has some shortcomings. First of all, because of the DEA models working principle, when a new sample is added, the model needs to find the results from the start and this will consume additional time. The neural network model just uses the pre-found weights to classify the new sample. Secondly, since the DEA model starts the analysis from the scratch, it will find new results, which can cause some inconsistencies with the previous results. For example, because of the addition of the new sample, a previously efficient sample can be found non-efficient and vice versa. But this shortcoming can be bypassed by using neural network because, again, neural network model just uses the pre-found weights to classify the new sample, the models is not started from the beginning and no new weights are found, so the results are consistent.

This study can be applied into many sectors and has many implementations over the business world. Each efficiency decision that uses other models can be used by this model with lesser attribute. Such as; Credit scoring, supplier selection, self-evaluation, resource allocation and management and etc.

As a future study, when additional data is collected, a more solid neural network model which is stronger on false negative can be form. Also in future, a neural network model which uses fewer inputs can be formed.

To conclude, we formed a neural network with the results taken from the DEA analysis. From the neural network, the classification results are found and their performances are measured. DEA needs two types of data, inputs and outputs in order to make classification. Our aim in this study is to use DEA as a stepping stone to the neural network model and make classification by just using the inputs from DEA. From the results, the target seems to be achieved and new SMEs can be easily classified upon their operational efficiencies with this model.

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