Expert Systems with Applications 36 (2009) 8839–8848

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

Modeling the competitive market efficiency of Egyptian companies: A probabilistic neural network analysis

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ARTICLE INFO

Keywords:
Data envelopment analysis
Probabilistic neural networks
Discriminant analysis
Market efficiency

ABSTRACT

Understanding efficiency levels is crucial for understanding the competitive structure of a market and/or segments of a market. This study uses two artificial neural networks (NN) and a traditional statistical classification method to classify the relative efficiency of top listed Egyptian companies. Accuracy indices derived from the application of a non-parametric data envelopment analysis approach are used to assess the classification accuracy of the models. Results indicate that the NN models are superior to the traditional statistical methods. The study shows that the NN models have a great potential for the classification of companies' relative efficiency due to their robustness and flexibility of modeling algorithms. The implications of these results for potential efficiency programs are discussed.

1. Introduction

The competitiveness of a country derives from the efficiency of its enterprises. While competitiveness at the national level is reflected in the performance of the country, it is reflected in the size of the market share at the company level (Porter, 1998). Both notions highlight the importance of efficiency and performance evaluation. Efficiency evaluation and benchmarking are widely used methods to identify the best practices as a means to improve the performance and increase productivity (Barros, 2004). Measuring efficiency levels has become an important issue for managers and investors alike (Galagedera & Silvapulle, 2002). Consumers also benefit from efficient resource usage and allocation because this may mean lower prices and more professional service (Anderson, Fok, Zumpano, & Elder, 1998).

Gandjour, Kleinschmit, Littmann, and Lauterbach (2002) concluded that many quality and efficiency indicators used by executives are lacking in general validity. Using a recognized and valid measure of efficiency is critical for managers seeking to increase the effectiveness of their organizations. Over the past two decades, data envelopment analysis (DEA) has become a popular methodology for evaluating the relative efficiencies of decision making units (DMUs) within a relatively homogenous set (e.g. Sun & Lu, 2005). DEA is an approach to estimate the production function of organizations and organizational units and enables the assessment of their efficiency.

Although widely employed to evaluate efficiency across industries (e.g. Rickards, 2003), DEA can hardly be used to predict the performance of other DMUs (Wu, Yang, & Liang, 2006). As a result, neural network models (NN) were introduced recently to complement DEA in estimating efficiency frontiers of DMUs (Wang, 2003). Wang (2003) showed formally that neural network find data envelopes based on the entire data set, rather than some extreme data points. Athanassopoulos and Curram (1996) were first to combine NN and DEA for classifying and predicting efficiency in bank branches. A comprehensive search through several databases yielded no studies dealing with companies' efficiency using a DEA-NN approach. This confirms Santin, Delgado, and Valino (2004, p. 630) claim that NN models "have no theoretical studies in efficiency analysis and few applications have been made in this field." We, going beyond the conventional methods, have attempted to merge both methodologies to evaluate the relative efficiency of the top listed companies in Egypt. The paper also contributes methodologically through the comparison of various parametric and non-parametric techniques, which results in considerable information for business analysis. More specifically, the purpose of this research is twofold:

- To assess the market performance of the top listed companies in Egypt; and
- To benchmark the performance of NN models against traditional statistical techniques.

This paper is organized as follows. The next section summarizes the methodology used to conduct the analysis. The subsequent section presents empirical results of the efficiency levels of Egyptian companies. After a brief preliminary data analysis, this section first set out efficiency scores derived from estimating the basic DEA models; it also presents sensitivity analysis of DEA-NN derived efficiency scores as a rough validity check on the results. Next, the

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doi:10.1016/j.eswa.2008.11.024

paper sets out some managerial and policy implications of the analysis. The final section of the paper deals with the research limitations and explores avenues for future research.

2. Literature review

PFA, pre-eminently data envelopment analysis (DEA), has been widely used as an efficiency measurement tool in a variety of fields. For instance, in the banking industry, Miller and Noulas (1996) examined the efficiency of large U.S. banks. They found overall technical efficiency of around 97%. However, the majority of banks were found to be too large and experiencing decreasing returns to scale. A second stage regression analysis showed that pure technical efficiency is positively related to bank size and bank profitability. Bhattacharya, Lovell, and Sahay (1997) used a two-stage DEA approach to examine the impact of liberalization on the efficiency of the Indian banking industry. In the first stage a technical efficiency score was calculated, whereas in the second stage a stochastic frontier analysis was used to attribute variation in efficiency scores to three sources: temporal, ownership and noise component. Using a bootstrapping DEA technique, Casu and Molyneux (2003) investigated efficiency across European banking systems. Results suggest that there has been a slight improvement in bank efficiency levels since the implementation of the EU's Single Market Programme. Krishnasamy (2003) used both DEA and Malmquist total factor productivity index (MPI) to evaluate bank efficiency and productivity changes in Malaysia over the period 2000–2001. The results from the analysis indicated that total MPI increased in all the bans studied. The growth of productivity in these banks was attributed to technological change rather than technical efficiency change. Lo and Lu (2006) employed a two-stage DEA approach including profitability and marketability to explore the efficiency of financial holding companies (FHCs) in Taiwan. Factor-specific measures and BCC (Banker-Charnes-Cooper) model were combined together to identify the inputs/outputs that are most important and to distinguish those FHCs which can be treated as benchmarks. Results show that big-sized FHCs are generally more efficient than small-sized ones. Wu et al. (2006) integrated DEA and neural networks (NNs) to examine the relative branch efficiency of a large Canadian bank. Findings suggest that the predicted efficiency using the DEA-NN model has good correlation with that calculated by DEA, which indicates that the predicted efficiency using the DEA-NN approach is a god proxy to classical DEA approach.

Substantial research has been conducted on DEA applications to hospitals. For example, Sherman (1984) examined the efficiency of seven teaching hospitals in Massachusetts. The study found that two of the seven hospitals were inefficient and suggested specific input reductions for the inefficient hospitals. Using a sample of 3000 urban hospitals, Ozcan and Luke (1993) looked at the relationship between four hospital characteristics (size, membership in a multi-hospital system, ownership and payer mix) and hospital efficiencies. O'Neill (1998) applied supper-efficiency to hospitals by calculating supper-efficiency scores for a DEA model using data from 27 large, urban hospitals. Hu and Huang (2004) applied DEA to compute hospital efficiencies in Taiwan, and then used both the Mann-Whitney test and Tobit regression to explore the effects of environmental variables on these efficiency scores. The study found that public ownership adversely affects hospitals' efficiency. Laine et al. (2005) analyzed the association between quality of care and technical efficiency in hospitals' long-term care wards for the elderly in Finland. DEA was used to calculate technical efficiency while the Mann-Whitney test and correlation coefficients were used to explore the association between quality and efficiency. The results suggest that an association may exist between technical efficiency and some dimensions of quality.

Numerous studies have also been done on DEA applications in farm production. For instance, Audibert, Mathonnat, and Henry (2003) assessed the role of malaria and some social determinants on the cotton crop efficiency in Ivory Coast. The study found that high parasite density infection has a direct and indirect negative effect on efficiency in the cotton crop. Krasachat (2004) applied DEA to study efficiency of rice farms in Thailand. A Tobit regression was also used to explain the likelihood of change in efficiencies by farm-specific factors. Results indicated that the diversity of natural resources has an influence on Thai rice farms' technical efficiency. Lee (2005) compared stochastic frontier analysis (SFA) and DEA methods on measuring production efficiency of forest companies. Although the study found slight differences in the efficiency scores obtained from the two methods, the highest and lowest relative efficiency ranking for forest companies remain the same. Chauhan, Mohapatra, and Pandey (2006) applied DEA to determine the efficiencies of farmers with regard to energy use in rice production activities in India. The results reveal that a possible about 12% of the total input energy could be saved if the best practice farm was used as a benchmark.

Other application areas include Internet companies (e.g. Serrano-Cinca, Fuertes-Callen, & Mar-Molinero, 2005), audit services (e.g. Dopuch, Gupta, Simunic, & Stein, 2003), football teams (e.g. Haas, Kocher, & Sutter, 2004), retail stores (e.g. Barros & Alves, 2003), aquaculture (e.g. Cinemre, Ceyhan, Bozoglu, & Kilic, 2006), insurance industry (e.g. Cummins & Rubio-Misas, 2006), supplier evaluation (Narasimhan, Talluri, & Mendez, 2001), seaports (e.g. Cullinane, Wang, Song, & Ji, 2006), airports (e.g. Sarkis, 2000), advertising agencies (e.g. Luo & Donthu, 2005), hotels (e.g. Sigala, Jones, Lockwood, & Airey, 2005), schools (e.g. Mancebon & Mar-Molinero, 2000), universities (e.g. Flegg, Allen, Field, & Thurlow, 2004), local government (e.g. Hughes & Edwards, 2000) and nations (e.g. Ramanathan, 2006).

From this brief review we find that although numerous studies have attempted to assess efficiency in the West and other parts of the world, virtually no studies have focused on measuring efficiency in Egypt. In this investigation we aim to fill this research gap by empirically evaluating marketing efficiency of top listed companies in Egypt using intelligent modeling techniques.

3. Methodology

3.1. Data envelopment analysis

Introduced in 1978 by Charnes, Cooper, and Rhodes (1978), DEA assigns an efficiency score to each unit by comparing the efficiency score of ach unit with that of its peers. It identifies a frontier comprising best performers. The DEA frontier traces the geometrical locus of all Pareto-optimal points of the production set. Those units that lie on the frontier are recognized as efficient, and those that do not, as inefficient. DEA involves the solution of a linear programming problem to fit a non-stochastic, non-parametric production frontier-based on the actual input-output observations in the sample. In the basic DEA model (CCR), the objective is to maximize the efficiency value of a test firm k from among a reference set of s firms, by selecting the optimal weights associated with the input and output measures. The maximum efficiencies are constrained to 1. The formulation is represented by model (1).

$$\begin{aligned} &\text{maximize} \quad E_{kk} = \frac{\sum_y O_{ky} V_{ky}}{\sum_x I_{kx} U_{kx}} \\ &\text{subject to}: \quad E_{ks} \leqslant 1 \quad \forall \text{ firms } s \\ &u_{ks}, v_{ky} \geqslant 0, ks, \end{aligned} \tag{1}$$

where E_{ks} is the efficiency score of firm s, using the weights of test firm k; O_{sy} is the value of output y for firm s; I_{sx} is the value for input