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The analysis of bank business performance and market risk—Applying Fuzzy DEA

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A B S T R A C T

In the fast changing financial circumstances of nowadays, in avoiding the crisis of closing down, financial institutions are concerned about the efficiency and risk strictly in the meantime. Therefore, efficiency and risk management are goals for a financial institution administrator. Data Envelopment Analysis (DEA) is a non-parameter approach to evaluate the performance of DMU's efficiency and the variables used in the DEA are all accurate values. However, when the input or output variables are fuzzy, the performance of DMUs must proceed by the Fuzzy-DEA. On the basis of risk uncertainty, this research plans to apply the expanding model of Fuzzy Slack-Based Measurement (Fuzzy SBM). The efficiency scores estimated by Fuzzy SBM model are subordinate to functional form, which provides efficiency value region in different degrees of confidence, conforms to the characteristic of risk anticipation, and estimates the management achievement of Taiwan banking under market risk.

1. Introduction

As financial institutions around the world become more internationalized and globalized, the trading activities of the financial industry continue to rise. The market structure is further complicated due to the diversity and innovativeness of products available. Therefore, the risk of investment for financial institutions likewise increases. With such changes in the economic state, banks no longer have the sole role of being the purely monetary intermediary. They must now develop a whole range of investment channels in order to survive under such conditions. However, bearing the objective of profit-making in mind, banks will naturally increase their investments in high-risk products or increase leveraged trading, which means that the high potential profits mask the high risks involved and increase the probability of a bank's bankruptcy due to poor management. For this reason, more attention must be paid to the high risks attached to the high potential profits. The topic of Risk Adjusted Performance Measurement has, in recent years, gained increasing awareness and has become more widely discussed as people place more importance on risk management.

From the perspective of efficiency measurement, Data Envelopment Analysis (DEA) takes into consideration both inputs and outputs. The mathematical method therefore provides a fair measurement of efficiency. Since this analytical model was first proposed, it has been widely applied in a whole range of industries. Most studies to date on bank efficiency have focused mainly upon the economies of scale and scope (Berger and Humphrey, 1991; Berger et al., 1987; Hunter and Timme, 1986; McAllister and McManus, 1993), total productivity (Aly et al., 1990; Favero and Papi, 1995; Fukuyama et al., 1999; Grabowski et al., 1993; Schaffnit et al., 1997; Zaim, 1995), and the efficiency effect (Barr et al., 1994; Casu and Molyneux, 2003; Cebenoyan et al., 1993; Chang, 1999; DeYoung and Hasan, 1998; Elyasiani et al., 1994). The fact that increasing importance is gradually being placed on risk management means that more attention is also given to DEA models that include risk in their equations. There are two issues concerning banks' efficiency and risk. One issue treats risk as exogenous in order to analyze efficiency effects (Ataullah et al., 2004; Barr et al., 1994; Berger and DeYoung, 1997; Chang and Chiu, 2006; Cebenoyan et al., 1993; Elyasiani et al., 1994; Pastor, 2002). The above results show that the efficiency level is significantly correlated with the risk indicators. The other issue treats risk as endogenous in order to analyze banks' efficiency (Altunbas et al., 2000; Chang, 1999; Chiu and Chen, 2008; Drake and Hall, 2003; Girardone et al., 2004; Hughes, 1999; Hughes et al., 2001; Mester, 1996; Pastor, 1999). However, the majority of literatures adopt the overdue loan ratio as the substitute variable for risks, which does not reflect the characteristic of uncertainty that risks display.

Risk is defined as the presence of the characteristic uncertainty, and the degree of risk varies with the asset value fluctuation and the manager's attitude toward risk. Risk may therefore either bring profit or loss to the asset value. The basic function of capital in this

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context is to help bear the possible loss incurred by taking risks. The appropriate provision of capital is therefore key to a stable financial structure, which can help prevent a situation of an inability to make payments. In 2002, the Basel Committee on Banking Supervision (BCBS) proposed the New Basel Capital Accord (Basel II), which sets out guidelines for international banks in terms of taking risks, and therefore, to prevent financial crises. In the section on minimum capital requirement outlined in Basel II, the internal rating uses Value at Risk (VaR) as the basis to estimate the maximum potential loss of the portfolio selection. In simple terms, the VaR 'uses a single value to represent the maximum potential loss of an investment portfolio during a period of time, with a certain confidence level'. Hence, VaR is a prediction interval that provides different estimates according to the different confidence intervals, and therefore takes into account the characteristic of uncertainty that risks displays.

While VaR is widely used to represent the level of risks entailed, the input and output values of the original DEA models are considered crisp values. This is a reoccurring issue encountered when using VaR to estimate the efficiency values of banks. Considering both domestic and foreign literatures, there have been none that have combined these two issues and provided an analytical discussion on the topic. Therefore, this paper seeks to combine the Slack-Based Measure of Efficiency (SBM) as proposed by Tone (2001), with the Fuzzy Measure Theory, and develops the non-radial Fuzzy Slack-Based Measure of Efficiency model (Fuzzy-SBM).

2. Literature review

DEA was a method first proposed by Charnes et al. (1978); then Banker et al. (1984) developed the method for variable returns to scale, called the BCC model. Both the CCR and BCC models considered the weighting of inputs and outputs, and used linear programming to estimate efficiency values. Tone (2001) proposed the Slack-Based Measure of Efficiency (SBM). This model adopts a non-radial method of estimation, while considering the input and output slacks. Therefore, when the efficiency value of a Decision Making Unit (DMU) equals 1, the DMU displays no slacks in either its input or output.

DEA is widely used to estimate the efficiency values of various organizations and industries, and the SBM model solves the issue presented in efficiency ranking. However, these traditional DEA models assume crisp input and output values. If these values are fuzzy numbers, the traditional DEA models cannot accurately measure the efficiency values. For this reason, scholars (Cooper et al., 1999; Despotis and Smirlis, 2002; Guo and Tanaka, 2001; Jahanshahloo et al., 2004; Kao and Liu, 2000) developed the Fuzzy-DEA model, which has the fuzzy measure characteristic. Fuzzy-DEA was originally proposed by Sengupta (1992), in which Sengupta proposed the fuzzy goal-oriented and constraint-based technique based on Zimmermann's (1976) method. This provided the results of Fuzzy-DEA, although the technique is limited to analyzing efficiency with multiple inputs and a single output. Kao and Liu (2000a,b) argued that when fuzzy data exists or there is missing data, it is necessary to adopt the fuzzy measurement concept and the Extension Principle as proposed by Zadeh (1965) to transform the Fuzzy-DEA model into a traditional DEA model with parameters of the level α. Subsequently, Saati et al. (2002) and Lertworasirikul et al. (2003) proposed respectively the Fuzzy-CCR model with asymmetric triangular fuzzy numbers, and the Fuzzy-BCC model that uses probability to conduct analysis. They used a-cut to transform the Fuzzy-DEA model into a linear structure model. Kao and Liu (2004) published a research paper, which was the first research based on financial institutions in Taiwan, with research using the Fuzzy-DEA model to evaluate the efficiency values of those banks. Unfortunately, this paper did not take into account the risks faced by the banks, and in the ever changing market conditions, this was a limitation.

The Basel Capital Accord was created due to the increasing importance placed on risk management. The VaR approach detailed in the Basel Capital Accord has been, so far, the most popular method employed in risk management. Beder (1995) used the Historical Simulation and the Monte Carlo Simulation methods to estimate the VaR of three simulated investment portfolios. Research carried out by Hendricks (1996) concluded that there is no one particular risk valuation model that was more superior to other models under every set of performance criteria. Alexander and Leigh (1997) believed that because the Historical Simulation method tends to use data collected over a few years to evaluate the market variants and the distribution of profits and losses, it was therefore a better model as no distribution hypothesis is required to estimate the VaR. Jackson et al. (1997) stressed that there can be significant differences in VaR values due to the different types of portfolios, and that the simulation method is able to provide more precise tail probabilities than the parameter formula. Looking at all the literatures mentioned and their empirical results, it is evident that the use of VaR models to measure adequacy for market risk is very popular.

When evaluating risk characteristics and estimating efficiencies, it is suitable to employ the Fuzzy-DEA model where the input and output are non-particular values. The above method suggested by this research paper is different from the traditional DEA models proposed in past literatures. Another unique aspect of this paper is to have developed the Fuzzy-DEA model into the Fuzzy-SBM model, which is also different from the current Fuzzy-BCC and Fuzzy-CCR models. To summarize, this research considers the operational risk of banks and uses the VaR values as fuzzy numbers to estimate the business performance of banks in Taiwan.

3. Research methodology

Tone (2001)proposed that Slack-Based Measure of Efficiency model utilizes non-radial estimation method. It also takes the slacks of investment and production items into consideration. Due to the employment of the non-radial method to estimate the efficiency value, the issues such as infeasible would not occur. Thus, this study tends to base on the SBM model, utilizing Fuzzy DEA (Kao and Liu, 2000) to further develop Fuzzy SBM based on the concepts of fuzzy numbers. In the following, the SBM model will be first illustrated, then the derivation of Fuzzy SBM.

3.1. Slack-based measure of efficiency

Tone (2001) proposed the SBM model which is in a manner of a non-ray efficiency of the estimated value, and it will not incur a problem that cannot be estimated. Assume there are n DMUs, m inputs, and s outputs. The production possibility set is defined as $P=\{(x,y)| x\geq X\lambda, y\leq Y\lambda, \lambda\geq 0\}$ in which $X=(x_{ij})\in R^{m\times n}$ is the input matrix and $Y=(y_{rj})\in R^{s\times n}$ is the output matrix. The index δ_j for the DMU_j is from (x_0, y_0) so as to average distances $(\overline{x},\overline{y})\in\overline{P}\ (x_0, y_0)$. The SBM is as follows.

$$
\begin{aligned}
\min_{\delta_j,\lambda_1,\lambda_2,\ldots,\lambda_n} \quad & \delta_j = \frac{\frac{1}{m}\sum_{i=1}^{m} \overline{x}_{ij} \big/ x_{i0}}{\frac{1}{s}\sum_{r=1}^{s} \overline{y}_{rj} \big/ y_{r0}} \qquad (1) \\
s.t. \quad & \overline{x}_j \geq \sum_{k=1}^{n} \lambda_k x_k \\
& \overline{y}_j \leq \sum_{k=1}^{n} \lambda_k y_k \\
& \overline{x}_j \geq x_0 \text{ and } \overline{y}_j \leq y_0 \\
& \overline{y}_j \geq 0, \lambda_k \geq 0.
\end{aligned}
$$