MODELLING BANKING SECTOR EFFICIENCY: A DEA AND TIME SERIES APPROACH

Fadzlan Sufian*
University Putra, Malaysia

Abstract. *The paper provides a new approach to modeling bank efficiency. Unlike previous bank efficiency studies, the present paper employs the data envelopment analysis (DEA) method on quarterly data to construct the efficiency frontiers. The Malaysian banking sector is used for a case study. The results show that the Malaysian banking sector has exhibited the mean technical efficiency of 97.3%, suggesting the minimal input waste of 2.7%. The empirical findings suggest that the pure technical efficiency outweighs the scale efficiency in determining the Malaysian banking sector's technical efficiency. The results imply that, although the Malaysian banking sector has been efficient in managerial terms, it has been operating at a non-optimal scale of operations.*

Key words: *bank efficiency, data envelopment analysis, time series*

Introduction

The banking system remains to be the main provider of funds in the Malaysian economy. Therefore, various initiatives have been introduced to build the capacity and capability of the domestic banking sector. Given the importance of the domestic banking sector for the well-being of the overall economy, various efforts have been made to gauge the performance of the Malaysian banking sector. One of the indicators used by bank managements, policymakers, stakeholders, etc. is the banking sector's efficiency level. As Malaysia advances into the new millennium, the transition to the new economy – more globalized, digitized, and knowledge-based – will require the financial system to evolve accordingly to support the transformation and growth processes. The financial system has also been operating in an era of rapid changes shaped by technological advances and trends towards a greater market orientation and globalization.

Based on the factors mentioned above, the Malaysian banking sector was used for a case study. Unlike the previous bank efficiency studies, the present paper employs the data envelopment analysis (DEA) method on quarterly data to construct the efficiency frontiers. Furthermore, the DEA method allows us to focus on the technical efficiency of input savings, which can be further detailed into its pure technical and scale efficiency components.

* Khazanah Research and Investment Strategy, Khazanah Nasional Berhad, Level 35, Tower 2, Petronas Twin Towers, Kuala Lumpur City Centre, 50088 Kuala Lumpur, Malaysia;
e-mail: fadzlan.sufian@khazanah.com.my

The results of this study are useful to enrich knowledge on the factors that influence the performance of banks in a developing economy. The present paper also provides important findings in regard to the best practice among banks. The findings from this study could be useful to bank managements and policymakers in developing and transition economies in regard to attaining optimal utilization of capacities, improvement in managerial expertise, efficient allocation of scarce resources and the most productive scale of operation in the banking sector.

The paper is structured as follows. The following section reviews the related literature. In section 3, we describe the data, sources, and model specifications employed in the study. Section 4 presents the results, and finally we conclude the paper in section 5.

1. Related studies

Since its introduction by Charnes et al. (1978), the literature examining the efficiency of financial institutions has expanded rapidly. The liberalization of the banking sector and the increasing number of bank failures in the 1980s and early 1990s contributed to an increasing academic interest in the topic. Apart from focusing on the banking sector, the DEA method has also been employed to examine the efficiency of other economic sectors worldwide, such as insurance, manufacturing, ports, hospitals, universities, etc.

However, a large body of literature exists on banking efficiency in the United States (see surveys in Berger et al. 1993; Berger and Humphrey, 1997; Berger, 2007 and references therein) and the banking systems in the western and developed countries (Sathye, 2001; Drake, 2001; Canhoto and Dermine, 2003; Webb, 2003; Fiordelisi, 2007; Pasiouras, 2008; Sturm and Williams, 2008; Siriopoulos and Tziogkidis, 2009, etc.).

Among the notable research performed to examine the efficiency of the Malaysian banking sector are those of Katib and Mathews (2000), Okuda and Hashimoto (2004), Sufian (2007). Katib and Mathews (2000) employ the DEA method to examine characteristics of the management structure and technical efficiency of the banking industry in Malaysia during the period 1989 to 1985. Okuda and Hashimoto (2004) examined the production technology of Malaysian domestic commercial banks by the stochastic cost function approach adjusted to non-performing loans during 1991–1997. More recently, Sufian (2007) has employed the DEA method to investigate the effects of mergers and acquisitions on the efficiency of Malaysian banks. He divided the study period into three sub-periods, namely pre-merger, during merger, and post-merger, to compare the differences in Malaysian banks' technical, pure technical, and scale efficiency levels. The result suggests that during the merger year, Malaysian banks' technical efficiency level declined slightly due to scale inefficiency, but during the post-merger period Malaysian banks have exhibited higher mean technical levels compared to the pre-merger period.

On the other hand, Krishnasamy et al. (2004) are among the first to examine the total factor productivity change in the Malaysian banking sector. By employing the Malm-

quist Productivity Index (MPI), they have found that during the period 2000–2001, post-merger Malaysian banks exhibited a total factor productivity growth of 5.1%. They suggest that the merger programme among the domestic banks has not resulted in a better scale efficiency of Malaysian banks as all banks, except two, exhibited a scale efficiency regress. The results also suggest a rapid technological change of post-merger Malaysian banks, ranging from 5.0% to 16.8%. Two banks, however, experienced a technological regress during the period of study. Sufian and Ibrahim (2005) extended the study by Krishnasamy et al. (2004) to assess the impact of off-balance sheet items on the efficiency and productivity of the Malaysian banking sector. The inclusion of OBS items has resulted in an increase in estimated productivity levels for all banks. They suggest the impact to be more pronounced on the technological rather than the efficiency change.

To the best of our knowledge, virtually nothing has been published to examine the efficiency of the banking sector by using a time series data and the data envelopment analysis (DEA) method. In the light of the knowledge gaps, this paper seeks to provide, for the first time, empirical evidence on the efficiency of the banking sector by using a time series data and the DEA method.

2. Methodology and data

The data envelopment analysis (DEA) is a non-parametric mathematical programming method, first developed by Charnes et al. (1978), to evaluate the relative efficiency of a group of entities or decision making units (DMUs). To measure the efficiency for each bank, we assume that there are data on K inputs and M outputs for each N bank. For the i^{th} bank, these are represented by the vectors x_i and y_i respectively, and we calculate the ratio of all inputs such as $(u' y_i / v' x_i)$ where u is an $M \times 1$ vector of output weights and v is a $K \times 1$ vector input weights. To select the optimal weights, we specify the following mathematical programming problem:

$$\begin{aligned} &min\ (u' y_i / v' x_i)\ , \\ &u' y_i / v' x_i \leq 1, \quad j = 1, 2, \ldots, N, \\ &u, v \geq 0. \end{aligned} \tag{1}$$

The above formulation has a problem of infinite solutions, and therefore we impose the constraint $v' x_i = 1$ which leads to

$$\begin{aligned} &\min\ (\mu' y_i), \\ &\Phi' x_i = 1 \\ &\mu' y_i - \Phi' x_i \leq 0, \quad j = 1, 2, \ldots, N, \\ &\mu\varphi \geq 0\ , \end{aligned} \tag{2}$$

where we change notation from u and v to μ and φ, respectively, in order to reflect transformations. Using the duality in linear programming, an equivalent envelopment form of this problem can be derived:

$$\begin{aligned} &min\ \theta, \\ &y_i + Y\lambda \geq 0, \\ &\theta x_i - \lambda \geq 0, \\ &\lambda \geq 0, \end{aligned} \tag{3}$$

where θ is a scalar representing the value of the efficiency score for the i^{th} DMU, which will range between 0 and 1. λ is a vector of $N \times 1$ constants. The linear programming has to be solved N times, i.e. once for each DMU in the sample.

We adopt a variant of the "intermediation approach", which views banks as financial intermediaries whose primary business is to borrow funds from depositors and lend those funds to others for profit. Berger and Humphrey (1997) pointed out that "this approach has been found to be more relevant for financial institutions…". Accordingly, the present paper considers *loans and advances (y1)*, which include overdrafts, term loans (i.e. housing loans / financing, syndicated term loans – hire purchase receivables, lease receivables, factoring receivables and other term loans and financing), bill receivables, trust receipts, subordinated debt, staff loans, credit card receivables, revolving credits, share margin financing, other loans, allowance for bad and doubtful debts and *investments (y2)* (i.e. securities held for trading, available-for-sale securities and held-

TABLE 1. **Descriptive statistics for inputs and outputs (in millions of RM)**

	Y1	Y2	X1	X2	X3
Min	11,257,225	1,770,217	13,787,393	88,983	70
Mean	43,574,639	12,381,163	56,729,857	641,483	298,446
Max	140,864,736	36,068,582	193,211,452	1,446,807	1,198,259
S.D	29,745,090	8,469,204	38,254,770	392,100	215,129

Notes. Y1: loans and advances (includes overdrafts, term loans (i.e. housing loans/financing, syndicated term loans – hire purchase receivable, trust receipts, lease receivables, factoring receivables and other term loans and financing), bill receivables, trust receipts, subordinated debts, staff loans, credit card receivables, revolving credits, share margin financing, other loans, allowance for bad and doubtful debts). Y2: investments (i.e. securities held for trading, available-for-sale securities and held-to-maturity securities). X1: total deposits (includes deposits from customers and deposits and placements of banks and other financial institutions), X2: fixed assets. X3: overhead expenses (inclusive expenses for personnel costs (i.e. salaries, allowances and bonuses, pension cost and others), establishment costs (i.e. depreciation of fixed assets, rental, insurance, other), marketing expenses (i.e. sales commission, advertisement, others), administration and general expenses (i.e. amortization of good will, legal and professional fees, communication, others))*.

Source: Banks annual reports and author's own calculations.

* As data on the number of employees are not readily made available, personnel expenses have been used as a proxy measure.

to-maturity securities) as outputs. The outputs represent the banks' revenues and major business activities.

The inputs used are deposits (×1) which consist of deposits from customers and of deposits and placements of banks and other financial institutions, fixed assets (×2) and overhead expenses (×3) which include expenses for personnel costs (salaries allowances and bonuses, pension cost and others), establishment costs (depreciation of fixed assets, rental, insurance, other), marketing expenses (sales commission, advertisement, others), administration and general expenses (amortization of good will, legal and professional fees, communication, others). The inputs represent measures for the banks' labour, capital, and operating costs. The summary statistics of the inputs and outputs used in the study are presented in Table 1.

3. Empirical findings

Table 2 presents the results of the technical efficiency, scale efficiency, and pure technical efficiency change of the Malaysian banking sector during the period of the first quarter of the year 2000 to the third quarter of the year 2007. Due to incomplete and missing observations, we have to exclude observations for the fourth quarter of 2007. It is apparent from Table 2 that the Malaysian banking sector has exhibited a mean technical efficiency of 97.3% during the period 2000–2007, suggesting the minimal input waste of 2.7%. Similar studies performed on the efficiency of Malaysian banks by Sufian (2004) found the minimal input waste of 4.1%, while Sufian (2007) found the mean input waste of 6.2%.

The results show that the Malaysian banking sector's efficiency level has progressively improved during the period under study, particularly after the post-merger period of 2001. Furthermore, the results indicate that the Malaysian banking sector has exhibited a 100% pure technical efficiency level beginning from the third quarter of the year 2005 to the third quarter of the year 2007. There are several plausible reasons for the favourable development. First, the small and medium size banks could have benefited from the merger programme which was concluded in 2001 and could have reaped significant cost savings from expansion and mergers via economies of scale and synergy. Second, the merger programme has resulted in the domestic commercial banks to be relatively more managerially efficient because of their larger size. Previous studies, among others by Noulas et al. (1990) and Miller and Noulas (1996), have also found that large banks tend to exhibit higher PTE levels compared to their smaller bank peers. Third, Berger et al. (1999) have pointed out that bank mergers may lead to changes in efficiency, market power, economies of scale and scope, availability of services to small customers and payment systems' efficiency. And finally, Sufian (2007) suggests that bank mergers may enable banking firms to benefit not only from new business opportunities that have been created by changes in the regulatory and technological environment, which could lead banks to earn higher profits.

TABLE 2. **Summary of efficiency measures***

	Technical efficiency		Pure technical efficiency		Scale efficiency	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Panel A: 2000						
Q1	0.957	0.084	0.974	0.074	0.983	0.041
Q2	0.951	0.072	0.979	0.061	0.972	0.052
Q3	0.967	0.087	0.970	0.087	0.997	0.006
Q4	0.945	0.088	0.964	0.082	0.980	0.028
Panel B: 2001						
Q1	0.979	0.046	0.984	0.046	0.995	0.015
Q2	0.957	0.061	0.988	0.034	0.969	0.049
Q3	0.970	0.061	0.980	0.058	0.990	0.027
Q4	0.971	0.062	0.972	0.060	0.999	0.002
Panel C: 2002						
Q1	0.974	0.059	0.980	0.059	0.955	0.013
Q2	0.970	0.068	0.977	0.066	0.994	0.015
Q3	0.982	0.051	0.983	0.051	0.999	0.002
Q4	0.946	0.086	0.965	0.069	0.979	0.033
Panel D: 2003						
Q1	0.991	0.025	0.995	0.016	0.996	0.010
Q2	0.991	0.028	0.995	0.016	0.996	0.013
Q3	0.995	0.014	1.000	0.000	0.996	0.010
Q4	0.996	0.010	1.000	0.000	0.996	0.010
Panel E: 2004						
Q1	0.867	0.158	0.983	0.032	0.882	0.157
Q2	0.990	0.031	0.999	0.003	0.991	0.028
Q3	0.998	0.006	1.000	0.000	0.998	0.006
Q4	0.990	0.021	0.996	0.013	0.994	0.018
Panel F: 2005						
Q1	0.996	0.013	1.000	0.000	0.996	0.013
Q2	0.990	0.031	0.999	0.004	0.991	0.026
Q3	0.994	0.018	1.000	0.000	0.994	0.018
Q4	1.000	0.000	1.000	0.000	1.000	0.000
Panel G: 2006						
Q1	0.991	0.018	0.988	0.006	0.993	0.016
Q2	0.986	0.027	1.000	0.000	0.986	0.027
Q3	0.972	0.053	1.000	0.000	0.972	0.053
Q4	0.965	0.044	1.000	0.000	0.965	0.044
Panel H: 2007						
Q1	0.966	0.062	1.000	0.000	0.969	0.062
Q2	0.969	0.061	1.000	0.000	0.969	0.061
Q3	0.959	0.065	1.000	0.000	0.959	0.065
All periods	0.973		0.989		0.982	

* The table presents the mean and standard deviations of technical, pure technical, and scale efficiencies. The efficiency scores are bounded between 0 and 1.

The demand for financial services tends to grow as economies expand and societies become wealthier. In line with the favourable economic conditions, the results suggest that the Malaysian banking sector has exhibited the average technical efficiency score of 95.5% in 2000, 96.9%, 96.8%, 99.3%, and 96.1% in 2001, 2002, 2003 and 2004, before recording the highest technical efficiency score of 100% in the fourth quarter of 2005.

However, the average mean technical efficiency declined to 97.9% in 2006 and 96.5% in 2007. The decomposition of technical efficiency into its pure technical and scale efficiency suggest that scale inefficiency outweighs pure technical efficiency in determining Malaysian banks' technical efficiency during the period under study. The results imply that during the period of study, the Malaysian banking sector has been operating at a non-optimal scale of operations rather than being inefficient in controlling their operating costs. On the other hand, pure technical inefficiency seems to dominate scale inefficiency during the years 2000 to 2002, suggesting that the Malaysian banking sector has been inefficient in controlling their costs. In contrast, scale inefficiency seems to outweigh pure technical inefficiency in 2003 to 2007. This implies that during this period the Malaysian banking sector has been relatively less managerially efficient in controlling their costs but has been operating at the optimal scale of operations.

The results suggest that most of Malaysian banks have exhibited a higher pure technical efficiency beginning from the third quarter of 2003 and have been fully efficient from the third quarter of 2005. Also, the Malaysian commercial banks have been managerially efficient in controlling their costs. Another plausible reason which could lead to the higher bank efficiency is the creation of investment banks during the period. This could be argued to have reduced duplication of resources through the rationalization of common functions, to enhance the range of products and services, and strengthen their competitive advantage (Isik, Hassan, 2002). This should enable banks to be more effective, efficient, and resilient in undertaking capital market activities both domestically and abroad.

On the other hand, beginning from the third quarter of 2003 to the third quarter of 2007, Malaysian banks were found to have been scale-inefficient in eleven out of the twelve quarters analyzed. The results seem to suggest that scale efficiency has been declining for most of the banks in the sample beginning from the fourth quarter of 2002. The year-to-year variations in technical efficiency could be explained by the variation in scale rather than pure technical efficiency. The empirical findings also seem to suggest that the Malaysian banking sector's scale inefficiency was due to decreasing returns to scale (DRS) beginning from the fourth quarter of 2002. A plausible reason could be the creation of large banks which have transgressed the optimal scale of operations to meet the excess market demand for financial services and products induced by the growing Malaysian economy.

This could have resulted in banks to face DRS due to the expansion in the number of bank branches with a poor interconnectivity. On the other hand, Malaysian banks could

also have experienced increasing returns to scale (IRS) during the period under study, due to being of a less than optimum size. Thus, the increasing asset quality and lending to priority sectors could be argued to have improved the scale efficiency of the Malaysian banking sector.

Conclusions

The paper provides a new approach to modeling bank efficiency. Unlike the previous bank efficiency studies, the present paper employs the data envelopment analysis (DEA) method on quarterly data to construct the efficiency frontiers. The Malaysian banking sector is used for a case study. The results show that the Malaysian banking sector has exhibited the mean technical efficiency of 97.3%, suggesting the minimal input waste of 2.7%. The empirical findings suggest that pure technical efficiency outweighs scale efficiency in determining the Malaysian banking sector's technical efficiency. The results imply that although the Malaysian banking sector has been efficient in managerial terms, it has been operating at a non-optimal scale of operations.

Various initiatives have been undertaken to build the capacity and capability of the domestic banking institutions. These include the industry-wide benchmarking exercise, enabling cross-selling of products and services as well as developing alternative delivery channels such as internet banking. This is also complemented by initiatives to promote efficiency, innovation, and dynamism within the financial sector. In addition, the banking sector commenced preparations for the adoption of the New Basel Capital Accord (Basel II) which is targeted for implementation in 2008 for those adopting the standardized approach and in 2010 for those adopting the internal-rating-based (IRB) approach.

Domestic banking groups are also encouraged to provide complete and integrated financial solutions to their customers and achieve cost efficiency through group rationalization. The emphasis will be on enhancing the role of financial holding companies in pursuing group strategies that promote greater risk and income diversification, synergy creation, and enhanced branding. The greater use of ICT will also be promoted to enhance risk management capabilities, to improve service delivery, and provide seamless and customized services.

Thus, we can conclude that the current position of the Malaysian banking sector is successful in reducing costs. The Malaysian banking sector is expected to be able to meet the increasing and more sophisticated demands from consumers and businesses, to adapt and adjust to the technological advances, to face the challenges of globalization and liberalization, and to withstand the economic cycle, thereby contributing to the overall economic growth and stability.

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