Determinants of Malaysian bank efficiency: evidence from bootstrap data envelopment analysis

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Abstract: The paper follows Simar and Wilson's (2007) two-stage procedure to analyse the efficiency of the Malaysian banking sector. In the first stage, we employ the data envelopment analysis (DEA) method to compute the efficiency of individual banks during the period 1999 to 2008. We then use panel regressions to examine the impact of ownership on bank efficiency, while controlling for the potential impacts of contextual variables. The DEA results indicate an increase in efficiency over the sample period. The results from the panel regression suggest that productive efficiency is positively related to bank size, capitalisation, and foreign ownership. On the other hand, the publicly listed and government owned banks have been relatively inefficient in their intermediation function.

Keywords: banks; efficiency; bootstrap DEA; panel regressions; Malaysia.

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1 Introduction

As in other developing economies, the banking system plays an important intermediary role in the Malaysian economy (Sufian, 2009). The banking sector controls most of the financial flows and accounts for more than 70% of the financial system's total assets. Therefore, knowledge of the underlying factors that influence the performance of the banking sector is essential for the managers of the banks, the central bank, bankers association, and other financial authorities to help them formulate policies to improve the performance of the banking sector.

The purpose of the present study is to employ the data envelopment analysis (DEA) method to examine the performance of the Malaysian banking sector. The present paper contributes to the present literature in several important ways. First, the paper attempts to empirically investigate the impact of foreign ownership on bank efficiency. The earlier evidence suggests that foreign owned banks tend to outperform their domestic bank peers in developing and transition countries, but not so in less developed countries (Claessens et al., 2001). Within the context of the Malaysian banking sector, it is interesting to examine this issue on the account that some of the foreign owned banks operating in the country's banking sector originate from the less developed countries as well (e.g., Thailand and China).

Second, the paper attempts to examine the association between stock exchange listing (wider public ownership) and bank efficiency. The earlier studies by Havrylchyk (2006) find inconsequential difference in the efficiency between listed and non-listed banks in Poland. On the other hand, Perera et al. (2007) among others suggest that listed banks in the South Asian banking sectors have been relatively more cost efficient compared to their non-listed bank peers. In light of these inconsistencies, it is interesting to examine whether there is significant relationship between bank efficiency and stock exchange listing in a small developing market like the Kuala Lumpur Stock Exchange (KLSE).

Third, we seek to provide new empirical evidence on the impact of government ownership on the productive efficiency of banks operating in the Malaysian banking sector. In general, government ownership of banks has been characterised as inefficient (La Porta et al., 2002), incompetent and corrupt practices (Shleifer and Vishny, 1994), and poor performance and negative outcomes (Berger et al., 2005). Furthermore, La Porta et al. (2002) point out that the negative outcome of political control of banks is more prevalent in developing countries where the financial systems are underdeveloped. In light of La Porta et al. (2002) argument, it would be interesting to examine whether the government owned banks are less efficient compared to banks with other ownership forms in a small developing country like Malaysia.

Finally, we employ two different estimating principles. The DEA method, which is one of the techniques we employ, is a non-parametric and oriented to the frontier rather than central tendency estimates (Cooper et al., 2006). Unlike the previous studies focusing on the Malaysian banking sector (e.g., Sufian and Habibullah, 2014a, 2014b; Sufian, 2011), the present study adopts the more recent DEA bootstrap method proposed by Simar and Wilson (1998, 1999, 2000). Furthermore, following Banker et al. (2010), Assaf et al. (2011), and Tecles and Tabak (2011) among others, we also use the central tendency and parametric method to investigate the efficiency of the Malaysian banking sector, while controlling for the potential effects of contextual variables. In this way, we protect against the 'methodological bias' that could occur when only one method is used [see the exchange between Evans and Heckman (1988) and Charnes et al. (1988)].

This paper is set out as follows: In the next section, we provide a brief review of the main literature. In Section 3, we outline the approaches to the measurement of efficiency change and data sources. In Section 4, we present the bias-corrected DEA results and the results from the panel regression analysis. Section 5 concludes the paper and offers avenues for future research.

2 Review of the literature

Since its introduction by Charnes et al. (1978) and Banker et al. (1984), researchers have welcomed DEA as a methodology for performance evaluation. However, a large body of literature exists on banking efficiency in the USA [Berger and Humphrey (1997), Berger (2007) provide excellent survey of the literature] and the banking systems in the western and developed countries (e.g., Siriopoulos and Tziogkidis, 2010; Brissimis et al., 2010; Tsolas, 2011, etc). On the other hand, empirical evidence on the developing countries banking sectors, particularly Malaysia is scarce. To date, studies by Katib and Matthews (2000), Matthews and Ismail (2006), and Sufian (2009) are the most notable empirical research performed to examine the efficiency of the Malaysian banking sector.

By employing the DEA method, Katib and Matthews (2000) investigate technical efficiency of the Malaysian banking sector during 1989 to 1995. The results indicate that technical inefficiency in Malaysian banking was due to scale. They suggest that banks with more market power (measured by their ratio of deposits to market deposits) tend to exhibit higher technical efficiency. Matthews and Ismail (2006) examine the technical efficiency and productivity of the Malaysian banking sector during the period 1994 to 2000. They find that the foreign banks have exhibited higher efficiency levels compared to their domestic bank counterparts. The results suggest that the efficient banks are characterised by size, but not profitability or loans quality.

More recently, Sufian (2009) examines the impact of the Asian financial crisis on the efficiency of the Malaysian banking sector. He employed the DEA method and focuses on three major approaches namely the intermediation, value added, and operating approaches. The empirical findings clearly bring forth the high degree of inefficiency in the Malaysian banking sector, particularly a year after the Asian financial crisis. The results suggest that the decline in technical efficiency is more abrupt under the intermediation approach relative to the value added and operating approaches. The regression results focusing on bank efficiency and other bank specific traits suggest that efficiency is negatively related to expense preference behaviour and economic conditions, while bank efficiency is positively related to loans intensity.

Apart from the few studies discussed above, virtually nothing has been published to critically examine the impact of ownership on the efficiency of the Malaysian banking sector. Most importantly, despite its advantages over the traditional DEA method, none of these studies employs the Simar and Wilson (2007) method. In light of these knowledge gaps, this paper seeks to examine the impact of ownership (domestic, foreign, stock exchange listing, and government) on the efficiency of banks operating in the Malaysian banking sector.

3 Estimation of efficiency scores

3.1 Data envelopment analysis

There are two different frontier analysis methods normally employed to measure bank efficiency namely, the non-parametric and parametric methods (Berger and Humphrey, 1997). The most commonly employed non-parametric methods are the DEA and free disposal hull (FDH), while the parametric methods are stochastic frontier approach (SFA), thick frontier approach (TFA), and distribution free approach (DFA).

This study employs the non-parametric DEA method, also known as mathematical programming approach to compute the efficiency of individual banks operating in the Malaysian banking sector. The method constructs the frontier of the observed input-output ratios by linear programming techniques [see Coelli et al. (1998) for a detailed review]. The linear substitution is possible between observed input combinations on an isoquant (the same quantity of output is produced while changing the quantities of two or more inputs) that is assumed by the DEA method.

To discuss the DEA method in more technical terms, let us assume that there is data on K inputs and M outputs for each N bank. For the i^{th} bank, these are represented by x_i and y_i vectors, respectively.

$$\hat{\delta}_i = \min_{\hat{\delta}_i, \lambda} \left\{ \delta > 0 \mid \hat{\delta}_i y_i \leq \sum_{i=1}^{n} y_i \lambda;\ x_i \geq \sum_{i=1}^{n} x_i \lambda;\ \lambda \geq 0 \right\}, \quad i = 1, \ldots, n \text{ banks} \tag{1}$$

where y is a vector of bank outputs, x is a vector of bank inputs, λ is a $N \times 1$ vector of constants. The value of $\hat{\delta}_i$ is the technical efficiency score for the i^{th} bank. A measure of $\hat{\delta}_i = 1$ indicates that the bank is technically efficient, while $\hat{\delta}_i > 1$ indicate that a bank is inefficient. The linear programming problem must be solved n times, once for each bank in the sample.

It is also worth noting that the DEA model can be estimated by using either the constant returns to scale (CRS) or the variable returns to scale (VRS) assumptions. For the purpose of the present study, we employ the VRS assumption, since the CRS assumption is valid if all banks in the sample are operating at the optimal level of scale. However, technological advances and regulatory changes may have different impacts across banks of different sizes. The VRS assumption permits modelling the entire range of technology (Assaf et al., 2011).

3.2 The bootstrap DEA method

Simar and Wilson (1998, 1999) argue that DEA efficiency scores are strongly dependent on each other in the statistical sense. Thus, by using the DEA scores in a second-stage violates regression models assumption. They also suggest that the DEA efficiency score is a relative efficiency index and not an absolute one. To address this issue, Simar and Wilson (1998) propose a double bootstrap procedure, which enables consistent inference in the second-stage regression models. The bootstrap method is based on the idea of re-sampling from the original data in order to assign statistical properties for the quantities of interest. More recently, Simar and Wilson (2007) extend their approach to account for the impact of environmental variables on productive efficiency.[1] Before illustrating their procedure, we first present the following model:

$$\hat{\delta}_i = z_i \beta + \varepsilon_i \tag{2}$$

where $\hat{\delta}_i$ is a bias corrected estimates of efficiency scores of bank i at time t, z_i is a vector of environmental variables that explain the productive efficiency between banks under consideration and β refers to a vector of parameters with some statistical noise ε_i. Simar and Wilson (2007) suggest that naïve regression models may lead to estimation problems due to correlation and dependency problems of the efficiency scores which may violate the regression assumption that ε_i are independent of z_i. The importance of the Simar and Wilson (2007) procedure is that it produces bias-corrected estimates of $\hat{\delta}_i$ and therefore valid estimates of the parameters in the regression model. The process can be summarised as follows:

1 Calculate the DEA input-oriented efficiency score $\hat{\delta}_i$ for each bank using the linear programming in (1).

2 Use the maximum likelihood method to estimate the truncated regression of $\hat{\delta}_i$ on z_i to provide and estimate $\hat{\beta}$ of β and an estimate $\hat{\sigma}_\varepsilon$ of σ_ε.

3 For each bank $i = 1, \ldots, n$, repeat the next four steps (a–d) B times to yield a set of bootstrap estimates $\{\hat{\delta}^*_{i,b}, b = 1, \ldots, B\}$.

   a Draw ε_i from the $N(0, \hat{\sigma}^2_\varepsilon)$ distribution with left truncation at $(1 - \hat{\beta} z_i)$.

   b Compute $\hat{\delta}^*_i = \beta z_1 + \varepsilon_i$.

   c Construct pseudo dataset (x^*_i, y^*_i), where $(x^*_i = x_i)$ and $(y^*_i = y_i \hat{\delta}_i / \delta^*_i)$.

   d Compute a new DEA estimate $\hat{\delta}^*_i$ on the set of pseudo data (x^*_i, y^*_i), i.e.

4 For each bank, compute the bias corrected estimate $\hat{\hat{\delta}}_i = \hat{\delta} - \hat{bias}_i$, where $\hat{bias}_i$ is the bootstrap estimator of bias obtained as $\hat{bias}_i = \frac{1}{B} \sum_{b=1}^{B} \hat{\delta}^*_{i,b} - \hat{\delta}_i$.

5 Use the maximum likelihood method to estimate the truncated regression of $\hat{\hat{\delta}}_i$ on z_i, providing estimates $(\hat{\hat{\beta}}, \hat{\hat{\sigma}})$ of $(\beta, \sigma_\varepsilon)$.

6 Repeat the next three steps (a–c) B_2 times to obtain a set of bootstrap estimates $\{(\hat{\hat{\beta}}^*_b, \hat{\hat{\sigma}}^*_b, b = 1, \ldots, B_2)\}$.

   a For $i = 1, \ldots, n$, ε_i is drawn from $N(0, \hat{\hat{\sigma}})$ with left truncation at $(1 - \hat{\hat{\beta}} z_i)$.

   b For $i = 1, \ldots, n$, compute $\delta^{**}_i = \hat{\beta} z_i + \varepsilon_i$.

   c The maximum likelihood method is again used to estimate the truncated regression of δ^{**}_i on z_i, providing estimates $(\hat{\hat{\beta}}^*, \hat{\hat{\sigma}}^*)$.

7 Use the bootstrap results to construct confidence intervals.

3.3 Data

We use annual bank level data of all Malaysian commercial banks over the period 1999 to 2008. The period of analysis can be considered as the pre-liberalisation period of the Malaysian banking sector. The variables are obtained from published balance sheet information in annual reports of each individual bank. The macroeconomic and financial markets indicator variables are retrieved from the IMF Financial Statistics (IFS) and World Bank World Development Indicators (WDI) databases. The total number of commercial banks operating in the Malaysian banking sector varies from 33 banks in 1999 to 22 banks in 2008 due to entry and exit of banks during the past decade. This gives us a total of 237 bank year observations. The sample represents the whole gamut of the industry's total assets.

As in the most recent studies, (e.g., Isik and Hassan, 2003; Sufian, 2009; Assaf et al., 2011), we adopt the intermediation approach. The intermediation approach views banks as financial intermediaries. Under the intermediation approach, banks primary role is to obtain funds from savers and convert them into loans for profit (Chu and Lim, 1998). Banks are regarded to purchase labour, materials, and deposits to produce outputs such as loans and investments. The inputs considered are among others interest expense, non-interest expense, deposits, purchased capital, number of staffs (full time equivalent), and physical capital (fixed assets and equipment).

The present study adopts the intermediation approach for three main reasons. First, the study attempts to evaluate the efficiency of the whole banking sector and not branches of a particular bank. Second, researchers investigating the efficiency of banking sectors in developing countries generally opt for the intermediation approach over production or value added approaches (e.g., Isik and Hassan, 2003). Third, Sealey and Lindley (1977) suggest that financial institutions normally employ labour, physical capital, and deposits as their inputs to produce earning assets.

Therefore, it is reasonable to assume that the efficiency of banks in terms of their intermediation functions is crucial as an effective channel for business funding. In this vein, Jaffry et al. (2007) point out that banks play an important economic role in providing financial intermediation by converting deposits into productive investments in developing countries. The banking sector of developing countries have also been shown to perform critical role in the intermediation process by influencing the level of money stock in the economy with their ability to create deposits (Mauri, 1983; Bhatt, 1989; Askari, 1991).

Table 1 Descriptive statistics for inputs, outputs, and input prices

	Y1	*Y2*	*Y3*	*X1*	*X2*	*X3*
Min	53,411.00	205.00	14.00	131,352.00	1,248.00	1,898.00
Mean	12,335.73	3,767,524.55	180,873.30	888,037.68	184,255.20	152,612.30
Max	109,070.50	36,423.40	1,800,718.00	137,864.10	1,417,961.00	1,419,973.00
S.D	5,790.82	2,346,414.05	80,638.77	6,551.73	61,636.41	78,243.08

Notes: Y1: loans (includes loans to customers and other banks), Y2: investments (includes dealing and investment securities), Y3: non-interest income (defined as fee income and other non-interest income, which among others consist of commission, service charges and fees, guarantee fees, and foreign exchange profits), X1: Total deposits (includes deposits from customers and other banks), X2: capital (measured by the book value of property, plant, and equipment), X3: personnel expenses [inclusive of total expenditures on employees such as salaries, employee benefits and reserve for retirement pay (as data on the number of employees are not readily made available, personnel expenses have been used as a proxy measure].

Source: Banks annual reports and authors own calculations

Table 2 Descriptive of the variables used in the bootstrap regressions

Variable	*Description*	*Mean*	*Std. dev.*	*Sources/database*
	Dependent			
LN(TE)	Natural log of the bias-corrected technical efficiency derived from the DEA method.	–0.120	0.156	Authors' own calculation
	Independent			
	Internal factors			
LN(LLP/TL)	Natural log of loan loss provisions/total loans. An indicator of credit risk, which shows how much a bank is provisioning in year *t* relative to its total loans.	–2.228	0.421	Banks' annual financial statements
LN(EQASS)	A measure of bank's capital strength in year *t*, calculated as the natural log of equity/total assets.	–1.617	0.335	Banks' annual financial statements
LN(NIE/TA)	Calculated as the natural log of non-interest expense/total assets and provides information on the efficiency of the management regarding expenses relative to assets in year *t*.	–4.385	0.618	Banks' annual financial statements
LN(NII/TA)	A measure of bank's diversification towards non-interest income, computed as the natural log of non-interest income over total assets.	–4.637	0.559	Banks' annual financial statements
LN(LOANS/TA)	A measure of bank's loans intensity calculated as the natural log of total loans divided by total assets.	–0.782	0.672	Banks' annual financial statements
LN(TA)	The natural log of the accounting value of bank *j*'s total assets in year *t*.	16.411	1.507	Banks' annual financial statements
	External factors			
LN(GDP)	The natural log of gross domestic products.	11.750	1.051	IMF International Financial Statistics.
LN(INFL)	The natural log of the rate of inflation.	0.836	0.504	IMF International Financial Statistics.
LN(CR3)	The natural log of the three largest banks asset concentration ratio.	–0.802	0.158	IMF International Financial Statistics.

Table 2 Descriptive of the variables used in the bootstrap regressions (continued)

Variable	*Description*	*Mean*	*Std. dev.*	*Sources/database*
		Independent		
		External factors		
LN(Z-SCORE)	The natural log of the z-score and is used as a proxy measure of the banking sector's risk to default.	2.384	0.289	IMF International Financial Statistics.
LN(MKTCAP/GDP)	The natural log of the stock market capitalisation divided by GDP ratio. The variable serves as a proxy of financial development.	0.392	0.140	IMF International Financial Statistics.
		Bank ownership		
FORB	A dummy variable that takes a value of 1 for foreign banks, 0 otherwise.	NA	NA	Authors' own calculation.
PUBL	A dummy variable that takes a value of 1 for publicly listed banks, 0 otherwise.	NA	NA	Authors' own calculation.
GOVT	A dummy variable that takes a value of 1 for government links banks, 0 otherwise.	NA	NA	Authors' own calculation.

Accordingly, three inputs and three output variables are chosen.[2] The input vectors used are (X1) total deposits, (X2) capital, and (X3) labour, while, (Y1) total loans, (Y2) investments, and (Y3) non-interest income are the output vectors. Table 1 presents the summary of data used to construct the efficiency frontiers.

We include six bank specific variables in the regression models. We incorporate the ratio of loan loss provisions to total loans (LLP/TL) as an independent variable in the regression analysis as a proxy of credit risk. To recognise that banks in recent years have increasingly been generating income from 'off-balance sheet' businesses, we employ the ratio of non-interest income over total assets (NII/TA) in the regression analysis as a proxy measure of bank diversification into non-traditional activities. We include the ratio of non-interest expenses to total assets (NIE/TA) to provide information on the variations of bank operating costs. The variable represents total amount of wages and salaries, as well as the costs of running branch office facilities.

The loans market, especially credit to households and firms is risky. Henceforth, it is reasonable to expect higher returns on bank loans relative to other bank assets, such as government securities. To address this concern, we include the LOANS/TA variable as a proxy measure of bank liquidity in the regression models. We use the LNTA variable as a proxy of size to capture the possible cost advantages associated with size (economies of scale). The variable controls for cost differences according to the size of the bank. We incorporate the EQASS variable in the regression models to examine the relationship between efficiency and bank capitalisation.

The performance of banks is sensitive to macroeconomic conditions despite the trend in the industry towards greater geographic diversification and wider use of financial engineering techniques to manage risk. Generally, higher economic growth encourages bank to lend more, permits them to charge higher margins, and improves the quality of their loan assets. As GDP growth slows down during recessions, credit qualities tend to deteriorate and default rate increase, thus reducing bank profitability.

To address this concern, we use the gross domestic product (GDP) to control for cyclical output effects. We also account for macroeconomic risk by controlling for the rate of inflation (INFL). The CR3 (measured as the concentration ratio of the three largest banks in terms of assets) is entered the regression models as a proxy variable for the banking sector's concentration. The Z-Score (Z-SCORE) variable is used as a proxy of bank soundness. We also control for the impact of financial market development on bank efficiency. Following among others (Ben Naceur and Omran, 2011), we use the ratio of stock market capitalisation over GDP (MKTCAP/GDP) as a measure of the size of the equity market.

Table 2 presents the summary statistics of the dependent and independent variables.

4 Empirical findings

4.1 Efficiency in the Malaysian banking sector

Panels A and B of Table 3 contains the VRS technical efficiency estimates of the domestic and foreign banks respectively.[3,4] To conserve space, we do not report the original (non-bootstrap) DEA scores in the paper.[5] The results in Panel A of Table 3 clearly indicate that the mean technical efficiency of the domestic banks range from a low of 73.7% during the year 1999 to a high of 94.4% during the year 2002. During the period under study, we find that RHB Bank, Southern Bank, and EON Bank are the most technically efficient domestic banks. On the other hand, the least efficient domestic banks are Hock Hua (Sabah) Bank, Wah Tat Bank, and Sabah Bank. It is also worth highlighting that these three banks have failed and were acquired during the year 2000. The empirical findings to a certain extent support the findings by Sufian and Habibullah (2014a). To recap, Sufian and Habibullah (2014a) find that the acquired Malaysian banks tend to be less productive relative to their acquirers.

Turning to examine the efficiency of the foreign owned banks, the empirical findings given in Panel B of Table 3 seem to suggest that the foreign banks have exhibited a mean technical efficiency (inefficiency) of 90.0% (10.0%). By examining the technical efficiency of each bank, we find that Bank of America, ABN-Amro Bank, and Bank of Nova Scotia are the least efficient foreign banks, while OUB Bank, OCBC Bank, and Bank of China are the most technically efficient foreign banks operating in the Malaysian banking sector. It is also interesting to note that the most efficient foreign banks in Malaysia originate from other Asian countries with similar language and culture providing support to the *liability of unfamilianess* hypothesis (see Berger et al., 2000). To recap, the *liability of unfamiliarness* hypothesis posits that the weight of proximity is greater and more difficult to overcome for foreign banks headquartered in distant countries due to differences in market environments, languages, cultures, supervisory, and regulatory structures.

Table 3 The bootstrapped efficiency results in Malaysian banking sector: 1999–2008

Bank	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*Mean efficiency*
					Panel A: domestic banks						
AFFIN BANK	0.818	0.843	0.883	0.949	0.909	0.877	0.854	0.815	0.825	0.854	*0.863*
ALLIANCE BANK	0.810	-	0.965	0.872	0.931	0.886	0.854	0.863	0.935	0.853	*0.885*
ARAB-MALAYSIAN BANK	0.778	0.911	0.911	0.964	0.906	0.984	0.968	0.963	0.945	0.946	*0.928*
BAN HIN LEE BANK	0.782	-	-	-	-	-	-	-	-	-	*0.782*
BANK UTAMA	0.854	0.893	0.925	0.966	-	-	-	-	-	-	*0.910*
BSN COMMERCIAL BANK	0.751	-	-	-	-	-	-	-	-	-	*0.751*
CIMB BANK	0.729	0.920	0.957	0.966	0.924	0.969	0.941	0.958	0.938	0.946	*0.925*
EON BANK	0.880	0.960	0.958	0.973	0.951	0.976	0.901	0.900	0.914	0.911	*0.932*
HOCK HUA BANK (SABAH)	0.323	-	-	-	-	-	-	-	-	-	*0.323*
HOCK HUA BANK	0.728	-	-	-	-	-	-	-	-	-	*0.728*
HONG LEONG BANK	0.782	0.914	0.936	0.957	0.923	0.921	0.943	0.908	0.929	0.814	*0.903*
MAYBANK	0.707	0.916	0.913	0.965	0.892	0.970	0.942	0.958	0.934	0.946	*0.914*
ORIENTAL BANK	0.738	0.836	-	-	-	-	-	-	-	-	*0.787*
PHILEO ALLIED BANK	0.875	-	-	-	-	-	-	-	-	-	*0.875*
PUBLIC BANK	0.850	0.876	0.950	0.858	0.892	0.891	0.902	0.964	0.938	0.945	*0.907*
RHB BANK	0.817	0.942	0.954	0.976	0.931	0.971	0.959	0.959	0.920	0.945	*0.937*
SABAH BANK	0.588	-	-	-	-	-	-	-	-	-	*0.588*
SOUTHERN BANK	0.902	0.965	0.936	0.936	0.900	0.969	0.940	-	-	-	*0.936*
PACIFIC BANK	0.733	-	-	-	-	-	-	-	-	-	*0.733*
WAH TAT BANK	0.288	-	-	-	-	-	-	-	-	-	*0.288*
Mean efficiency	*0.737*	*0.907*	*0.935*	*0.944*	*0.916*	*0.941*	*0.920*	*0.921*	*0.920*	*0.907*	*0.905*
Std. dev.	*0.164*	*0.043*	*0.025*	*0.041*	*0.019*	*0.043*	*0.041*	*0.054*	*0.037*	*0.052*	*0.041*

Note: Detailed results are available from the authors upon request.

Table 3 The bootstrapped efficiency results in Malaysian banking sector: 1999–2008 (continued)

Bank	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*Mean efficiency*
Panel B: foreign banks											
ABN AMRO BANK	0.603	0.703	0.799	0.965	0.928	0.970	0.939	0.960	0.484	0.944	*0.830*
BANGKOK BANK	0.702	0.917	0.915	0.936	0.941	0.970	0.941	0.959	0.942	0.939	*0.916*
BANK OF AMERICA	0.385	0.647	0.513	0.966	0.600	0.970	0.941	0.959	0.905	0.948	*0.783*
BANK OF CHINA	-	-	0.917	0.965	0.888	0.970	0.940	0.960	0.907	0.945	*0.937*
BANK OF NOVA SCOTIA	0.702	0.913	0.911	0.965	0.554	0.970	0.941	0.960	0.912	0.945	*0.877*
BANK OF TOKYO	0.902	0.939	0.948	0.970	0.884	0.949	0.833	0.970	0.933	0.954	*0.928*
CITIBANK	0.775	0.914	0.922	0.965	0.866	0.969	0.941	0.961	0.970	0.951	*0.923*
DEUTSCHE BANK	0.762	0.918	0.918	0.965	0.886	0.968	0.943	0.967	0.909	0.947	*0.918*
HONGKONG BANK	0.840	0.873	0.950	0.941	0.956	0.970	0.768	0.958	0.853	0.798	*0.891*
JP MORGAN CHASE	0.703	0.914	0.957	0.976	0.895	0.969	0.943	0.958	0.908	0.946	*0.917*
OCBC BANK	0.926	0.912	0.945	0.966	0.862	0.970	0.949	0.937	0.946	0.971	*0.938*
OUB BANK	0.956	0.926	-	-	-	-	-	-	-	-	*0.941*
STANDARD CHARTERED BANK	0.876	0.943	0.933	0.967	0.858	0.969	0.941	0.960	0.935	0.946	*0.933*
UOB BANK	0.868	0.894	0.842	0.872	0.886	0.970	0.887	0.960	0.952	0.973	*0.910*
Mean efficiency	*0.769*	*0.878*	*0.882*	*0.955*	*0.846*	*0.968*	*0.916*	*0.959*	*0.889*	*0.939*	*0.900*
Std. dev.	*0.156*	*0.092*	*0.120*	*0.027*	*0.124*	*0.006*	*0.055*	*0.007*	*0.125*	*0.044*	*0.055*

Note: Detailed results are available from the authors upon request.

Unlike the earlier studies on the Malaysian banking sector (e.g., Sufian, 2009; Matthews and Ismail, 2006; Katib and Matthews, 2000), the empirical findings from this study indicate that the domestic banks have been relatively more efficient compared to their foreign bank peers. We attribute the difference to two main factors. First, the earlier studies cover the pre-Asian financial crisis period. And secondly, the earlier studies employ the more traditional DEA method resulting in a different conclusion.

4.2 *Determinants of bank efficiency*

An important understanding that arises after the computation of the efficiency scores is to attribute variations in efficiency change to bank specific characteristics and the environment in which they operate. Therefore, the following section proceeds with the discussions of the multivariate regression analysis results. By using the bias-corrected technical efficiency score as the dependent variable, we estimate the following baseline regression model:

$$\hat{\hat{\delta}}_{i,t} = \beta_1 \sum_{n=33}^{6} BankCharacteristics_{i,t} + \beta_2 \sum_{n=33}^{3} Ownership_{i,t} + \varepsilon_{i,t} \tag{3}$$

where $\hat{\hat{\delta}}_{i,t}$ is the bias-corrected DEA technical efficiency score, *BankCharacteristics* is a vector of bank specific characteristics, Ownership is a set of ownership dummy variables, ε is the error term, and the subscripts '*i*' and '*t*' represents individual bank and time period, respectively.[6]

Columns 1 to 5 of Table 4 present the bootstrap regression results. The empirical findings seem to suggest that the coefficient of the NII/TA variable is always positive, implying that Malaysian banks which derive a higher proportion of its income from non-interest sources tend to report higher efficiency levels. However, the result should be interpreted with caution since the coefficient of the variable is only statistically significant at the 10% level and when we control for the macroeconomic and market condition variables and the publicly listed banks in the regression models.

During the period under study, the estimates show that technical efficiency increases with size, a fact that support the results of Hauner (2005) among others. Hauner (2005) offers two potential explanations for which size could positively influence bank efficiency. First, if it relates to market power, large banks should pay less for their inputs. Second, there may be increasing returns to scale through the allocation of fixed costs over a higher volume of services, or efficiency gains from a specialised workforce.

We find that the level of capitalisation (EQASS) positively influences the efficiency of banks operating in the Malaysian banking sector, providing support to the argument that well capitalised banks face lower costs of going bankrupt, thus reduce their cost of funding. Furthermore, strong capital structure is essential for banks in developing economies, since it provides additional strength to withstand financial crises and safety for depositors during unstable macroeconomic conditions (Sufian, 2009). Moreover, lower capital ratios in banking imply higher leverage and risk and therefore higher borrowing costs. Thus, it is reasonable for the better capitalised banks to exhibit higher efficiency levels.

Table 4 Panel bootstrap and OLS regression analysis

	Bootstrap regression					OLS regression				
	Model I	*Model II*	*Model III*	*Model IV*	*Model V*	*Model VI*	*Model VII*	*Model VIII*	*Model IX*	*Model X*
CONSTANT	–0.662***	–0.274	–0.500*	–0.347	–0.317	–0.288	–0.097	–0.500*	–0.347*	–0.317
	(–3.07)	(–1.26)	(–1.82)	(–1.54)	(–1.42)	(–1.53)	(–1.27)	(–1.85)	(–1.65)	(–1.51)
Bank characteristics										
LN(LLP/TL)	0.051	0.036	0.044	0.042	0.037	0.060	0.037	0.044	0.042	0.037
	(1.18)	(0.77)	(0.85)	(0.82)	(0.73)	(1.46)	(1.08)	(1.23)	(1.21)	(1.11)
LN(NII/TA)	0.033	0.038*	0.022	0.039*	0.036	0.055**	0.043**	0.022	0.039*	0.036
	(1.36)	(1.64)	(0.95)	(1.67)	(1.54)	(2.18)	(2.07)	(0.99)	(1.73)	(1.60)
LN(NIE/TA)	–0.040	–0.035	–0.036	–0.038	–0.034	–0.030	–0.034	–0.036*	–0.038*	–0.034
	(–1.37)	(–1.22)	(–1.32)	(–1.29)	(–1.20)	(–1.31)	(–1.58)	(–1.67)	(–1.69)	(–1.58)
LN(LOANS/TA)	–0.013	0.004	0.004	0.000	0.004	0.005	0.007	0.004	0.000	0.004
	(–0.59)	(0.17)	(0.17)	(0.02)	(0.15)	(0.24)	(0.34)	(0.18)	(0.02)	(0.16)
LN(TA)	0.054***	0.043***	0.056***	0.056***	0.047***	0.042***	0.042***	0.056***	0.056***	0.047***
	(3.58)	(2.92)	(3.01)	(3.08)	(3.13)	(2.99)	(2.93)	(2.94)	(3.21)	(3.15)
LN(EQASS)	0.160***	0.134**	0.139**	0.167***	0.142**	0.164***	0.138***	0.139***	0.167***	0.142***
	(3.10)	(2.51)	(2.53)	(2.61)	(2.54)	(3.24)	(2.71)	(2.54)	(2.75)	(2.64)

Notes: The dependent variable is the bias-corrected technical efficiency derived from the DEA method. LLP/TL is a measure of bank's credit risk, calculated as the ratio of total loan loss provisions divided by total loans. NII/TA is a measure of bank's diversification towards non-interest income, calculated as total non-interest income divided by total assets. NIE/TA is a measure of bank management quality calculated as total non-interest expenses divided by total assets. LOANS/TA is a measure of bank's loans intensity calculated as the ratio of total loans to bank total assets. TA is the size of the bank's total asset measured as total bank assets. EQASS is a measure of banks capitalisation measured by banks total shareholders equity divided by total assets. GDP is the gross domestic product. INFL is the rate of inflation. CR3 is the three largest banks asset concentration ratio. Z-SCORE is a proxy measure of the banking sector's risk to default. MKTCAP/GDP is the ratio of stock market capitalisation and serves as a proxy of financial market development. DUMFORB is a dummy variable that takes a value of 1 for foreign banks, 0 otherwise. DUMPUBL is a dummy variable that takes a value of 1 for publicly listed banks, 0 otherwise. DUMGOVT is a dummy variable that takes a value of 1 for government links banks, 0 otherwise.
Values in parentheses are z-statistics.
***, **, and * indicates significance at 1%, 5% and 10% levels.

Table 4 Panel bootstrap and OLS regression analysis (continued)

	Bootstrap regression					OLS regression				
	Model I	*Model II*	*Model III*	*Model IV*	*Model V*	*Model VI*	*Model VII*	*Model VIII*	*Model IX*	*Model X*
Macroeconomic and market conditions										
LN(GDP)		–0.013	0.018*	–0.017*	–0.013		–0.016**	–0.018**	–0.017**	–0.013*
		(–1.38)	(–1.78)	(–1.71)	(–1.43)		(–2.00)	(–2.02)	(–2.03)	(–1.66)
LN(INFL)		–0.011	–0.008	–0.007	–0.011		–0.006	–0.008	–0.007	–0.011
		(–0.50)	(–0.34)	(–0.31)	(–0.49)		(–0.31)	(–0.35)	(–0.32)	(–0.51)
LN(CR3)		0.493***	0.490***	0.493***	0.492***		0.570***	0.490***	0.493***	0.492***
		(3.28)	(3.43)	(3.23)	(3.27)		(4.47)	(3.60)	(3.55)	(3.50)
LN(Z-SCORE)		0.205***	0.197***	0.192***	0.202***		0.209***	0.197***	0.192***	0.202***
		(4.56)	(4.50)	(4.37)	(4.53)		(4.77)	(4.77)	(4.63)	(4.74)
LN(MKTCAP/GDP)		–0.405***	–0.399***	–0.407***	–0.406***		–0.483***	–0.399***	–0.407***	–0.406***
		(–2.89)	(–2.91)	(–2.84)	(–2.86)		(–4.12)	(–3.04)	(–3.07)	(–3.03)
Bank ownership										
FORB			0.064**					0.064**		
			(2.01)					(1.99)		
PUBL				–0.064***					–0.064***	
				(–2.77)					(–2.95)	
GOVT					–0.028*					–0.028*
					(–1.66)					(–1.79)
No. of observations	237	237	237	237	237	237	237	237	237	237
R^2	0.167	0.265	0.287	0.281	0.268	0.145	0.272	0.287	0.281	0.268
Wald χ^2 statistics	14.72**	47.77***	47.51***	47.21***	47.98***	-	-	-	-	-
F-statistics	-	-	-	-	-	2.22**	6.15***	4.51***	4.47***	4.45***
No. of iterations	2,000	2,000	2,000	2,000	2,000	-	-	-	-	-

Notes: The dependent variable is the bias-corrected technical efficiency derived from the DEA method. LLP/TL is a measure of bank's credit risk, calculated as the ratio of total loan loss provisions divided by total loans. NII/TA is a measure of bank's diversification towards non-interest income, calculated as total non-interest income divided by total assets. NIE/TA is a measure of bank management quality calculated as total non-interest expenses divided by total assets. LOANS/TA is a measure of bank's loans intensity calculated as the ratio of total loans to bank total assets. TA is the size of the bank's total asset measured as total bank assets. EQASS is a measure of banks capitalisation measured by banks total shareholders equity divided by total assets. GDP is the gross domestic product. INFL is the rate of inflation. CR3 is the three largest banks asset concentration ratio. Z-SCORE is a proxy measure of the banking sector's risk to default. MKTCAP/GDP is the ratio of stock market capitalisation and serves as a proxy of financial market development. DUMFORB is a dummy variable that takes a value of 1 for foreign banks, 0 otherwise. DUMPUBL is a dummy variable that takes a value of 1 for publicly listed banks, 0 otherwise. DUMGOVT is a dummy variable that takes a value of 1 for government links banks, 0 otherwise. Values in parentheses are z-statistics.

***, **, and * indicates significance at 1%, 5% and 10% levels.

In contrast to Sufian (2009) who employs the standard DEA and a multivariate Tobit regression analysis, the empirical findings from this study indicate that credit risk (LLP/TL), overhead expenses (NIE/TA), and liquidity (LOANS/TA) are not statistically significant in explaining the variations in the efficiency of banks operating in the Malaysian banking sector.

Turning to the impact of macroeconomic and financial market conditions, we find that the coefficient of the GDP variable is negative. The result to a certain extent provides support to the view that high economic growth improves business environment and lowers bank entry barriers. This would result in competition to intensify and consequently dampens banks' profitability (Liu and Wilson, 2011). The results however should be interpreted with caution since the coefficient of the variable is only statistically significant at the 10% level and when we control for the publicly listed banks in the regression model. Concerning the impact of banking sector's concentration, it can be observed that the coefficient of the three banks concentration ratio (CR3) exhibits a positive sign and is statistically significant at the 1% level in all regression models. The empirical findings clearly lend support to the structure-conduct-performance (SCP) hypothesis of Molyneux et al. (1996) which states that banks in a highly concentrated market tend to collude and therefore earn monopoly profits.

Interestingly, we find that the impact of banking sector risk (Z-SCORE) is positive. The result is in consonance with the findings of among others Boyd and De Nicolo (2006) lending support to the stringent capital requirements of Basel III. From the policymaking point of view, the findings seem to call for a more effective policymaker's role in reducing excessive bank risk exposures and at the same time induce a more efficient risk management by banks. It can be observed from Table 4 that the impact of stock market capitalisation (MKTCAP/GDP) is negative on the efficiency of Malaysian banks (statistically significant at the 1% level in all cases). The results clearly advocate that during the period under study, the Malaysian stock market serves as a substitute rather than complementing products and services banks offer to their customers.

4.3 Bank ownership and efficiency

Banks of different ownership forms may react differently to the same efficiency determinants. Thus, in the following section, we repeat equation (3) to include FORB (a dummy variable that takes a value of 1 if a bank is a foreign bank, 0 otherwise), PUBL (a dummy variable that takes a value of 1 if a bank is listed on the stock exchange, 0 otherwise), and GOVT (a dummy variable that takes a value of 1 if a bank is a government owned bank, 0 otherwise) to examine the impact of foreign ownership, stock exchange listing, and government ownership on bank efficiency respectively. Columns 3 to 5 of Table 4 present the results.

As expected FORB enter the regression model with a positive sign and is statistically significant at the 5% level (column 3 of Table 4). The results imply that the foreign owned banks tend to be more efficient relative to their domestically owned bank counterparts. This should come as no surprise because of the ability of the foreign owned banks to capitalise on advanced risk management systems and operational techniques. The findings also lend support to the notion that the technical savvy of the foreign owned banks generally overcome the home field advantage of the domestic banks particularly when the domestic economy has relatively unsophisticated financial markets and institutions.

The empirical findings given in column 4 of Table 4 indicate that the coefficient of PUBL is negative (statistically significant at the 1% level). Within the context of the Malaysian banking sector, the empirical findings seem to suggest that the publicly traded banks tend to be relatively inefficient relative to their privately owned bank counterparts. Although the market discipline hypothesis suggests that banks whose shares are publicly traded should exhibit higher efficiency, the empirical findings from this study seem to suggest that the Malaysian capital market has not exerted discipline over bank managements.

Finally, we find that the coefficient of GOVT is negative and statistically significant at the 10% level (column 5 of Table 4). The empirical findings to a certain extent lend support to the 'political' theory of government ownership of firms (see La Porta et al., 2002). The theory posits that governments acquire control of banks to provide employment, subsidies, and other benefits to supporters (Shleifer and Vishny, 1994). La Porta et al. (2002) point out that the negative outcome of political control of banks is more prevalent in developing countries where the financial systems are underdeveloped and countries with weak property rights because the government does not need to compete with the private sector for source of funds. In essence, La Porta et al. (2002) characterised government ownership of banks as inefficient, incompetent, and corrupt.

4.4 Robustness checks

In an important development, Banker and Natarajan (2008) provide statistical foundation that the use of a two-stage procedure involving DEA followed by an ordinary least square (OLS) regression yields consistent estimators of the regression coefficients. Likewise, McDonald (2009) provides statistical proof that the use of DEA and OLS is a consistent estimator. Furthermore, McDonald (2009) suggests that White (1980) heteroskedastic consistent standard errors allows for large sample tests to be performed which are robust to heteroskedasticity and the distribution of the disturbances. Following Banker et al. (2010) and McDonald (2009) among others, we re-estimate equation (3) by using the OLS method with White (1980) heteroskedastic consistent standard errors. The results are given in columns 6 to 10 of Table 4.

It is worth noting that all the regression models perform reasonably well with most of the baseline variables coefficients stay the same: they keep the same sign, the same order of magnitude and they remain significant as they were so in the baseline regressions (albeit sometimes at different levels). It is interesting to note that the coefficient of the NII/TA variable is statistically significant in the baseline regression model and when we control for the macroeconomics and financial market conditions in the regression model. The empirical findings seem to suggest that the coefficient of the NIE/TA variable becomes statistically significant when we control for foreign owned and publicly listed banks in the regression models (columns 8 and 9 of Table 4). We also find that the coefficient of the GDP variable has statistically significant impact in all regression models.

4.5 Additional robustness checks

To further check for the robustness of the results, we perform several other sensitivity analyses. First, we restrict our sample to banks with more than three years of observations. All in all, the results remain qualitatively similar in terms of directions and significance levels. Finally, we address the effects of outliers in the sample by excluding the top and bottom 1% of the sample. The results continued to remain robust in terms of directions and significance levels. To conserve space, we do not report the results in the paper, but are available upon request.

5 Concluding remarks

The present study investigates the efficiency of the Malaysian banking sector during 1999 to 2008. We compute the efficiency of individual banks by using the DEA method. We employ panel regression analysis to examine the impact of ownership on bank productive efficiency, while controlling for other bank specific traits such as size, profitability, capitalisation, and credit risk. The empirical findings from the DEA method indicate an increase in efficiency of the Malaysian banking sector over the sample period.

The results from the panel regression analysis suggest that productive efficiency is positively related to size, non-interest income, and capitalisation. The empirical findings seem to suggest positive impact of the banking sector's concentration and risk on the efficiency of banks operating in the Malaysian banking sector. During the period under study, the impact of stock market capitalisation seems to be negative on Malaysian banks' technical efficiency, implying that the Malaysian stock market offers substitution possibilities, rather than complementing the products and services offered by banks to borrowers in Malaysia.

We find that productive efficiency is positively related to foreign ownership. The empirical findings seem to suggest that technical efficiency is negatively related to stock exchange listing, implying that the Malaysian capital market has not exert discipline over bank management, therefore rejecting the market discipline hypothesis. Likewise, the result from the panel regression analysis indicates a negative relationship between efficiency and government ownership of banks.

Due to its limitations, the paper could be extended in a variety of ways. First, the scope of this study can be further extended to examine changes in cost efficiency over time. Second, future research into the efficiency of the Malaysian banking sector could also consider the production function along with the intermediation function. Third, investigation of changes in productivity over time as a result of technical change or technological progress or regress by employing the bootstrap Malmquist productivity index (MPI) could yet be another extension to the paper.

Despite these limitations, the findings of this study are expected to contribute significantly to the existing knowledge on the operating performance of the Malaysian banking sector. Nevertheless, the study has also provided further insight to the bank's specific management as well as the policymakers with regard to attaining optimal utilisation of capacities, improvement in managerial expertise, efficient allocation of scarce resources, and the most productive scale of operation of the banks in the industry. This may also facilitate directions for sustainable competitiveness of Malaysian banking operations in the future.

References

Askari, H. (1991) *Third World Debt and Financial Innovation: The Experiences of Chile and Mexico*, OECD Development Studies, OECD, Paris.

Assaf, A.G., Barros, C.P. and Matousek, R. (2011) 'Technical efficiency in Saudi banks', *Expert Systems with Applications*, Vol. 38, No. 5, pp.5781–5786.

Banker, R. and Natarajan, R. (2008) 'Evaluating contextual variables affecting productivity using data envelopment analysis', *Operations Research*, Vol. 56, No. 1, pp.48–58.

Banker, R., Chang, H. and Seok, Y.L. (2010) 'Differential impact of Korean banking system reforms on bank productivity', *Journal of Banking and Finance*, Vol. 34, No. 7, pp.1450–1460.

Banker, R.D., Charnes, A. and Cooper, W.W. (1984) 'Some models for estimating technical and scale inefficiencies in data envelopment analysis', *Management Science*, Vol. 30, No. 9, pp.1078–1092.

Ben Naceur, S. and Omran, M. (2011) 'The effects of bank regulations, competition, and financial reforms on banks' performance', *Emerging Markets Review*, Vol. 12, No. 1, pp.1–20.

Berger, A.N. (2007) 'International comparisons of banking efficiency', *Financial Markets, Institutions and Instruments*, Vol. 16, No. 3, pp.119–144.

Berger, A.N. and Humphrey, D.B. (1997) 'Efficiency of financial institutions: international survey and directions for future research', *European Journal of Operational Research*, Vol. 98, No. 2, pp.175–212.

Berger, A.N., Clarke, G.R.G., Cull, R., Klapper, L. and Udell, G.F. (2005) 'Corporate governance and bank performance: a joint analysis of the static, selection and dynamic effects of domestic, foreign and state ownership', *Journal of Banking and Finance*, Vol. 29, No. 8, pp.2179–2221.

Berger, A.N., DeYoung, R., Genay, H. and Udell, G.F. (2000) 'Globalization of financial institutions: evidence from cross border banking performance', *Brookings-Wharton Papers on Financial Services*, Vol. 3, No. 1, pp.23–158.

Bhatt, V.V. (1989) *Financial Innovation and Credit Market Development*, Working Paper, World Bank.

Boyd, J.H. and De Nicolo, G. (2006) 'The theory of bank risk taking and competition revisited', *Journal of Finance*, Vol. 60, No. 3, pp.1329–1343.

Brissimis, S.N., Delis, M.D. and Tsionas, E.G. (2010) 'Technical and allocative efficiency in European banking', *European Journal of Operational Research*, Vol. 204, No. 1, pp.153–163.

Charnes, A., Cooper, W.W. and Rhodes, E. (1978) 'Measuring the efficiency of decision making units', *European Journal of Operational Research*, Vol. 2, No. 6, pp.429–444.

Charnes, A., Cooper, W.W. and Sueyoshi, T. (1988) 'A goal programming/constrained regression version of the Bell system breakup', *Management Science*, Vol. 34, No. 1, pp.1–26.

Chu, S.F. and Lim, G.H. (1998) 'Share performance and profit efficiency of banks in an oligopolistic market: evidence from Singapore', *Journal of Multinational Financial Management*, Vol. 8, No. 2, pp.155–168.

Claessens, S., Demirguc-Kunt, A. and Huizinga, H. (2001) 'How does foreign banking entry affect domestic banking markets?', *Journal of Banking and Finance*, Vol. 25, No. 5, pp.891–911.

Coelli, T., Prasada-Rao, D.S. and Battese, G.E. (1998) *An Introduction to Efficiency and Productivity Analysis*, Kluwer Academic Publishers, Boston.

Cooper, W.W., Seiford, L.M. and Tone, K. (2002) *Data Envelopment Analysis: A Comprehensive Text with Models, Applications, References and DEA-Solver Software*, Kluwer Academic Publishers, Boston.

Cooper, W.W., Seiford, L.M. and Tone, K. (2006) *Introduction to Data Envelopment Analysis*, Springer Science & Business Media, Inc., New York.

De Bandt, O. and Davis, P. (2000) 'Competition, contestability and market structure in European banking sectors on the eve of EMU', *Journal of Banking and Finance*, Vol. 24, No. 6, pp.1045–1066.

Evans, D. and Heckman, J. (1988) 'Natural monopoly and the Bell systems response to Charnes, Cooper and Sueyoshi', *Management Science*, Vol. 34, No. 1, pp.27–38.

Hauner, D. (2005) 'Explaining efficiency differences among large German and Austrian banks', *Applied Economics*, Vol. 37, No. 9, pp.969–980.

Havrylchyk, O. (2006) 'Efficiency of the Polish banking industry: foreign versus domestic banks', *Journal of Banking and Finance*, Vol. 30, No. 7, pp.1975–1996.

Isik, I. and Hassan, M.K. (2003) 'Efficiency, ownership and market structure, corporate control and governance in the Turkish banking industry', *Journal of Business, Finance and Accounting*, Vol. 30, Nos. 9–10, pp.1363–1421.

Jaffry, S., Ghulam, Y., Pascoe, S. and Cox, J. (2007) 'Regulatory changes and productivity of the banking sector in the Indian sub-continent', *Journal of Asian Economics*, Vol. 18, No. 3, pp.415–438.

Katib, M.N. and Matthews, K. (2000) 'A non-parametric approach to efficiency measurement in the Malaysian banking sector', *Singapore Economic Review*, Vol. 44, No. 2, pp.89–114.

La Porta, R., Lopez-de-Silanes, F. and Shleifer, A. (2002) 'Government ownership of banks', *Journal of Finance*, Vol. 57, No. 1, pp.265–301.

Liu, H. and Wilson, J.O.S. (2011) 'The profitability of banks in Japan', *Applied Financial Economics*, Vol. 20, No. 24, pp.1851–1866.

Matthews, K. and Ismail, M. (2006) *Efficiency and Productivity Growth of Domestic and Foreign Commercial Banks in Malaysia*, Working Paper, Cardiff University.

Mauri, A. (1983) 'The potential for savings and financial innovation in Africa', *Savings and Development*, Vol. 7, No. 1, pp.319–337.

McDonald, J. (2009) 'Using least squares and Tobit in second stage DEA efficiency analyses', *European Journal of Operational Research*, Vol. 197, No. 2, pp.792–798.

Molyneux, P., Altunbas, Y. and Gardener, E.P.M. (1996) *Efficiency in European Banking*, John Wiley & Sons, Chichester.

Perera, S., Skully, M. and Wickramanayake, J. (2007) 'Cost efficiency in South Asian banking: The impact of bank size, state ownership and stock exchange listings', *International Review of Finance*, Vol. 7, Nos. 1–2, pp.35–60.

Sealey, C. and Lindley, J.T. (1977) 'Inputs, outputs and a theory of production and cost at depository financial institutions', *Journal of Finance*, Vol. 32, No. 4, pp.1251–1266.

Shleifer, A. and Vishny, R. (1994) 'Politicians and firms', *Quarterly Journal of Economics*, Vol. 109, No. 1, pp.995–1025.

Simar, L. and Wilson, P.W. (1998) 'Sensitivity analysis of efficiency scores: how to bootstrap in non-parametric frontier models', *Management Science*, Vol. 44, No. 1, pp.49–61.

Simar, L. and Wilson, P.W. (1999) 'Estimating and bootstrapping Malmquist indices', *European Journal of Operational Research*, Vol. 115, No. 3, pp.459–471.

Simar, L. and Wilson, P.W. (2000) 'Statistical inference in non-parametric frontier models: the state of the art', *Journal of Productivity Analysis*, Vol. 13, No. 1, pp.49–78.

Simar, L. and Wilson, P.W. (2007) 'Estimation and inference in two-stage, semi-parametric models of productive efficiency', *Journal of Econometrics*, Vol. 136, No. 1, pp.31–64.

Siriopoulos, C. and Tziogkidis, P. (2010) 'How do Greek banking institutions react after significant events? – A DEA approach', *Omega*, Vol. 38, No. 5, pp.294–308.

Staikouras, C., Mamatzakis, E. and Koutsomanoli-Filippaki, A. (2008) 'An empirical investigation of operating performance in the new European banking landscape', *Global Finance Journal*, Vol. 19, No. 1, pp.32–45.

Sufian, F. (2009) 'Determinants of bank efficiency in an unstable macroeconomic environment: empirical evidence from Malaysia', *Research in International Business and Finance*, Vol. 23, No. 1, pp.54–77.

Sufian, F. (2011) 'Banks total factor productivity change in a developing economy: does ownership and origins matter?', *Journal of Asian Economics*, Vol. 22, No. 1, pp.84–98.

Sufian, F. and Habibullah, M.S. (2014a) 'Banks' total factor productivity change in a developing economy: does globalization matter?', *Journal of International Development*, Vol. 26, No. 6, pp.821–852.

Sufian, F. and Habibullah, M.S. (2014b) 'The impact of mergers and acquisitions on banks total factor productivity: empirical evidence from Malaysia', *Journal of Asia Pacific Economy*, Vol. 19, No. 1, pp.151–185.

Tecles, P.L. and Tabak, B.M. (2011) 'Determinants of bank efficiency: the case of Brazil', *European Journal of Operational Research*, Vol. 207, No. 3, pp.1587–1598.

Tsolas, I.E. (2011) 'Relative profitability and stock market performance of listed commercial banks on the Athens exchange: a non-parametric approach', *IMA Journal of Management and Mathematics*, Vol. 22, No. 4, pp.323–342, DOI: 10.1093/imaman/dpq017.

White, H. (1980) 'A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity', *Econometrica*, Vol. 48, No. 4, pp.817–838.

Wilson, P.W. (2006) 'FEAR: a software package for frontier efficiency analysis with R', *Socio Economic Planning Sciences*, Vol. 42, No. 4, pp.247–254.

Notes

1 These variables are neither inputs nor outputs, but are used to mainly explain the variation in the efficiency scores.

2 Cooper et al. (2002) points out that there is a rule required to be complied with in order to select the number of inputs and outputs. A general rule of thumb is given as

$$n \geq \max\{m \times s, 3(m + s)\}$$

where

n is a number of DMUs

m is a number of inputs

s is a number of outputs.

3 To obtain a reliable bootstrap estimates Simar and Wilson (1998) recommended the use of 2000 bootstrap iterations.

4 The program is written by using the FEAR software developed by Wilson (2006).

5 The original DEA estimates (non-bootstrapped), the bias levels, and the upper and lower bounds for each bank in the sample are available upon request from the authors.

6 Following De Bandt and Davis (2000) and Staikouras et al. (2008) among others, the log-linear form is chosen as it typically improves the regression's goodness of fit and may reduce simultaneity bias.