An examination of cost structure and production performance of commercial banks in Singapore

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Abstract

This paper uses a parametric approach in the framework of a translog cost function and a non-parametric approach in the framework of linear programming to examine production performance and cost structure of a sample of Singaporean commercial banks. The results of the parametric methodology suggest that the average cost curve of these banks is U shaped and there are economies of scale for small and medium-size banks. Further analysis provides evidence of economies of scope for all banks regardless of their size. The non-parametric results indicate that the Singaporean banks could have reduced cost by 43% had they all been overall efficient. The sources of this cost inefficiency seem to be caused equally by allocative and technical inefficiencies. © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

Due to the global trend toward deregulating financial services, the increasing use of advanced technology, and a revolution in the dissemination of financial information, banking firms are under competitive pressure domestically and internationally. In response to this competitive pressure, banking firms are actively looking for alternative ways to reduce their production costs by enhancing production efficiency, and to exploit scale and scope economies. Consequently, in the last few years, a large number of research papers have examined the cost structure, efficiency and production economies of the banking industry. While most of these studies have examined the cost structure and performance of the banking industry in the US and other developed countries, little attention has been focused on banks located in the Pacific-Basin and other emerging markets.

The implications of the results from studies of the US and other developed economies, however, cannot directly be extended to the banking firms of the Pacific-Basin economies. This is because the banking industry is highly regulated and the regulatory environment that affects the cost structure and performance of banks is not uniform across nations. The examination of the cost structure and performance of banks operating in emerging economies is as important as that of developed countries for the following reasons. First, bond and other debt markets in a number of emerging economies are not well developed and efficient; hence, the role of the banking system in the process of intermediation of funds is essential. Second, commercial banks have been exposed to global competition by the recent waves of deregulatory and anti-protectionism policies imposed on the banking industry as well as the internationalization of financial markets. In order to make appropriate adjustments in managerial policies such that the banking firms become well equipped to face challenges brought about by this new competitive environment, the examination of production and cost efficiency of these banks is worthwhile. The results of the cost study may, then, provide managers and policy makers with valuable information that can be utilized to establish optimal managerial strategies and public policies. Third, few countries in the Pacific-Basin region have been able to become regional financial centers. The findings of the study of the cost structure and performance of banking firms may assist policy makers, regulatory agencies and management of these centers to effectively evaluate their competitive viability.

The present paper attempts to provide empirical evidence on the cost structure and production performance of a sample of commercial banks operating in Singapore. First, we use a translog cost function to estimate overall and product-specific economies of scale and scope to examine banks' cost

saving opportunities through size expansion and product diversification. [1] Second, we apply Data Envelop Analysis (DEA) technique to measure overall, allocative, technical and scale efficiency indexes in order to assess the production performance of the sample. The overall technical efficiency of each bank is then decomposed into two components, a measure of pure technical efficiency and a measure of scale efficiency, to identify the basis of technical inefficiency. Further analysis will be undertaken to identify the sources of scale inefficiency if it exists. The rest of the paper is organized as follows: Section 1 briefly reviews the previous studies and provides an overview of the banking environment in Singapore. Section 2 describes the methodology and the data used. Section 3 presents the empirical results and Section 4 provides the summary and conclusions of the paper including the implications of the findings.

2. Review of literature

2.1. Parametric

The economies of scale and scope of commercial banks operating in the US have been extensively studied (Benston et al., 1982a,b; Murray and White, 1983; Gilligan et al., 1984; Kim, 1986; Berger et al., 1987; Shaffer, 1991, 1988; Clark, 1988; Hunter and Timme, 1986, 1989; Hunter et al., 1990; Berger and Humphrey, 1991; Mester, 1987, 1992; Evanoff and Israilevich (1995), Noulas et al., 1990, 1993; Humphrey, 1990; Rezvanian et al., 1996; Mehdian and Rezvanian, 1998). The results of these studies indicate that the average cost curve for banks is U shaped and economies of scale exist only for small banks. The findings of scope economies are inconclusive; specifically, except for Berger et al. (1987) who report diseconomies of scope, the others find either none or some evidence of positive scope economies. [2]

The cost structure of European banks has not been studied as extensively as that of the US (for instance, Zardkoohi (1990, 1994) for Finland; Dietsch (1993), Martin and Sassenou (1992) for France; Lang and Welzel (1994) for

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[1] For a detailed analysis of the differences between the two approaches – production economies and cost efficiency studies – see Kumbhakar (1991, 1996) and Berger and Humphrey (1991). Although the underlying assumptions of these two approaches differ, it is suggested that these two techniques should be taken as complementary, rather than as substitutes for each other (see also Elyasiani and Rezvanian, 2001).

[2] For a review of production economies studies, see Mester (1987); Clark (1988); Hunter and Timme (1989); Humphrey (1990) and Berger et al. (1993).

Germany; Rodriguez et al. (1993) for Spain; Drake and Weyman-Jones (1992) for UK). The findings of these authors generally suggest the presence of economies of scale only for financial institutions of small and medium size. The conclusion emerging from these studies regarding the scope economies, however, is contradictory.

2.2. Non-parametric

The non-parametric technique has been extensively used to evaluate the efficiency of the US banking system. For instance, Aly et al. (1990), Ferrier and Lovell (1990), Elyasiani and Mehdian (1990, 1992) and Grabowski et al. (1993, 1994) have used this approach to assess the production performance of their samples relative to constructed best practiced frontiers. The findings of these authors suggest that overall efficiency of the US banking industry ranges from 65% to 90%.

The non-parametric technique has also been employed by other researchers to measure the efficiency of the banking firms operating in countries other than the US. For example, Berg et al. (1992) and Berger et al. (1993) have assessed efficiency and productivity growth of banking industries in the Nordic countries: Drake and Howcroft (1997) have measured technical and scale efficiency of building societies in the UK; Pastor et al. (1997) have analyzed and compared efficiency of the banking industry in several countries including the US; and finally more recently Lozano-Vivas (1998) has used this approach to assess the efficiency of Spanish banks. [3] There are also a limited number of papers in which the authors have used the non-parametric approach to evaluate the efficiency of banks of Pacific-Basin countries (see, for instance, Fukuyama (1995) for Japan, Yeh (1996) for Taiwan, Bhallachayye et al. (1997) for India, Leightner and Lovell (1998) for Korea, Gilbert and Wilson (1998) for Thailand).

The results of all these studies reveal that, in general, depository financial institutions experience an average efficiency of around 77% and median of 82% (Berger and Humphrey, 1997) and these statistics are significantly different across the countries studied. The origins of these variations across countries may be the dissimilar regulatory regimes and market structures. More recently, Lim and Chu (1998) and Chu and Lim (1998) examined profit and cost efficiency of a sample of banks consisting of six publicly held Singaporean commercial banks. They report that the average cost efficiency of these banks is high and consistently over 95%. They also report that profit efficiency and cost

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[3] A comprehensive collection of the recent studies on the efficiency of financial institutions can be found in the special issues of the *Journal of Banking and Finance* (1993), *European Journal of Operational Research* (1997) and *Journal of Economics and Business* (1998).

efficiency are related while profit efficiency is more highly correlated with profitability ratios than with cost efficiency. This study contributes to the literature on the banking industry in Singapore in several directions. First, it uses the most recent and more comprehensive data set on the banking industry in Singapore. Second, it employs a set of well-defined input and output measures utilized by banks in the process of intermediation. Third, it considers each bank as an activity and independent economic agent. Fourth, it decomposes cost and production efficiency indices into different components to pinpoint the sources of inefficiency of each bank included in the sample. Finally, it brings together the two most broadly used approaches of banking cost and performance analysis.

2.3. Overview of banking environment in Singapore

Before 1971, all commercial banks in Singapore were licensed as full-licensed banks. These banks were permitted to carry out the whole range of banking services regardless of their size and country of incorporation. Since 1971, to protect domestic banks and to mitigate the problem of "over-banking", the banking regulatory agency, the Monetary Authority of Singapore (MAS), stopped issuing full-licensed bank charters. The new banks were chartered as restricted-licensed or off-shore-licensed banks. These two charters impose additional restrictions on the banks' assets, liabilities and their geographic expansion. As of 1971, Singapore was served by 143 commercial banks with total of 475 offices all around the city-state. There are also 22 finance companies and 214 Asian Currency Units (ACUs). [4] We excluded restricted-licensed, off-shore-licensed commercial banks as well as finance companies and ACUs from our sample because these institutions operate under a different set of restrictions and regulatory environment. The remaining institutions consist of 34 full-licensed commercial banks, of which 12 are locally owned (total offices of 267) and 22 are foreign owned (with total offices of 208). We also removed the 22 foreign owned banks from our study due to unavailability of data. The Overseas Union and the Overseas Chinese Bank of China absorbed two of the remaining 12 local banks, International Bank of Singapore and Four Seas Bank, respectively. Therefore, our sample consists of 10 full-licensed, domestically owned commercial banks for the period of 1991–1997 with total

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[4] Finance companies are set up with primary objectives akin to commercial banks, albeit on a small scale. These institutions are regulated and supervised by the same regulations and regulatory agency as commercial banks. Asian Currency Units (ACUs) are an integral part of the commercial banks; however, they are required to maintain separate accounting records for their transactions. Their activities are supervised by the MAS and are subject to the Singapore banking legislation but they are exempt from some provisions of the banking Act such as minimum cash balance and liquidity requirements imposed by the MAS.

observations of 70 banks. These 10 banks on average accounted for 75% of total bank deposits and 80% of total bank loans for the years under study. [5]

The banking environment in Singapore can be characterized as a market protected both from internal and external competition. Entry barriers erected by the MAS on the grounds that the Singapore financial market is "over-banked" combined with the recent merger and acquisitions among domestic banks have reduced the number of banks. At the same time, the activities of both domestic non-full-licensed banks such as restricted-licensed banks, finance companies and ACUs, and all foreign banks (full-licensed and restricted-licensed) are restricted on their product and geographic activities. Operation-ally, these banks behave as oligopolies (Lim and Chu, 1998; Chu and Lim, 1998), with the largest four banks leading the market in terms of market share and market rate on both source and use of funds. This uneven and protected environment, accompanied by entry restrictions has created a situation where there is not enough competitive pressure to force banks to behave as cost minimizing institutions. The link between entry barriers and incentive to op-erate inefficiently is theoretically straightforward. Specifically, this link can be looked at in the framework of cost inefficiency in the absence of competitive pressure. That is, cost inefficiency (internal waste and hence, deviation from production cost minimization) is attributed to monopoly power of the firm. It follows that increased competitive pressure in the market results in manager's effort to minimize cost (Leibenstein, 1966; Scherer and Ross, 1990). In light of

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[5] The banks included in our sample, ranked based on their 1997 total assets (thousands of Singaporean dollars), are:

Development Bank of Singapore (DBS)	S$101,645,967
Overseas Union Bank (OUB)	49,973,365
Overseas Chinese Bank Corporation (OCBC)	40,473,958
United Overseas Bank (UOB)	35,781,042
Keppel Bank	11,688,608
Tat Lee Bank	10,106,895
Industrial and Commercial Bank	4,356,798
Chung Khiaw Bank	3,736,500
Bank of Singapore	3,300,765
Far Eastern Commercial Bank	630,100

Notes: (i) Three of the above banks, namely, Industrial and Commercial Bank, Chung Khiaw Bank and Far Eastern Commercial Bank were acquired by UOB and the Bank of Singapore has been acquired by OCBC in recent years. Though these banks are subsidiaries, they still operate as separate entities and hence, in our study, we treated them as independent institutions. (ii) Given the small sample size, due to the unavailability of data on other financial institutions, the results of this study should be interpreted cautiously.

the above argument, we expect the fully licensed domestic bank in Singapore at less than optimal efficient level.

3. Methodology

3.1. Parametric

Banks are multi-product firms producing a vector of outputs from a vector of inputs. Using duality theory, the multi-product cost function dual to the production function can be written as

$$C = f(Y, W), \tag{1}$$

where Y is a vector of outputs, W is a vector of input prices and C is the total cost. The recent studies in banking have suggested that the cost function of banks can be represented by a translog function (see, e.g., Benston et al., 1982a,b; Hunter and Timme, 1986).[6] For a multiproduct bank, using two inputs producing three outputs, the translog cost function would take the following form:

$$\text{Ln}\,C = A + \sum_i B_i \text{Ln}\,Y_i + \sum_j C_j \text{Ln}\,W_j + \frac{1}{2}\sum_i \sum_k D_{ik}\text{Ln}\,Y_i\text{Ln}\,Y_k$$

$$+ \frac{1}{2}\sum_j \sum_l E_{jl}\text{Ln}\,W_j\text{Ln}\,W_l + \sum_j \sum_i F_{ji}\text{Ln}\,P_j\text{Ln}\,Y_i,$$

$$i, k = 1, 2, 3, \text{ and } j, l = 1, 2, \tag{2}$$

where C is total costs, Y_i is ith output ($i = 1, 2, 3$), and W_j is jth input price ($j = 1, 2$). $A, B_i, C_j, D_{ik}, E_{jl},$ and F_{ji} are parameters to be estimated. The set of factor share equations (Shephard's lemma, 1970) is presented by Eq. (3):

$$S_j = \partial \text{Ln}\,C/\partial \text{Ln}\,w_j = C_j + \sum_l E_{jl}\text{Ln}\,w_l + \sum_i F_{ji}\text{Ln}\,y_i. \tag{3}$$

Symmetry and homogeneity restrictions require the following restrictions, respectively:

$$E_{jl} = E_{lj}, \; D_{ik} = D_{ki}, \; \sum_j C_j = 1, \; \sum E_{jl} = 0, \text{ and } \sum_j F_{ji} = 0. \tag{4}$$

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[6] In order to determine whether or not the translog cost function is superior to the more restricted cost functions, three structural tests were conducted: constant returns to scale, homotheticity and homogeneity in outputs. Using likelihood ratio tests, the restricted functional forms were rejected at the 0.05 level of significance. Thus, we believe that the use of flexible functional form to estimate the cost structure of banks in Singapore is more appropriate.

The translog cost function (2) and one of the share equations comprise the cost system to be estimated.

3.1.1. Economies of scale

Overall economies of scale provide information on the relation between the scale of operation of a bank and its total costs. Overall economies of scale exist if an equal proportionate increase in all outputs leads to a less than equal proportionate increase in cost. According to Hanoch (1975) and Panzar and Willig (1977), overall economies of scale are the inverse of the sum of the cost elasticities. In terms of Eq. (2), the overall economies of scale (SE) are defined as

$$\text{SE} = C(y, W) \bigg/ \sum_i y_i \, \text{MC}_{yi} = 1 \bigg/ \sum_i E_{yi}, \tag{5}$$

where MC_{yi} is the ith output marginal cost and $E_{yi} = \partial \text{Ln} \, C / \partial \text{Ln} \, y_i$ is the cost elasticity of the ith output.

If SE is greater than (less than) one, the technology exhibits economies (diseconomies) of scale. If $\text{SE} = 1$, there are constant returns to scale.

Product-specific economies of scale provide information on the change in the total costs because of an increase in production of a specific product, holding the other outputs constant. According to Panzar and Willig (1981), Kim (1986) and Mester (1987), the approximate measure of product-specific scale economies (PSSE) for the ith output can be estimated as

$$\text{PSSE}_{yi} = (\text{IC}_{yi}/y_i)/\text{MC}_{yi} = (\text{IC}_{yi}/C)/E_{yi}, \tag{6}$$

where IC_{yi} is the incremental cost of producing y_i, IC_{yi}/y_i is the average incremental cost of producing y_i, MC_{yi} and E_{yi} are defined as before. From Eq. (6), if marginal cost is less (more) than average incremental cost, then the value of PSSE_{yi} is greater than (less than) one, indicating that the bank exhibits product specific economies (diseconomies) of scale with respect to the ith output.

3.1.2. Economies of scope

Scope economies exist if a bank can produce two outputs jointly with lower cost than the two single product banks can, i.e.,

$$C(y_1, 0) + C(0, y_2) > C(y_1, y_2).$$

According to Panzar and Willig (1981), the measure of overall scope economies (SC) for the case of two outputs can be calculated by the following ratio:

$$\text{SC} = [C(y_1, 0) + C(0, y_2) - C(y_1, y_2)]/C(y_1, y_2).$$

If SC is greater than (less than) zero, there are overall economies (diseconomies) of scope.

The problem with this approach is that the translog cost function cannot be used to estimate cost when one or more outputs have a value of zero. Kolari and Zardkoohi (1987), however, suggested an alternative, and that is substituting the minimum quantity of output, y^{min}, in the sample for the zero level of output. Following these authors, the increase in total costs due to an increase in each output is obtained as:

$$\Delta C_1 = C(y_1^{min} + \Delta y_1, y_2^{min}, y_3^{min}) - C(y_1^{min}, y_2^{min}, y_3^{min}),$$
$$\Delta C_2 = C(y_1^{min}, y_2^{min} + \Delta y_2, y_3^{min}) - C(y_1^{min}, y_2^{min}, y_3^{min}),$$
$$\Delta C_3 = C(y_1^{min}, y_2^{min}, y_3^{min} + \Delta y_3) - C(y_1^{min}, y_2^{min}, y_3^{min}),$$

where the superscript 'min' represents the minimum output value in the sample. Similarly, the increase in cost of producing y_1 through y_3 jointly is

$$\Delta C_{1,2,3} = C(y_1^{min} + \Delta y_1, y_2^{min} + \Delta y_2 + y_3^{min} + \Delta y_3) - C(y_1^{min}, y_2^{min}, y_3^{min}),$$

where $\Delta C_{1,2,3}$ denotes the increase in cost of producing all outputs jointly. Using the above definition and following Panzar and Willig (1981), the measure of economies of scope can be redefined as

$$SC = [(\Delta C_1 + \Delta C_2 + \Delta C_3)/(\Delta C_{1,2,3})] - 1. \tag{7}$$

Product-specific economies of scope (PSES) exist if the cost of joint production of one particular output with the existing output bundle is less than the sum of the cost of production of that output and the remaining outputs in the bundle separately. Specifically, product-specific economies of scope are said to exist in production of the ith output if $PSES_{yi} > 0$, where

$$PSES_{yi} = [C(y_1, \ldots, y_{k-1}, 0, y_{k+1}, \ldots, y_i) + C(0, \ldots, y_i, 0, \ldots, 0) - C(y)]/C(y). \tag{8}$$

3.2. Non-parametric technique

In the non-parametric approach, linear programming is used to construct a set of benchmark, best-practiced frontiers relative to which several efficiency indexes are calculated for each bank in the sample (see, Färe et al., 1985). The first efficiency index that we calculate for each bank included in the sample is overall efficiency (OE). This efficiency measure is then decomposed into overall technical efficiency (OTE) and allocative efficiency (AE). The OTE will also be decomposed into pure technical efficiency (PTE) and scale efficiency (SE) to better pinpoint the sources of the inefficiency of each bank in the sample. Formally, the overall efficiency of each bank can be express as

$$OE = OTE * AE = PTE * SE * AE.$$

The non-parametric technique to efficiency measurement is extremely flexible in modeling the production technology of the banks in sample in a multi-input,

multi-output framework. It does not impose any functional form and error structure on data, and avoids the possible multi-collinearity problem among variables used in estimation.

While AE and SE are derived measures, the other efficiency indexes are calculated relative to the best-practiced frontiers constructed by linear programming. Specifically, the overall efficiency of each bank is determined as

$$OE_i = C_i^* / C_i$$

where C_i is actual cost and C_i^* is minimum cost of production of the ith bank, C_i^* is the solution to the following linear programming (LP):

$$C_i^* = \min\{p \cdot m : aM \leqslant m_i, \ z \leqslant aZ, \ a_i \in T^+\}, \tag{9}$$

where m is the vector of observed inputs utilized by the ith bank, a the vector of intensity variable, p the vector of input prices, z the vector of observed outputs produced by the ith bank, Z the matrix of observed outputs produced by all banks in the sample, M the matrix of observed inputs for all the banks under study and T is the total number of banks in the sample.

The measures of technical efficiency of the ith bank (OTE_i) is calculated as

$$OTE_i = \min\{q_i : aM \leqslant q_i m_i, \ z_i \leqslant aZ, \ a_i \in T^+\}, \tag{10}$$

where all variables are as defined earlier, having OE calculated from LP (9) and OTE from LP (10), the AE is computed as AE = OE/OTE. To calculate pure technical efficiency of the ith bank (PTE_i), the following LP is solved for all banks included in the sample space:

$$PTE_i = \min\left\{k_i : aM \leqslant k_i m_i, \ aZ, \ z_i, \ \sum a_i = 1, \ a_i \in T^+\right\}. \tag{11}$$

Note that the pure technical efficiency index is a measure of efficiency calculated relative to a frontier characterized by constant, increasing and decreasing returns to scale. Overall technical efficiency of the ith bank (OTE_i), on the other hand, measures efficiency relative to a frontier that is restricted to constant returns to scale (for details, see Färe et al., 1985).

Having k_i and q_i calculated, the scale efficiency index for the ith bank is then simply derived as

$$SE_i = q_i / k_i.$$

Note that if $SE_i = 1$, then the ith bank is called scale efficient. It follows that if $SE_i \in (1, 0]$ then the ith bank is scale inefficient, i.e., it operates either at increasing (IRTS) or decreasing returns to scale (DRTS). To identify the source of scale inefficiency, we solve the following LP for each bank:

$$VTE_i = \min\left\{j_i : aM \leqslant j_i m_i, \ aZ \leqslant z_i, \ \sum a_i < \ = 1, \ a_i \in T^+\right\}. \tag{12}$$

Given the solution to LP (11) and (12), Färe et al. (1985) prove that if $j_i = k_i$, then, the scale inefficiency of the ith bank is due to decreasing returns to scale and if $j_i \neq k_i$, the source of scale inefficiency is increasing returns to scale.

3.3. Data

The data set used in this study is obtained from financial statements of banks on their web pages on the Internet and other annual reports. We selected the 10 privately held and domestically owned Singaporean banks that are fully licensed commercial banks. The period that the sample covers is from 1991 to 1997. Hence, our sample consists of 70 observations.

We employ the intermediation approach to model the production process of the banking firm. Based on this modeling, outputs are measured as the dollar value of the earning assets, and the total cost is calculated as the sum of the production costs and interest expenses. Three outputs are identified: total loans (y_1), securities (y_2), and other earning assets (y_3). These outputs are produced using two inputs: borrowed funds (x_1), and "other inputs" [7,8] (x_2). The unit price of borrowed funds (w_1, interest expenses) is calculated by dividing the annual interest expenses on time deposits and other borrowed funds expenses by x_1. The price of other inputs (w_2, non-interest expenses) is calculated as the ratio of the sum of total salaries and benefits of employees, total expenditure on premises plus other fixed assets to the other input (x_2). Table 1 provides the descriptive statistics of these variables.

4. Empirical results

4.1. Parametric

The cost system consisting of Eq. (2) and one of the share equations is estimated using Zellner's Seemingly Unrelated Regression method. [9] Table 2

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[7] "Other inputs" consist of labor and capital (fixed assets). We did not separate labor expenses from capital, as has been done in many studies, since for most banks in our sample either the number of employees was not available or these expenses were not reported separately in the banks' income statements.

[8] Our definition of other inputs is different form other banking studies using transcost function. This may introduce biasness to the extent that different banks may have different ratios of employees to fixed assets. Hence, the results of this paper should be interpreted with regards to this possible biasedness.

[9] Barten (1969) has shown that the estimated coefficients of the translog cost function are not sensitive to the share equations used. We checked for this issue and the results were almost the same across different estimations. As a result, we dropped the other inputs share equation in the process of the estimation of cost system.

Table 1
Descriptive statistics of Singapore banks[a]

	N	Mean (S\$000)[b]	S.D.	Minimum	Maximum
Y_1	70	7,294,734	8,132,028	147,764	35,803,205
Y_2	70	921,180	914,967	17,951	3,276,397
Y_3	70	403,849	495,545	253	1,923,587
X_1	70	11,681,516	12,496,897	234,574	54,004,184
X_2	70	6,442,558	8,918,857	118,244	61,981,098
W_1	70	0.0378	0.0112	0.0040	0.0632
W_2	70	0.0135	0.0056	0.0034	0.0275
TA	70	15,065,694	17,705,520	320,114	101,645,967
TC	70	654,670	691,126	15,941	2,684,583

[a] N = number of observations; Y_1 = total loans; Y_2 = securities; Y_3 = other earning assets; X_1 = borrowed funds; X_2 = other inputs; W_1 = unit price of borrowed funds; W_2 = unit price of other input; TA = total assets; TC = total cost.
[b] All measures are in S\$(thousands), except for unit costs.

Table 2
Parameter estimates of the regression analysis

Variable label	Parameter estimate	t-ratio	Coefficient
Intercept	6.0484*	3.8456	A
$\mathrm{Ln}\,y_1$	0.8176*	5.3027	B_1
$\mathrm{Ln}\,y_2$	0.0614*	2.8297	B_2
$\mathrm{Ln}\,y_3$	0.1409*	3.0583	B_3
$\mathrm{Ln}\,W_1$	0.4456*	3.9630	C_1
$\mathrm{Ln}\,W_2$	0.5544*	2.7859	C_2
$(\mathrm{Ln}\,y_1)^2$	1.1683*	2.5739	D_{11}
$(\mathrm{Ln}\,y_2)^2$	1.3567*	7.4308	D_{22}
$(\mathrm{Ln}\,y_3)^2$	0.0337	1.3029	D_{33}
$\mathrm{Ln}\,y_1 * \mathrm{Ln}\,y_2$	−1.2564*	2.9842	D_{12}
$\mathrm{Ln}\,y_1 * \mathrm{Ln}\,y_3$	0.0073*	4.0930	D_{13}
$\mathrm{Ln}\,y_2 * \mathrm{Ln}\,y_3$	−0.0222	0.2049	D_{23}
$(\mathrm{Ln}\,W_1)^2$	0.2191*	3.9402	E_{11}
$(\mathrm{Ln}\,W_2)^2$	0.2191*	5.9302	E_{22}
$\mathrm{Ln}\,W_1 * \mathrm{Ln}\,W_2$	−0.2191*	2.0347	E_{12}
$\mathrm{Ln}\,W_1 * \mathrm{Ln}\,y_1$	−0.0466*	4.8920	F_{11}
$\mathrm{Ln}\,W_1 * \mathrm{Ln}\,y_2$	0.0509*	9.5384	F_{12}
$\mathrm{Ln}\,W_1 * \mathrm{Ln}\,y_3$	0.0019	1.0639	F_{13}
$\mathrm{Ln}\,W_2 * \mathrm{Ln}\,y_1$	0.0465*	3.5690	F_{21}
$\mathrm{Ln}\,W_2 * \mathrm{Ln}\,y_2$	−0.0509	0.1205	F_{22}
$\mathrm{Ln}\,W_2 * \mathrm{Ln}\,y_3$	−0.0019*	5.0589	F_{23}
Adj. R^2	0.9356		

* Coefficients are significantly different from zero at the 0.01 level.

presents the estimated parameters. The estimated coefficients satisfy the theoretical requirements of the cost function. As evident from Table 2, the signs of output and input coefficients are positive and statistically significant indicating

Table 3
Overall economies of scale and scope[a]

Asset categories (S$000)	No. of obs.	Scale economies	Scope economies
< 10,107	21	1.0204[*]	0.4557[**]
10,107–13,868	22	1.0030[*]	0.1923[**]
> 13,868	27	0.9672[*]	0.1275[**]
All obs.	70	0.9939[*]	0.2463[**]

[a] SE > 1 (SE < 1) indicate economies (diseconomies) of scale. SC > 0 (SC < 0) indicate economies (diseconomies) of scope.
[*] Scale economies are statistically different from one (zero) at the 0.01 level of significance.
[**] Scope economies are statistically different from one (zero) at the 0.01 level of significance.

a positive relation between cost and independent variables. [10] The adjusted R^2 is 95% indicating that 95% of the variation in total cost is explained by variation in independent variables.

The estimated coefficients of the translog cost system along with those of Eqs. (5) and (7) are used to calculate economies of scale and scope for each observation. Table 3 presents the mean of overall scale and scope economies for the entire sample. According to the figures in this table, overall economies of scale and scope for the entire sample are statistically different from one and zero, respectively, indicating that the banks in the sample, on average, have overall economies of scale and scope. Table 3 also provides information on the scale and scope economies for different size categories. We categorized banks in our sample based on their total assets as small, medium and large banks. As can be seen, small and medium-size banks exhibit increasing returns to scale and large banks decreasing returns to scale. These findings suggest that a size expansion by small and medium banks may have greater cost advantage than size expansion by the large banks. In addition, the results indicate that there are scope economies for banks in each of the three size categories. However, the magnitude of the scope measure is greater for smaller banks than larger banks. This indicates that joint production of the three outputs (loans, securities and other earning assets) is less costly than producing each output independently and, hence, all banks in our sample can reduce cost of production through product diversification. In addition, this cost saving through diversification of portfolio is larger for smaller banks than larger banks. [11]

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[10] In order to show that the coefficient estimates satisfy the theoretical requirements, we substituted the output and input price values into translog cost function and checked for regularity conditions: non-decreasing and concave in factor prices and positive marginal cost. The estimated values indicate that these regularity conditions are met for 94% of the observations.

[11] While the translog cost function has been extensively used in banking literature, McAllister and McManus (1993) question the appropriateness this model in measuring scale economies for a sample of banks consisting of different sizes and product mix. Specifically, they argue that the estimated U shaped average cost curve is the result of econometric misspecification. Therefore, the results presented here should be interpreted with caution and in light of the above argument.

We further estimated the changes in scale and scope economies for the banks over the period under study. Table 4 contains the results of this investigation. According to the figures in Table 4, measures of overall economies of scale (scope) have increased (decreased) over time indicating the existence of larger (smaller) scale (scope) economies in more recent years.

The means of the product-specific economies of scale and scope are presented in Table 5. According to the figures of this table, there are product-specific economies of scale with respect to loans and securities and diseconomies of scale with respect to "other earning assets". These findings suggest that marginal cost of producing loans and securities falls short of its average cost which in turn implies that expansion of banks by increasing their loans and securities is cost effective. The reverse is true for "other earning assets". The value of the product-specific economies of scale for this output is less than one, indicating diseconomies of scale associated with production of this output. Table 5 also includes the estimates of product-specific economies of scope. As can be seen, there are statistically significant product-specific economies of scope with respect to all three outputs. This indicates that producing all outputs jointly is less costly than production of each output separately.

Table 4
Scale and scope economies of bank for each year, 1991–1997[a]

Year	N	SE	SC
1991	10	0.9896	0.3251
1992	10	0.9756	0.2792
1993	10	0.9800	0.3361
1994	10	0.9840	0.2187
1995	10	1.0062	0.2359
1996	10	0.9970	0.2177
1997	10	1.0269	0.2113

[a] SE > 1 (SE < 1) indicate economies (diseconomies) of scale. SC > 0 (SC < 0) indicate economies (diseconomies) of scope.

Table 5
Product-specific economies of scale and scope[a]

Outputs	PSSE	PSES
Loans	1.0938[*]	0.6586[**]
Securities	1.3421[*]	0.8782[**]
Other earning assets	0.8217[*]	0.2381[**]

[a] PSSE > 1 (PSSE < 1) indicate product-specific economies (diseconomies) of scale. PSES > 0 (PSES < 0) indicate product-specific economies (diseconomies) of scope.
[*] Product-specific economies of scale are statistically different from one (zero) at the 0.01 level of significance.
[**] Product-specific economies of scope are statistically different from one (zero) at the 0.01 level of significance.

4.2. Non-parametric

The LPs (9) and (11) are solved for the sample to calculate efficiency indexes for each bank. Table 6 reports the summary statistics of the five efficiency indexes. As can be seen, the banks in the sample are on average 57% overall efficient. In other words, these banks, on average could have reduced cost by 43% from what they actually incurred had they all been operating with overall efficiency. This result differs from that of Lim and Chu (1998) and Chu and Lim (1998). They estimated *X*-efficiency for a sample consisting of six banks in Singapore and report an average cost efficiency of 95% over a period of six years. However, their measures of inputs and outputs are different from measures used in this paper.

The figures in Table 6 also suggest that the dispersion of the overall efficiency measures is wider compared to those of other efficiency measures. Decomposition of OE into AE and OTE provide information on the source of overall inefficiency. As it is evident from Table 6, overall inefficiency is in fact caused equally by allocative inefficiency (25%) and overall technical inefficiency (26%). Further decomposition of the OTE into PTE and SE reveals that banks in the sample could have saved, on average, 14% inputs if they had been operating on the frontier that exhibits variable returns to scale. It follows from the figures that the banks, on average, could have saved 13% inputs if they had been operating at constant returns to scale. In order to investigate whether this scale inefficiency is due to increasing returns to scale (IRTS) or decreasing returns to scale (DRTS), we follow Färe et al. (1985) and solve the LP (12) for each bank. The findings indicate that only four observations (5.71%) in the sample operate at constant returns to scale, 50 (71.43%) operate at DRTS and 16 (22.86%) operate at IRTS.

In addition, we calculate and evaluate the growth of efficiency measures relative to the constructed best-practiced frontier over the period 1991 to 1997.

Table 6
Summary statistics of efficiency measures[a]

Efficiency	N	Mean	S.D.	Minimum	Maximum
OE	70	0.5704	0.1879	0.2429	1.0000
AE	70	0.7529	0.1581	0.4487	1.0000
OTE	70	0.7426	0.1379	0.4411	1.0000
PTE	70	0.8577	0.1437	0.4420	1.0000
SE	70	0.8715	0.1072	0.6713	1.0000

[a] (i) OE = overall efficiency; AE = allocative efficiency; OTE = overall technical efficiency; PTE = pure technical efficiency; SE = scale efficiency. (ii) In order to check the robustness of our results, we dropped outliers and re-estimated the models as suggested by one of the referees. The results did not change significantly. For instance, the means of OE, AE, OTE, PTE and SE are 0.5755, 0.7686, 0.7488, 0.8700 and 0.8607, respectively.

Table 7 contains the results of this investigation. As data of this table indicate, all efficiency measures exhibit an upward trend from 1991 to 1993 and a downward trend afterward (except OTE). The interesting point is that PTE and SE are relatively constant over the period. Hence, all variations in OE are caused by variations in AE and OTE over the 1991–1997 period. The stability of SE over the period can be verified by data presented in Table 8. In this table the number of banks in different categories of return to scale are presented. It is evident from the figures of this table that number of banks exhibiting DRTS and IRTS are relatively constant over the period under study.

Table 7
Means and S.D. of efficiency measures for each year[a]

	OE	AE	OTE	PTE	SE
1991	0.3809	0.5352	0.7052	0.8178	0.8778
	(0.0948)	(0.0527)	(0.1221)	(0.1796)	(0.1107)
1992	0.6053	0.7802	0.7648	0.8624	0.8958
	(0.1959)	(0.1269)	(0.1455)	(0.1734)	(0.1009)
1993	0.7275	0.9082	0.7574	0.8740	0.8758
	(0.1872)	(0.1110)	(0.1661)	(0.1874)	(0.1107)
1994	0.6684	0.8921	0.7394	0.8526	0.8680
	(0.1981)	(0.0953)	(0.1549)	(0.1310)	(0.1137)
1995	0.5570	0.7497	0.7336	0.8586	0.8571
	(0.1642)	(0.1174)	(0.1351)	(0.1191)	(0.1187)
1996	0.5564	0.7654	0.7221	0.8510	0.8516
	(0.1409)	(0.1098)	(0.1215)	(0.1113)	(0.1114)
1997	0.4980	0.6389	0.7758	0.8876	0.8742
	(0.1294)	(0.0907)	(0.1451)	(0.1182)	(0.1091)

[a] The numbers in the parentheses represent S.D.

Table 8
Number of banks in different categories of scale economies[a]

Year	DRTS	CRTS	IRTS	Total
1991	6	0	4	10
1992	7	1	2	10
1993	7	1	2	10
1994	6	2	2	10
1995	8	0	2	10
1996	8	2	2	10
1997	8	0	2	10
Total	50	4	16	70

[a] DRTS = decreasing returns to scale; CRTS = constant returns to scale and IRTS = increasing returns to scale.

5. Summary and conclusion

In this paper, economies of scale, economies of scope and several efficiency measures are calculated for a sample of Singaporean commercial banks. The results suggest that the average cost curve is U shaped for the Singaporean banking industry and there are economies of scale for banks of small and medium size. The findings further indicate that there are economies of scope for banks regardless of their size. This means that joint production of outputs is less costly than producing each output separately.

The linear programming results indicate that the Singaporean banks in the sample could have reduced cost by 43% had they all been operating at full efficiency. The investigation of sources of overall inefficiency indicates that this cost inefficiency is caused almost equally by allocative and technical inefficiencies. This means that cost inefficiencies could be eliminated if the banks in the sample select the optimal input mix and utilize input more efficiently in the intermediation process.

The findings based on the non-parametric technique seem to be consistent with those of the parametric approach, which indicate cost efficiency is positively associated with size of the bank.

Consequently, our empirical results of both parametric and non-parametric techniques suggest that the recent movement in the Singaporean banking industry towards mergers and acquisitions of small and medium-size banks is economically justifiable. This is because there are significant cost advantages for the Singaporean banks to expand their size and to diversify into several outputs.

Acknowledgements

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