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Economies of Scale and Scope in Korea's Banking Industry: Evidence from the Fourier Flexible Form*

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This paper examines the efficiency of the Korean banking industry by studying both economies of scale and scope. The Fourier cost function, which is globally flexible, was used to estimate several efficiency measures. The findings of this paper are as follows. First, different data and models can lead to considerable differences. Second, the Fourier flexible functional form is more suitable for estimating an unknown cost function. Third, economies of scale were found in the Korean banking industry, with larger banks being more likely to have a higher scale efficiency than smaller ones. Fourth, the existence of economies of scope was somewhat inconclusive, as results varied across different models.

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Keywords: fourier flexible cost function, economies of scale, economics of scope

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1. INTRODUCTION

All over the world, the financial industry continues to change rapidly. Financial markets are merging into a single integrated global market where super-heated competition prevails. These changes are being driven by technological innovations in computers and telecommunications and the universal trend toward deregulation and globalization. To survive in such cutthroat conditions, many financial institutions have been forced into mergers or cooperative arrangements. They have also been coping with the competitive pressure by raising their operational efficiency through new financial products and financial restructuring.

In Korea, the state-led high-speed economic development program had dictated what the financial industry's main role would be, which was funneling the country's scarce capital resources into strategic industries. And it must be admitted that the banking industry's submissive compliance with government directives did contribute significantly to the growth of the real sector. However, over the long-run such excessive governmental interference has become the main factor underlying the Korean banking industry's inefficiency. Recognizing this, in the 1990s the government took steps to improve efficiency by deregulating the financial sector and liberalizing interest rates. The banks took some initiative on their own, too, by amassing size and diversifying their business scope, as well as cutting down on operating costs. Despite these efforts, Korean banks still lag behind their foreign counterparts in size, financial techniques, and efficiency of financial intermediation. The banking industry's inefficiency means higher financial intermediation costs, with adverse consequences for the competitiveness of Korea's real sector. Thus, a thorough discussion of the banking industry's efficiency and ways to improve its competitiveness is a prerequisite step toward securing stability in Korea's financial markets and promoting healthy banking sector development.

Focusing on scale and scope economies, this paper examines how the current trend among Korean banks toward expansion and business diversification is affecting the Korean banking industry's competitiveness. Although there is already a substantial literature on the subject of efficiency in the Korean banking industry, the results vary widely depending on the researcher's perspective on the banking industry, the data and the models used in the studies, etc. This paper aims to contribute to the literature by analyzing the efficiency of the banking industry through a variety of approaches, using accurate data from detailed financial statements that cover not only traditional commercial banking business but also banks' trust business.[1] Fourier Flexible functions as well as translog functions are used to estimate the cost function of banks. The results from the different approaches are then compared for discrepancies.

The rest of the paper is organized as follows. Section 2 outlines the current status of the Korean banking industry. Section 3 briefly reviews past studies and describes the models used for empirical analysis. Section 4 describes the data and presents results of our analysis. Finally, Section 5 concludes the paper with a summary and suggestions.

2. THE STATUS OF KOREA'S BANKING INDUSTRY

This section gives a brief review of the history of the Korean banking industry and describes its current status. The background material provided here should give the reader some basis on which to interpret the empirical results presented later on.

It is a well-known fact that the growth of the Korean banking industry parallels that of the Korean economy. The total assets of commercial banks increased by an annual average of 21.9 percent during 1980-1998, a rate that was substantially higher than the 14.7 percent average annual growth of nominal GDP over the same period.[2] As the economy continued to grow, so did the banks' role in attracting savings and distributing the resulting funds, which allowed the banking industry to grow at a faster pace than the rest of

[1] In Korea, banks handle not only traditional commercial banking business, i.e., taking deposits and providing loans, but also trust business. Although banks deal with both types of businesses in the same location, the accounting of the trust business is kept separate from commercial banking business.

[2] The increase in bank assets was driven both by the growth of existing banks and the increase in the number of banks.

the economy. The growth of the banking industry in Korea was also faster than its counterparts in other countries. The list of the world's 500 largest banks in terms of paid-in capital had included only 8 Korean banks in 1983, but this number had grown to 18 by 1996.[3)]

However, Korean banks are still puny by international standards. Not a single Korean bank can be found among the global top 100. This puts Korean banks at a competitive disadvantage in the international banking market. Matters have only worsened in the 1990s, as the global ranking of the top 5 Korean banks have slipped down. Despite their phenomenal growth, Korean banks are still not competitive in terms of their fund-raising capability and operating costs. They have not reached the size that can give them the economies of scale to compete with large foreign banks.

Neither has Korean banks' quality kept pace with their rapid growth. Because their staff lack adequate training, skills, and experience, Korean banks are lacking in the ability to collect and analyze information to make sound credit assessments. They have not been able to effectively exploit financial derivatives and new advanced financial technology, either.

The responsibility for such overall stagnation in Korea's banking sector must be laid at the government's regulations and intervention that shielded banks from market forces. In this protected environment, the banks concentrated primarily on attracting savings and were content to rely on collateralized loans. Consequently, they neglected to develop expertise in screening and monitoring loans. In particular, the banks lack in the ability to assess the profitability and credit risks of firms. It was only a matter of time before bad loans would cripple the system, which ultimately led to the financial debacle in 1997.

Table 1 shows the worsening health of Korean commercial banks as reflected in their aggregated balance sheets between 1980 to 1998. First, the share of deposits out of the banks' total assets, including demand deposits, savings deposits, CDs and foreign currency deposits, shrank from 58 to 43 percent over this period. An increasingly competitive deposit market

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[3)] This is mainly attributable to the large capital increases following the easing of restrictions on banks' paid-in capital in the late 1980s.

explains this steady shrinkage of the banks' market share, which began with the 1970s' proliferation of less-regulated non-bank financial institutions, such as merchant banks, investment & finance companies, investment trust companies, and mutual savings & finance companies. In particular, the share of demand deposits in total assets fell drastically from 22.3 percent in 1980 to 3.1 percent in 1998, reflecting greater consumer sensitivity to interest rates and the emergence of new financial products with better returns and liquidity.

In order to overcome the limits of relying primarily on commercial bank accounts for funds, banks strengthened their trust account business. Initially, only Seoul Trust Bank was given a license to manage trusts, but regional banks in 1983 and nation-wide commercial banks in 1984 were allowed to engage in the trust business in order to balance and promote the inflow of funds from households. Because they offered high returns and convenient transactions compared to other financial products offered by non-bank financial institutions, bank trusts were able to grow significantly.

Table 1 Assets and Liabilities of Korea's Commercial Banks

(unit: %)

	1980	1985	1990	1995	1998
Total (in billion won)	100.0 (12,046)	100.0 (36,831)	100.0 (112,502)	100.0 (340,543)	100.0 (560,060)
Liabilities & capital					
Deposits in bank accounts	58.3	48.2	45.1	40.5	43.1
Money in trust	0.0	8.1	19.0	31.8	25.7
Borrowings	29.3	35.8	19.1	13.4	11.7
Others	5.7	3.8	6.9	8.2	14.7
Capital	6.8	4.2	10.0	6.1	4.8
Assets					
Loans of bank account	63.4	56.0	46.8	37.6	37.0
Loans of credit account	0.0	5.5	7.8	11.4	8.5
Securities	7.2	10.1	21.6	32.6	33.0
Cash and deposits	23.7	21.1	17.3	11.4	9.8
Others	5.7	7.3	6.6	7.0	11.7

Note: Numbers are the average values for the year.
Source: Financial Supervisory Service of Korea.

On the asset side the most notable features of the 1980-1998 period were declining bank account loans and increasing loans and securities investments based on trust account funds. During this period, the sluggish growth of bank deposits hampered the ability of banks to increase loans based on deposit account funds. As a result, the ratio of bank loans to total assets dropped from 63.4 percent to 37.0 percent, while in contrast more security investments and loans came to be based on the growing trust accounts. Compared to their counterparts in other OECD member countries, in Korea a far smaller portion of loans is based on bank assets. This was one of the main factors that led to the recent financial crisis. An additional factor that contributed to the crisis was that Korean banks were incapable of assessing the quality of their loans effectively.

3. MODELS FOR ANALYZING THE EFFICIENCY OF THE BANKING INDUSTRY

3.1. Existing Models

The term 'efficiency' takes on different meanings depending on the context. In economics, 'efficiency' sometimes means Pareto efficiency or the optimal distribution of resources, while in the stock market, it refers to efficiency of information. But in the context of the banking industry and this paper, 'efficiency' refers to 'cost efficiency', indicating how changes in a bank's output affect its cost.[4] Therefore, the approach we take for measuring the banking industry's efficiency is to estimate the cost functions of the banking industry to analyze both scale and scope economies.

Various kinds of cost functions have been used in the existing literature, including the Cobb-Douglas, Leontief and translog cost functions. However, while they are easy to estimate, the Cobb-Douglas and Leontief functions restrict the elasticity of substitution to 0 or 1 on an ex ante basis. This limitation led to the translog functional specification in the mid-1970s by

4) Another well-known measure of efficiency in the banking industry is the X-efficiency, which compares between observed and optimal values of input-output combination.

Christenson, Jorgenson and Lau (1970). The translog cost function approximates the original cost function at a single data point by linearizing it with second-order Taylor expansion formulae.

After Baumol, Panzer and Willig (1980), many studies on banking industry efficiency have used the translog cost function to estimate economies of scale and scope in the banking sector (See Berger, Hanweck, and Humphrey (1987), Ferrier and Lovell (1990), Hunter and Timme (1986, 1991), Noulas, Ray, and Miller (1990), Berger and Humphrey (1991), Pulley and Humphrey (1993), and Mester (1993), among others).

But a serious limitation of the translog cost function is that it cannot satisfy the theoretical properties of a cost function at all the data points; it has a locally flexible functional form which satisfies the theoretical properties of the cost function at a single data point only. Because of this, estimators that use the translog functional form are biased,[5] often resulting in underestimation of economies of scale for large banks.

The Fourier Flexible (FF) functional form was proposed by Gallant (1981) to overcome the problems of the translog cost function. The FF functional form, specified as a combination of a second-order polynomial and a Fourier series, has the major advantage of being a globally flexible functional form which is able to satisfy the properties of a cost function at all data points. The Fourier series, by linear combination of trigonometric functions, in theory can approximate any function with great accuracy. Another advantage of the FF functional form is that it does not specify an ex ante functional form on a theoretical basis, e.g., as linear or a second-order polynomial. Rather, the choice of a functional form is determined by the data, which makes it a semi-non-parametric estimation method. The advantage of such a method is that it reduces the chances of a specification error from arbitrary assumptions about the functional form. Mitchell and Onvural (1996) used the FF functional form to measure economies of scale and scope in the banking sector.

In Korea, several studies have analyzed Korean banks' economies of scale and scope. But their results were not so reliable, having used some positive

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[5] White (1980) showed that the translog functions produce biased estimators.

monotonic cost function. To correct this, Jwa (1992) and other studies have used translog functions. But conclusive results have yet to be reached, as the findings varied according to estimation methods, the definition of outputs, etc.

Research on the efficiency of non-banking financial institutions has concentrated on the securities or the insurance industry. Work on efficiency in the securities industry includes Lee (1992), which used a translog cost function, and Lee and Choi (1989) and Kim (1992), both of which used Cobb-Douglas production functions and translog cost functions. These studies have shown that there are economies of scale in the Korean securities industry, but remain inconclusive on economies of scope.

Kwon (1994) and Na (1995) have looked into the Korean life insurance industry. They found evidence of economies of scale, but whether economies of scope existed varied by the type of business.

3.2. Estimation Methodology

3.2.1. Cost Functions

In order to measure the efficiency of financial institutions empirically, one first needs to estimate their production function, cost function, or profit function. This involves choosing a functional form that can accommodate the various theoretical properties of the functions, including second-order differentiability, convexity, or concavity. Since we analyze banking industry efficiency from the cost side, our approach is to estimate cost functions. We chose the FF functional form because it satisfies the theoretical properties at all the data points. The methodology for estimation mainly follows Mitchell and Onvural (1996). Following their lead, we adopted the simplified FF cost function proposed by Gallant (1981), as seen in equation (1).

$$\ln C = c_0 + \underline{\boldsymbol{a}}'\underline{x} + \frac{1}{2}\underline{x}'B\underline{x} + \sum_{k=1}^{K}(\boldsymbol{d}_k \cos(\underline{\boldsymbol{h}_k}'\underline{x}) + \boldsymbol{g}_k \sin(\underline{\boldsymbol{h}_k}'\underline{x})) + \boldsymbol{e} \qquad (1)$$

In equation (1), $\ln C$ represents the log of total expenses and c_0 is a constant. $\underline{x} = [\underline{u}', \underline{v}']'$, where $\underline{u} = [u_1, \ldots, u_N]'$ is the vector of the log of input prices and $\underline{v} = [v_1, \ldots, v_M]'$ is the vector of the log of outputs, both scaled appropriately for the estimation of FF cost function. Thus the vector $\underline{x}$ includes scaled log values of N input prices and M outputs. Because the FF function includes trigonometric terms, $\underline{x} = [\underline{u}', \underline{v}']'$ is scaled so that the minimum value be larger than zero and the maximum value be smaller than 2π, following the formulae given by equation (2).

$$\underline{u} = \boldsymbol{l}[\ln \underline{p} + \underline{w_p}], \quad \underline{v} = \boldsymbol{l}\,\underline{m}'[\ln \underline{v} + \underline{w_y}] \qquad (2)$$

In equation (2), $\underline{p}$ is an N-vector of unscaled input prices, and $\underline{y}$ is an M-vector of unscaled output. l, $\underline{m}$, $\underline{w_p}$, and $\underline{w_y}$ are scale factors.[6] $\underline{\boldsymbol{a}} = [\boldsymbol{a}_{u_1}, \ldots, \boldsymbol{a}_{u_N}, \boldsymbol{a}_{v_1}, \ldots, \boldsymbol{a}_{v_M}]'$ in equation (1) is the estimated (N+M) coefficient vector of input prices and outputs, and $B = [\boldsymbol{b}_{ij}]$ is the estimated (N+M) $\times$(N+M) symmetric coefficient matrix of a second-order Taylor expansion. $\boldsymbol{d}_k$ and $\boldsymbol{g}_k$ are the estimated coefficients of trigonometric terms and $\underline{\boldsymbol{h}_k}$ is an (N+M) vector of integers. It can be seen that equation (1) is a combination of the translog function shown in equation (3) and the Fourier expansion shown in equation (4). The FF function as shown in equation (1) can, by controlling K and $\underline{\boldsymbol{h}_k}$ properly, estimate the true cost function with almost any desired degree of precision.[7] $\boldsymbol{\varepsilon}$ is an error term.

$$c_1 + \underline{\boldsymbol{a}}'\underline{x} + \frac{1}{2}\underline{x}'B\underline{x} \qquad (3)$$

$$c_2 + \sum_{k=1}^{\infty}(\boldsymbol{d}_k \cos(\underline{\boldsymbol{h}_k}'\underline{x}) + \boldsymbol{g}_k \sin(\underline{\boldsymbol{h}_k}'\underline{x})) \qquad (4)$$

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6) In practice the FF cost function requires that the log values of input price and output quantity data must be scaled in order to limit the periodic sine and cosine functions to one period of length 2.

7) Gallant (1982) showed that the increase in the number of *K* vectors relative to the sample size can reduce approximation error, and Eastwood and Gallant (1991) developed rules (Eastwood and Gallant's criteria) for tying sample size to the total number of *FF* parameters estimated so as to produce consistent and asymptotically normal parameter estimates. Following their criteria, we set $K = 43$ when there are 4 outputs and 3 inputs and $K = 30$ when there are three of each.

The FF cost function, under the assumption of linear homogeneity in input prices as a theoretical property of cost function, has the restriction that the coefficients of the price variables in the sine and cosine terms must each sum to zero, as in equation (5).[8)]

$$\lambda \sum \alpha_{u_i} = 1$$

$$\sum_{j=1}^{N} b_{ij} = 0, \qquad i = 1, 2, \ .., \ \text{N+M} \tag{5}$$

Just as in the case of the translog cost function, better results can be obtained for the FF cost function when it is estimated simultaneously with a share equation. The share equation is derived from the FF cost function as in equation (6), and is composed of N-1 independent equations under the adding-up restriction.[9)]

$$S_i = \frac{p_i q_i}{C} = \frac{\partial \ln C}{\partial \ln p_i}$$

$$= \lambda[\alpha_{u_i} + \underline{b_{i\bullet}}' x + \sum_{k=1}^{K}(-d_k h_{ku_i} \cos(\underline{h_k}' \underline{x}) + g_k h_{ku_i} \sin(\underline{h_k}' \underline{x})], \ i = 1, \ .., \ \text{N} \tag{6}$$

3.2.2. Efficiency Measures

We examined several efficiency measures developed for multiproduct firms. Two commonly used measures are scale economy measures that compare cost efficiency at different firm sizes and scope economy measures that compare the cost efficiency of multiproduct firms. However, since these two efficiency measures assume identical product composition and complete production specialization, they are inappropriate for the banking

8) The trigonometric terms in the FF function consist of those for each output, $\cos(v_i)$ and $\sin(v_i)$ for i=1, .., M; those for combinations of two outputs, $\cos(v_i+v_j)$, $\cos(v_i-v_j)$, $\sin(v_i+v_j)$, and $\sin(v_i-v_j)$ for i=1, .., M and j=1, .., M, where $i \neq j$; those for combinations of two input prices, $\cos(u_m-u_n)$ and $\sin(u_m-u_n)$ for m=1, .., N and n=1, .., N, where $n \neq m$; and those for combinations of one output and two input prices, $\cos(u_m-u_n+v_i)$, $\cos(u_m-u_n-v_i)$, $\sin(u_m-u_n+v_i)$, and $\sin(u_m-u_n-v_i)$ for m=1, .., N, n=1, .., N, and i=1, .., M, where $n \neq m$.

9) This paper used the Seemingly Unrelated Regression (SUR) method, which estimates the *FF* cost function and the share equation simultaneously to get efficient estimates.

industry, where these assumptions do not hold. Aware of this problem, Berger, Hanweck and Humphrey (1987) developed the expansion path scale economy and the expansion path scope economy. These measures, by allowing changes in both scale and output composition, are suitable for more general use. The following is a brief explanation of these 4 efficiency measures.

(i) Ray Scale Economy (RSE)

Developed by Baumol, Panzar and Willig (1982), the RSE is a measure of cost efficiency with respect to output expansion, assuming there are no changes in commodity composition. More specifically, the RSE measures the rate of increase in total costs when the scale of all the outputs increase at the same rate, holding the output bundle composition constant. It is defined as in equation (7).

$$RSE^{A} = \sum_{i} \partial \ln C(p, y^{A}) / \partial \ln y_{i} \, , \tag{7}$$

where the superscript A denotes an arbitrary bank A. This equation measures the elasticity of cost with respect to output at the mean output quantity and input prices. Returns to scale are increasing, constant, or decreasing as RSE is less than, equal to, or greater than one.

(ii) Expansion path scale economy ($EPSE^{AB}$)

To allow for the possibility of changes in commodity composition, Berger, Hanweck and Humphrey(1987) developed the EPSE to measure scale economies. Unlike the RSE, this measures the elasticity of incremental cost with respect to incremental output, holding relative prices constant but allowing changes in commodity composition. It is defined as follows:

$$EPSE^{AB} = \frac{\sum_{i} [(y_i^{B} - y_i^{A}) / y_i^{B}][\partial \ln C(p, y^{B}) / \partial \ln y_i]}{[C(p, y^{B}) - C(p, y^{A})] / C(p, y^{B})} \tag{8}$$

y_i^A and y_i^B denote the quantities of the ith output at banks A and B, respectively, and $C(p, y^A)$ and $C(p, y^B)$ represent the respective total costs.

The numerator is the percentage change in cost when each output changes in the same proportion as it does between bundles A and B. The denominator is the percentage difference in costs between banks A and B computed from the cost function. The EPSE measures how much faster costs rise compared to output as a small bank A increases its scale up to the level of a large bank B while changing its output composition. Like the RSE, returns to scale are increasing, constant, or decreasing as $EPSE^{AB}$ is less than, equal to, or greater than one.

(iii) Scope Economy (SCOPE)

Developed by Baumol, Panzar and Willig(1982) to measure scope economies, this index compares costs between cases where a bank produces several outputs jointly and cases where each bank specializes in the production of a single output. The index is calculated as in equation (9).

$$SCOPE=[C(p,y_1^d,y_2^m)+C(p,y_1^m,y_2^d)-C(p,y_1,y_2)]/C(p,y_1,y_2) \qquad (9)$$

In the above equation, y_i^m is the smallest sample value of *i*th output, and is defined implicitly as $y_i^d = y_i - y_i^m$.[10] The SCOPE index measures the cost savings when a bank produces several outputs jointly instead of producing a single output exclusively. A positive index value indicates that scope economies exist in the banking industry.

(iv) Expansion Path Subadditivity (EPSUB)

The EPSUB index was developed by Berger, Hanweck and Humphrey (1987) to address the problem of SCOPE indexes in estimating the smallest possible output. The EPSUB index compares production costs between a larger bank A, which produces several products jointly, and smaller bank B and a hypothetical bank D, whose sum of outputs is equal to the sum of bank A's outputs. Its formula is given by equation (10).

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10) Though y_i^m is theoretically defined to be zero, during the estimation of the cost functions, we put it at the least positive value for which we could take its logarithm.

$$EPSUB^A = [C(p, y^B) + C(p, y^D) - C(p, y^A)] / C(p, y^A) \quad (10)$$

Bank D's hypothetical output is defined as $y^D = y^A - y^B$. If the value of EPSUB is estimated to be positive, bank A is more efficient as a single unit than a combination of banks B and D. On the other hand, if EPSUB is negative, the cost function shows superadditivity, meaning bank A cannot survive in competition with banks B and D.

4. DATA AND EMPIRICAL RESULTS

4.1. Data

The data used in the estimation of the cost function of commercial banks were taken from detailed financial statements from banks, instead of the abbreviated versions released by the Financial Supervisory Service. For balance sheet items, yearly averages were used instead of year-end totals in order to avoid any distortions from sudden changes at the end of a year. In both balance sheets and profit-loss statements, the data covers both bank accounts and trust accounts.[11] We included trust accounts because both bank and trust businesses are carried out by the same staff and branch offices. Omission of the trust business, therefore, could have led to misleading results. In Korea, all the personnel and non-personnel expenses of a bank are reported on the profit/loss statements of the bank account. Therefore, omitting the trust business would have meant that expenses would have been disproportionately represented in calculating the efficiency of the banking industry. While other studies have taken trust accounts into consideration, they did not examine the financial statements of trust accounts, leaving room for error in analyzing the cost function. The period covered in our study was from 1987 to 1996.[12] Seven nationwide banks and ten regional banks

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[11] Data taken from financial statements included statistical information from both domestic and overseas operations of Korean banks.

[12] Although nation-wide commercial banks began dealing in trusts in 1984, this paper was

were included, all of which were in business during the entire sample period.

Unlike other industries, the definition of inputs and outputs is unclear in the banking industry. Different approaches can lead researchers to contrasting conclusions. Therefore, taking possible disparities in definitions of inputs and outputs into consideration, we defined inputs and outputs to conform with several standard approaches.

In the banking industry, the classification of inputs and outputs fall generally under two approaches: the intermediation approach and the production approach. The intermediation approach classifies capital, labor, borrowings and deposits as inputs, and loans and security investment as outputs. Some scholars regard the clearing services of demand deposits to be an output, rather than an input. On the other hand, the production approach defines inputs as capital, labor and borrowings, while deposits, loans, and securities are considered outputs.[13)]

We considered the following six input/output definitions, taking into account these two approaches and variations in the definitions of bank and trust account outputs. In Table 2, Model A and B follow the intermediation approach, Model C and D regard demand deposits as output, and Model E and F follow the production approach.

In Korea, demand deposits officially include checking, passbook, and temporary accounts. We included some savings deposits in the demand deposits category, including regular savings, preferential savings and company savings deposits, because these savings deposits do not impose on customers any restriction against transactions nor do they charge any transactions fee. Actually, there are few differences between these and passbook demand deposits in providing clearing services. Moreover, compared to other time deposits, interest rates of these savings deposits are very low. Therefore, customers generally regard these savings accounts as a medium of exchange for transferring funds and to for getting supportive approval services rather than sources of income from interest. Since they

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unable to obtain information before 1987, and was forced to research data from 1987 and onwards. The data from 1997 were also excluded because the severe banking crisis caused a major structural change in 1997.

13) In this paper, taking into account the procurement and reliability of the data, we used the amounts of funds instead of the number of accounts.

Table 2 Definition of Inputs and Outputs

Model	Input	Output
A	Labor, capital, purchased funds (borrowings+deposits)	Loans of bank a/c, loans of credit a/c, securities of both bank and credit a/c
B	Labor, capital, purchased funds (borrowings+deposits)	Loans of bank a/c, loans of credit a/c, securities of bank a/c, securities of credit a/c
C	Labor, capital, purchased funds (borrowings+deposits-demand deposits)	Loans of both bank and credit a/c, securities of both bank and credit a/c, demand deposits
D	Labor, capital, borrowings, deposits other than demand deposits	Loans of bank a/c, loans of credit a/c, securities of both bank and credit a/c, demand deposits
E	Labor, capital, borrowings	Loans of both bank and credit a/c, securities of both bank and credit a/c, deposits
F	Labor, capital, borrowings	Loans of bank a/c, loans of credit a/c, securities of both bank and credit a/c, deposits

provide clearing services, these demand deposits can be considered part of the output of banks.

To examine a bank's cost function, we need the input prices. First, labor prices were calculated by dividing total personnel expenses, including allowances for employee retirement benefits, by the number of employees. Capital prices were calculated by dividing sum of non-personnel expenses and depreciation allowances by the value of the bank's fixed assets. The prices so obtained show little difference from those reported in other studies. The prices of purchased funds, however, can vary depending on the researcher's approach. In the intermediation approach, interest payments on borrowings and deposits are considered a part of procurement costs, while in the production approach, only interest payments on borrowings are considered a part of procurement costs since deposits are considered an output. When demand deposits were classified as output, we deducted demand deposits from bank deposits in measuring inputs prices. Total costs for a bank, which is the dependent variable of cost functions, were calculated by adding up all of the costs for the procurement of inputs.

Note that in order to formulate FF cost functions with the variables shown above, the variables had to be scaled to make the prices of inputs and amounts of outputs have values greater than 0 and less than 2π. Following equation (2), we selected the scale factors and controlled the variable sizes as shown below.

$$w_{p_i} = 0.00001 - \ln p_i^{\min},$$

$$l = 6/\text{Max}_i[\ln p_i^{\max} + w_{p_i}],$$

$$w_{y_i} = 0.00001 - \ln y_i^{\min},$$

$$m_i = 6/[\ln y_i^{\max} + w_{y_i}]. \tag{11}$$

Here, $p_i^{\min}$ and $p_i^{\max}$ represent the minimum and maximum values, respectively, for the *i*th input price, and $\text{Max}_i[n_i]$ denotes the maximum value among n_i's for all i. $y_i^{\min}$ and $y_i^{\max}$ represent the minimum and the maximum values, respectively, for the *i*th output. The data were scaled to have a minimum value of 0.00001 and a maximum value of 6.0.

4.2. Estimation Results

Because estimation of the FF cost function[14] involves so many variables (113 or 147), presenting the estimated coefficients of the individual explanatory variables and their significance levels in a table is not very useful. Instead, considering the fact that the FF cost function is constructed by adding trigonometric terms to the traditional translog cost function, we examined whether trigonometric terms as a whole have additional explanatory power for each of the 6 models, A through F. In Table 3, we set the null hypothesis as "$d_k = g_k = 0$, for all $k = 1, .., K$", which was rejected at the 1% significance level in all of the models. This indicates that the addition of trigonometric terms to the translog function in the FF cost function results in a meaningful difference. This also implies that using the

[14] The panel nature is not sufficiently explored in the estimation. However, taking into account the differences in properties arising from different banks and different periods, 16 dummy variables for different banks and 9 dummy variables for different periods were included in equation (1) in the process of estimation.

Table 3 Significance of Trigonometric Terms

	Null hypothesis ($d_k = g_k = 0$, $\forall k$)		*K*
	F-value	p-value	
Model A	24.91	0.00	30
Model B	3.70	0.00	43
Model C	8.81	0.00	30
Model D	8.82	0.00	43
Model E	19.63	0.00	30
Model F	2.45	0.01	43

FF cost function to analyze economies of scale and scope will yield more reliable results than other approaches.

Table 4 shows the estimation results of the RSE, as defined in the previous chapter, to study the existence of a ray scale economy. The estimated FF cost function and the translog cost function for models A through F were compared. Because of the difficulties in presenting the estimated results for individual banks, the average values are presented for all banks, nationwide commercial banks and local banks. Since the estimated values of the RSE are much smaller than unity and the standard deviations are very small, the null hypothesis of RSE = 1 is rejected with a high level of significance. This indicates that on average Korean banks have economies of scale. Comparison of the estimated RSE for the nationwide commercial banks and the local banks showed that the former enjoy a greater degree of scale economies than the latter. This result is the exact opposite of what most studies had obtained when it comes to large banks. Our results show that a larger bank has more room for saving costs than a smaller one by expanding its scale.

The table also shows that the FF cost function generally produces smaller estimates of the RSE than the translog cost function. This means that the translog cost function may underestimate the economies of scale in the

Table 4 Estimation Results for RSE

Model	FF cost function			Translog cost function		
	All	Nationwide	Local	All	Nationwide	Local
A	0.714 (0.009)	0.644 (0.017)	0.763 (0.006)	0.835 (0.002)	0.808 (0.002)	0.854 (0.002)
B	0.729 (0.010)	0.704 (0.014)	0.746 (0.014)	0.756 (0.003)	0.720 (0.004)	0.782 (0.003)
C	0.817 (0.009)	0.779 (0.020)	0.844 (0.007)	0.928 (0.0005)	0.925 (0.0009)	0.930 (0.0005)
D	0.787 (0.011)	0.741 (0.020)	0.819 (0.009)	0.889 (0.002)	0.868 (0.004)	0.904 (0.002)
E	0.716 (0.014)	0.677 (0.027)	0.743 (0.016)	1.111 (0.003)	1.070 (0.003)	1.139 (0.003)
F	0.799 (0.015)	0.761 (0.031)	0.826 (0.014)	0.982 (0.008)	0.900 (0.008)	1.039 (0.007)

Note: Numbers in parentheses are standard errors of estimates.

banking industry, considering that the FF functional form can estimate cost functions with greater accuracy than the translog function. In the case of models E and F, both of which take the production approach, the estimated FF cost functions indicate that there are economies of scale, while the translog cost functions indicate the opposite. Thus, judging whether economies of scale exist in the banking industry can be greatly affected by several factors, including the definition of inputs and outputs and the cost function specifications used. It is possible that this results from the specification error in using the translog cost function, which by definition is restricted to have a U shaped second-order function.

Table 5 shows the estimation results for the Expansion Path Scale Economy (EPSE) index. As in Table 4, the table shows the outcomes for FF and translog cost functions applied to models A through F. The EPSE has an advantage over the RSE in that it allows for the possibility of a change in the composition of output while RSE assumes the same output composition. The following 3 different cases were considered: (i) expanding scale from a local bank to a nationwide bank, (ii) expanding scale from the smallest nationwide bank to a larger nationwide bank, and (iii) expanding scale from a small local bank to a larger local bank. Two banks were chosen from as

Table 5 Estimation Results for EPSE

Model	FF cost function			Translog cost function		
	All	Nationwide	Local	All	Nationwide	Local
A	0.642 (0.009)	0.617 (0.019)	0.736 (0.016)	0.839 (0.005)	0.779 (0.003)	0.853 (0.007)
B	0.700 (0.010)	0.692 (0.015)	0.723 (0.051)	0.747 (0.005)	0.686 (0.003)	0.809 (0.010)
C	0.699 (0.011)	0.746 (0.021)	0.865 (0.007)	0.938 (0.017)	0.909 (0.001)	0.916 (0.006)
D	0.663 (0.007)	0.705 (0.018)	0.833 (0.022)	0.874 (0.001)	0.865 (0.003)	0.900 (0.009)
E	0.687 (0.010)	0.641 (0.031)	0.773 (0.011)	1.092 (0.005)	1.009 (0.003)	1.053 (0.006)
F	0.787 (0.030)	0.758 (0.034)	0.805 (0.015)	0.912 (0.005)	0.852 (0.007)	1.037 (0.017)

Note: Numbers in parentheses are standard errors of estimates.

wide a pool of data as possible in each case. Due to limits in space, however, in the table we show only whether or not economy of scale exists on average.

The estimated EPSEs lead to a similar conclusion about the presence of economies of scale in the Korean banking industry as the RSE, with only relatively minor differences in absolute values. Since the estimated values of EPSE are less than one in most of the models, this indicates that, overall, economies of scale exist in the Korean banking industry. Although an absolute comparison is difficult to make, the estimated values of the EPSE in general indicate greater economies of scale than the RSE. The reason for this might be that EPSE reflects changes in output composition in the process of bank expansion, which can bring about additional cost savings. The estimated EPSEs also show that using the FF cost function leads to greater estimated economies of scale than with the translog cost function. They also indicate that nationwide banks have greater economies of scale than local banks. However, the estimated translog cost functions in models E and F indicate decreasing returns to scale.

Table 6 presents a summary of our analysis of economies of scope, in which we used the common definition of the concept. As previously, the FF cost function and the translog cost function were both used in the 6 models, and we report results for nationwide commercial banks and local banks both separately and together. As a whole, contradictory results were found across the models and functional forms, and low significance levels were obtained for many cases. The translog cost function specification yielded results indicating economies of scope for models E and F, but for models A through D, which follow the intermediation approach, the empirical result indicates diseconomies of scope. In contrast, the FF cost function yielded more uniform results that indicate the possible presence of economies of scope, with positive values for SCOPE in all models except for F. However, with only a few exceptions the null hypothesis could not be rejected at the 5% significance level that economies of scope do not exist. The estimated values and their standard errors are very high. At least in part, the explanation is that there is a strong correlation between different outputs and that there are no Korean banks specializing in a single output. Therefore, it is difficult to reach a conclusive result regarding economies of scope in the Korean banking industry.

Table 6 Estimation Results for Economy of Scope

Model	FF cost function			Translog cost function		
	All	Nationwide	Local	All	Nationwide	Local
A	4.27e+11 (2.20e+11)	1.04e+12 (0.52e+12)	4.75e+4 (3.04e+4)	-0.225 (0.028)	-0.462 (0.016)	-0.059 (0.038)
B	7.31e+8 (3.40e+8)	1.77e+9 (0.81e+9)	1.87e+3 (1.13e+3)	-0.115 (0.049)	-0.578 (0.031)	0.209 (0.063)
C	4.33e+12 (2.29e+12)	1.05e+13 (0.55e+13)	2.14e+5 (1.40e+5)	-0.323 (0.031)	-0.590 (0.020)	-0.136 (0.042)
D	2.21e+8 (1.29e+8)	5.36e+8 (3.10e+8)	6.24e+1 (2.86e+1)	-0.272 (0.045)	-0.649 (0.027)	-0.008 (0.062)
E	2.31e+159 (NA)	5.61e+159 (NA)	9.16e+70 (9.11e+70)	6.71e+3 (1.62e+3)	1.63e+4 (0.36e+4)	2.45e+1 (0.72e+1)
F	-0.571 (0.063)	-0.961 (0.022)	-0.299 (0.098)	1.17e+2 (0.35e+2)	2.81e+2 (0.81e+2)	2.058 (0.562)

Note: Numbers in parentheses are standard errors of estimates.

Lastly, Table 7 shows the estimation results of expansion path subadditivity as suggested by Berger, Henweck and Humphrey (1987). Expansion path subadditivity for a specific bank indicates whether it is competitively viable. As in our earlier analyses, both the FF cost function and the translog cost function were used on the 6 models. The process of selecting 2 banks for comparison was similar to that of the case for EPSE. We considered the following 3 scenarios: (i) choosing a nationwide commercial bank and a local bank out of all the banks, (ii) choosing a smallest one and one of the others out of nationwide commercial banks, and (iii) choosing a smallest one and one of the others out of local banks. The results showed mostly positive values for expansion path subadditivity. The FF cost function always yielded positive values, while the translog cost function yielded positive values for 13 out of 18 results. This implies that keeping a single bank that provides multi-products is more profitable than splitting it into two separate specialized entities, i.e., that economies of scope do exist in the Korean banking industry to a certain extent. Another

Table 7 Estimation Results for Expansion Path Subadditivity

Model	FF cost function			Translog cost function		
	All	Nationwide	Local	All	Nationwide	Local
A	0.061 (0.002)	0.057 (0.006)	0.016 (0.018)	0.040 (0.001)	0.008 (0.003)	0.048 (0.008)
B	0.047 (0.003)	0.170 (0.098)	0.064 (0.021)	0.054 (0.001)	0.025 (0.004)	0.072 (0.009)
C	0.029 (0.002)	0.023 (0.007)	0.045 (0.010)	0.002 (2.92e-4)	-0.004 (0.001)	0.022 (0.007)
D	0.033 (0.002)	0.051 (0.006)	0.029 (0.019)	0.007 (0.000)	0.011 (0.003)	0.016 (0.009)
E	0.052 (0.003)	0.046 (0.007)	0.079 (0.014)	0.002 (7.70e-4)	-0.052 (0.002)	-0.063 (0.007)
F	0.053 (0.003)	0.061 (0.011)	0.018 (0.018)	0.030 (0.001)	-0.002 (0.004)	-0.016 (0.008)

Note: Numbers in parentheses are standard errors of estimates.

implication is that mergers between banks will save costs.[15)]

5. CONCLUSION

Active research has been going on to see whether the recent expansion through mergers and business diversification in the Korean banking industry is indeed efficient. This paper approaches this question by analyzing both economies of scale and scope. The FF cost function, which is globally flexible, was used to estimate several efficiency measures and the results were compared with results from the translog cost function specification, which has been widely used in previous studies. Bearing in mind that the results in the case of the Korean banking industry could vary widely depending on the data, data were collected with great care. Balance sheets and profit/loss statements not only from bank accounts but also from trust accounts were examined, in order to improve accuracy in assessing the efficiency of the Korean banking industry. In addition, taking differences in the definition of inputs and outputs into consideration, 6 different hypothetical models were used and compared.

The findings of this paper are as follows. First, our results show that different data and models can lead to considerable differences. The definition of inputs and outputs, data sources and models can all lead to very different conclusions. Second, inclusion of the trigonometric terms that represent the Fourier series in the FF cost function made a significant difference, justifying the FF cost function specification. Third, the results showed that there are economies of scale in the Korean banking industry, with larger banks in general being more likely to have a higher scale efficiency than smaller ones. Fourth, the existence of economies of scope was somewhat inconclusive, as we obtained varying results from different models, but it appears that business diversification contributed to cost

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15) However, in reality the effect of merging on efficiency can vary depending on not only the (non) existence of an economy of scope, but also on several factors such as managerial strategies after a merge, changes in the composition of assets and liabilities, reorganization of manpower and branches, changes in the marketing power and credibility from outside which are difficult to analyze empirically.

reduction.

Future research topics that would extend upon our results include using the profit function to estimate efficiency measures in the Korean banking industry and a comparison of efficiency with other, non-bank financial industries.

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