STUDIA UBB, OECONOMICA, VOLUME 58, ISSUE 3, 2013

TECHNICAL EFFICIENCY OF SOUTH AFRICAN BANKS IN GENERATING INTEREST AND NONINTEREST INCOME: A STOCHASTIC FRONTIER ANALYSIS

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Abstract. This study applies stochastic frontier analysis to estimate the technical efficiencies of the four largest banks in South Africa, for the period 1994 to 2010, with regard to their generation of interest income and noninterest income. Interest income and noninterest income of the banks are investigated separately using a stochastic frontier production function model. A stochastic frontier output-orientated distance function is also estimated in order to investigate the changes in interest and noninterest income for the banks. Using the stochastic production frontier model, it is found that deposits do not have any significant influence on the levels of interest and noninterest incomes of these banks. The inefficiency effects for the generation of interest income were found to significantly decline for larger values of loans and investments and interest costs, but increased with increasing values of financial capital and also increased over time. Using an alternative approach involving an output distance function for the two income variables, we find that deposits have a significant effect on the explanation of the interest and noninterest incomes and that inefficiency effects are still significant in explaining the generation of these incomes.

JEL classification: C50, G21, L21

Keywords: Technical efficiency, Stochastic Frontier Analysis, Production function, Bank inputs/outputs, Output distance function, South African banks.

1. Introduction

Banks are in the business of buying and selling money and simultaneously render financial services to customers. This means that in the economy banks buy money from surplus economic units (borrowing activity) and sell money to deficit

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Note: A first version of this paper was presented at the Conference in Memory of Lennart Hjalmarsson, 7-8 December, 2012, School of Business, Economics and Law, University of Gothenburg.

economic units (lending activity), while customers can utilise various services like the deposit function, collection function, payment function, insurance, etc. Banks exist because of the conflict between the requirements of lenders and borrowers with regard to risk, return and term to maturity. In the process of intermediating between surplus and deficit economic units, banks face various types of risk. These risks include, inter alia, risks such as credit risk, liquidity risk, and interest rate risk. Banks have to manage these risks and by doing that, bank management attempts to maximise profits. In order to maximise profits, banks must decide on how much risk the bank is willing to be exposed to, because there is an inverse relationship between risk and reward. However, greater risk manifests itself in greater volatility of net income and the market value of a bank's stockholders' equity.

A fundamental risk faced by all banks is the interest rate risk, and this risk is managed by a bank's asset and liability management committee (Koch and MacDonald, 2003). In a changing economic environment, this committee recommends pricing, investment, funding and marketing strategies to achieve the desired trade-off between risk and expected return (Falkena*,* Kok and Meijer 1987). The lending activity generates interest income for the bank, while the borrowing activity results in the bank having to pay interest to the surplus economic units. The difference between the interest received (generated by the lending rate) and the interest paid (generated by the borrowing rate) is the net interest income the bank receives from being involved in lending and borrowing activities.

Interest income is an important source of income for South African banks, although there is a noticeable change in the composition of bank income over the past decade. South African banks are experiencing pressure from foreign banks and non-bank financial institutions. These non-bank financial institutions render credit services that are not available at traditional banks. There have also been a number of changes in the regulatory environment, product offerings, and the number of participants which have resulted in a greater level of competition in the market from smaller banks, such as Capitec Bank and African Bank. These two banks have targeted the low-income and the previously unbanked market. These developments forced traditional banks to introduce new banking products and services, and as these services are paid for, it led to an increase in noninterest income. Two broad categories of income constitute the income (receipts) of a bank, namely interest income and noninterest income. The question now is to what extent did this change in the composition of bank income, affected the technical efficiency of South African banks in generating interest income and noninterest income.

Over the last three decades, a large number of studies on bank productivity and efficiency have applied quantitative techniques like data envelopment analysis (DEA) and stochastic frontier analysis (SFA), to estimate different types of efficiencies. DEA estimates the frontier by finding a set of linear segments that envelop the observed data, combining all the input and output data on sample firms into a single measure of productive efficiency. SFA involves specifying a functional form for the frontier and then estimating its parameters using econometric techniques. Some other studies applied the DEA-type Malmquist total factor productivity to examine productivity growth and the contributors to productivity change.

These performance studies were at both the firm/corporate level (e.g*.,* Drake, 2001; Seiford and Zhu, 1999; Devaney and Weber, 2000; Berger and Humphrey, 1997; Halkos and Salamouris, 2004; Mendes and Rebelo, 1999; Luo, 2003; Resti, 1997; Kwan, 2006; van der Westhuizen, 2008; van der Westhuizen and Oberholzer, 2009; Matthews and Zhang, 2010; Fung and Cheng, 2010; Manlagñit, 2011;

Chang et al., 2012) and at the branch level (e.g., Sherman and Ladino, 1995; Sherman and Gold, 1985; Vassiloglou and Giokas, 1990; Oral and Yolalan, 1990; O'Donnell and van der Westhuizen, 2002; van der Westhuizen and Oberholzer, 2003; Oberholzer and van der Westhuizen, 2004; van der Westhuizen, 2012).

This study applies SFA models to estimate the technical efficiencies of the four largest banks in South Africa, with regard to the generation of interest income and noninterest income. This is the first study to apply SFA to estimate technical efficiencies of South African banks at the corporate level. A similar study by Van der Westhuizen (2010) applied DEA to estimate the efficiency of thirty seven regions of a large South African bank. The remainder of this paper is structured as follows: in Section 2, the South African banking sector is briefly discussed. The empirical models for investigating banking efficiency are discussed in Section 3, together with the SFA model that is applied in this paper. In Section 4 the data are discussed, followed by the presentation of empirical results in Section 5. The results of the paper are discussed and summarised in Section 6.

2. The South African Banking Sector

The South African financial sector is dominated by the four banks, Amalgamated Banks of South Africa (ABSA), First National Bank, Nedbank and Standard Bank. According to the BA 900 reports (Department of Bank Supervision, 2011), these four banks control over 84% of total deposits and assets in South Africa.

Over the last decade, South African banks saw the first substantial rewrite of the Banks' Act and Regulations since 1990, following the adoption of the international guidelines, called Basel II, which took effect on 1st January, 2008 (Booysen, 2008). Banks also saw the introduction of the National Credit Act, as well as the Financial Sector Charter. All these changes had the effect that banks experienced pressure on their lending activities and, thus, on their profitability. By the end of 2010, the South African banking industry was made up of 19 registered banks, two mutual banks, 13 local branches of foreign banks, and 43 foreign banks with approved local representative offices (Department of Bank Supervision, 2010).

All four banks included in this study experienced considerable changes during the years, 1994 to 2010, for which we have data for our empirical analysis. The South African banks are under pressure to maintain their revenues in the competitive environment in which they operate. The banks make a significant amount of their incomes from noninterest income which is the bulk of the unsecured lending market. The current environment favours higher fees and commissions from these sources, especially when the interest rates are low, which puts pressure on their margins, when they are faced with increased costs for funding, bad debts increasing and high operational costs.

3. Empirical Models for Banking Efficiency

Because of the multiproduct nature of banks, there is no general agreement on defining bank inputs and outputs. Favero and Papi (1995) identify five approaches to input and output specifications, namely, the production approach, the intermediation approach, the asset approach, the user-cost approach and the value-added approach.

The production approach considers banks to be producers of loans and deposit accounts and measures output in terms of the number of loans and accounts produced and/or serviced (Cronje, 2002). According to Matthews and Zhang (2010) the production approach recognises that banks provide intermediation services and payments to depositors. According to Berger, Hanweck and Humphrey (1987), under the production approach, banks produce accounts of various sizes by processing deposits and loans, which incur capital and labour costs. Under this approach, operating costs are specified as inputs and the number of accounts is used as the output metric, while average account sizes are specified to control for other account characteristics.

Sealey and Lindley (1977) first identified the intermediation approach and stated that the main function of a bank is to conduct financial intermediation. In this approach, the bank's assets measure outputs and liabilities measure inputs (Matthews and Zhang, 2010). Cronje (2002) indicated that this approach views the activities of banks as borrowing funds from depositors and lending the funds to borrowers for profit. From this point of view, the banks' outputs comprise loans (indicated in monetary terms), and inputs comprise the various costs of these funds (e.g., interest expenses, labour, capital and operational costs).

According to Berger and Humphrey (1997), the asset, the user-cost, and the value-added approaches of assigning goods to input-and-output categories all agree that loans and other major assets of financial institutions should count as outputs. The asset approach is a variant of the intermediation approach and focuses on recent developments in the theory of intermediation. Outputs are strictly defined by assets and mainly by the production of loans, in which banks have advantages over other financial institutions (Favero and Papi, 1995). According to this approach, banks produce various loans and other investments as outputs from deposits, other funding sources, labour and materials (Cronje, 2002).

Favero and Papi (1995) state that the user-cost and the value-added approaches are not related to the macro-economic functions carried out by banks. Under the user-cost approach, the net contribution to bank revenue determines the nature of inputs and outputs (Cronje, 2002). Under the value-added approach, the identification of inputs or outputs is based on the share of value added. Items of the balance sheet with a substantial share of value added are considered as important outputs (Favero and Papi, 1995).

Resti (1997) indicates that a pivotal issue throughout the literature that is based on stock measures of banking products is the role of deposits. On the one hand, it is argued that they are an input in the production of loans (intermediation or asset approaches). Yet, other lines of reasoning (value-added or user-cost approaches) suggest that deposits themselves are an output, involving the creation of value added, for which the customers bear an opportunity-cost. According to Berger and Humphrey (1997), deposits have input characteristics because they are paid for in part by interest payments and the funds raised provide the institution with the raw material of investible finds. However, deposits also have output characteristics because they are associated with a substantial amount of liquidity, safekeeping, and payment services to depositors.

In this study, a variant of the intermediation approach is adopted and we initially specify a stochastic frontier production function model for the two individual output variables, interest income and noninterest income of the banks. The inputs for the analysis of both types of incomes are labour, capital, operating costs, and deposits. Other variables included in our empirical analysis to explain the inefficiency of the generation of the interest and noninterest incomes of the banks are loans and investments (hereafter, loans & investments), interest expenses and financial capital.

We apply the SFA model, proposed by Battese and Coelli (1995), in which production functions for interest and noninterest incomes are specified by the translog functional form with random errors and nonnegative inefficiency effects, the latter being specified in terms of other observable variables that possibly influence the inefficiency of generation of the two sources of bank incomes.
The model for *interest income* is defined by:

$$Y_{1it} = \beta_0 + \sum_{j=1}^{4} \beta_j X_{jit} + 0.5 \sum_{j=1}^{4} \sum_{k=1}^{4} \beta_{jk} X_{jit} X_{kit} + \beta_5 t + V_{it} - U_{it} \quad (1)$$

where Y_{1it} denotes the logarithm of *interest income* for the i^{th} bank (i=1,2,3,4) in year t (t=1,2, …, 17 for 1994, 1995, …, 2010, respectively)[1];

X_1 denotes the logarithm of *labour costs*;

X_2 denotes the logarithm of *capital costs* (land, buildings and other fixed assets);

X_3 denotes the logarithm of *operating costs*; and

X_4 denotes the logarithm of *deposits*;

The random errors (the $V_{it}s$) and the technical inefficiency effects (the $U_{it}s$) in the production function of equation (1) are assumed to be independently distributed for different banks and years, such that the $U_{it}s$ are independently distributed nonnegative random variables that are obtained by truncation (at zero) of normal distributions with respective means defined by

$$\mu_{it} = \delta_0 + \sum_{j=1}^{3} \delta_j Z_{jit} + \delta_4 t + \sum_{j=1}^{3} \delta_{0j} D_{jit} \quad (2)$$

where Z_1 denotes the logarithm of *loans & investments*;

Z_2 denotes the logarithm of *interest costs*;

Z_3 denotes the logarithm of *financial capital* (ordinary shareholders' interest); and

D_j denotes the dummy variable for the j^{th} bank (j=1,2,3) that has value one if the observation is for the j^{th} bank and zero otherwise.

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[1] Hereafter, the subscripts, *i* and *t*, are not included on all variables for simplicity of presentation.

We note that the translog production function for interest income in equation (1) accounts for neutral technical change in the generation of interest income over the years observed and the inefficiency model of equation (2) specifies that the inefficiency effects for the four banks may have different means and they may change over time. We do not account for non-neutral technical change in the production function nor do we consider that the Z-variables (loans & investments, interest income, and financial capital) may affect the inefficiency effects of the banks differently in their operations of generating interest income.

The model for *noninterest income* of the banks is assumed to be the same functional form as for interest income defined above. For noninterest income, the model is defined in terms of the logarithm of noninterest income, represented by Y_2 below.

We also consider the alternative approach of the output distance function for investigating the generation of the two sources of incomes for the banks. The translog *output-orientated distance function* for the case of M outputs and K inputs (see Coelli and Perelman, 1999. p. 130) is specified as

$$\ln D_{Oi} = \alpha_0 + \sum_{m=1}^{M} \alpha_m \ln Y_{mi} + 0.5 \sum_{m=1}^{M} \sum_{n=1}^{M} \alpha_{mn} \ln Y_{mi} \ln Y_{ni}$$
$$+ \sum_{k=1}^{K} \beta_k \ln X_{ki} + 0.5 \sum_{k=1}^{K} \sum_{l=1}^{K} \beta_{kl} \ln X_{ki} \ln X_{li} + \sum_{k=1}^{K} \sum_{m=1}^{M} \delta_{km} \ln X_{ki} \ln Y_{mi} \qquad (3)$$

where D_{Oit} is defined as the output distance for the i^th^ firm (the smallest scalar by which outputs can be divided and the resulting outputs remain in the production set).

The restrictions required for the distance function to be homogeneous of degree one in outputs are defined by:

$$\sum_{m=1}^{M} \alpha_m = 1; \ \sum_{n=1}^{M} \alpha_{mn} = 0, \ m = 1, 2, ..., M; \ \sum_{m=1}^{M} \delta_{km} = 0., \ k = 1, 2, ..., K.$$

Using the symmetry restrictions, $\alpha_{mn} = \alpha_{nm}$, $\beta_{kl} = \beta_{lk}$, and the fact that the number of outputs in our model is M=2 and the number of inputs is K=4, the model to be estimated can be shown to be expressed by

$$\ln D_{Oi} - Y_{2i} = \alpha_0 + \alpha_1 Y_{1i}^* + 0.5\alpha_{11} (Y_{1i}^*)^2 + \sum_{k=1}^{4} \beta_k X_{ki} + 0.5 \sum_{k=1}^{4} \sum_{l=1}^{4} \beta_{kl} X_{ki} X_{li} + \sum_{k=1}^{4} \delta_{k1} X_{ki} Y_{1i}^*$$

where $Y_{1i}^* = Y_{1i} - Y_{2i}$.[2]

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[2] Note that in the expressions after equation (3), and hereafter, the *X*- and *Y*-variables are defined in log terms, as in equations (1) and (2). However, equation (3) uses the notation of Coelli and Perelman (1999).

Introducing random errors in the translog output distance function, re-expressing terms and accounting for our case of having panel data, the model to be estimated is expressed by

$$-Y_{2it} = \alpha_0 + \alpha_1 Y_{1it}^* + 0.5\alpha_{11}(Y_{1it}^*)^2 + \sum_{k=1}^{4}\beta_k X_{ki} + 0.5\sum_{k=1}^{4}\sum_{l=1}^{4}\beta_{kl} X_{kit} X_{lit} + \sum_{k=1}^{4}\delta_{k1} X_{kit} Y_{1it}^* + V_{it} + U_{it} \quad (4)$$

where $U_{it} = -\ln D_{Oit}$ is a non-negative random variable associated with inefficiency of production and the V_{it} s are random errors that account for departure of the observations from the deterministic translog output distance function on the right-hand side of equation (4). The random errors are assumed to be independent and identically distributed normal with mean zero and constant variance, σ_V^2. These inefficiency effects are assumed to have the same distributional properties as those in the model of equations (1) and (2).

We test several null hypotheses of interest in our models using the generalized likelihood ratio statistic, defined by

$$\lambda = -2\{\ln[L(H_0)/L(H_1)]\} \quad (5)$$

where $L(H_0)$ is the value of the likelihood function under the restrictions of the null hypothesis, H_0, being tested; and $L(H_1)$ is the value of the likelihood function for the SFA model of equations (1) and (2) (see Coelli, 1995). Under H_0, the test statistic, λ, is asymptotically distributed as a central or non-central Chi-square with parameter equal to the difference between the numbers of parameters estimated under H_1 and H_0.

Interest income and noninterest income are the main income for banks and are therefore regarded as outputs in the production process. Interest income and noninterest income were specified as outputs in the models by inter alia, Charnes et al. (1990), Chen (1998), Howcroft and Ataullah (2006) and Matthews and Zhang (2010).

Labour and capital in some variant are applied as inputs in the production process. The user cost of capital can be used as capital input. These are the inputs that are needed in many production processes and were specified as inputs in the models by, inter alia, Sherman and Gold (1985), Elyasiani and Mehdian (1990, 1992), Berger and Humphrey (1991), English et al. (1993), Kaparakis, Miller and Noulas (1994), Favero and Papi (1995), Chen (1998), Stavarek (2002), Weill (2003), Casu and Girardone (2004), and Lin, Hu and Sung (2005), and Manlagñit (2011).

Operating expenditure, excluding labour costs, was specified as an input in the models by, inter alia, Charnes et al. (1990), Chen (1998), Stavarek (2002), Weill (2003), Howcroft and Ataullah (2006), Fung and Cheng (2010) and Matthews and Zhang (2010). Operating expenditure is an important item in the income statement of banks, being of the same magnitude as labour cost.

Deposits are regarded by some researchers as an input in the production process, while other researchers regard deposits as an output. In the intermediation process, deposits are used for lending purposes and was specified as one of the inputs in the models by, inter alia, Elyasiani and Mehdian (1990, 1992), English et al. (1993), Kaparakis, Miller and Noulas (1994), Chen (1998), Casu and Girardone (2004), and Lin, Hu and Sung (2005).

4. Data on South African Banks

Financial data on the four largest South African banks were obtained for the years 1994 to 2010 from the McGregor (2012) BFA database of listed companies' financial statements. The aggregate descriptive statistics for these data are presented in Table 1 for variables in original units, not in the logarithmic forms of the variables in the SFA model of equations (1) and (2).

It is evident that these variables show considerable variation over the 17 years for the four banks. A graph of the interest income and the noninterest income values for the four banks are given in Figures 1 and 2, respectively.

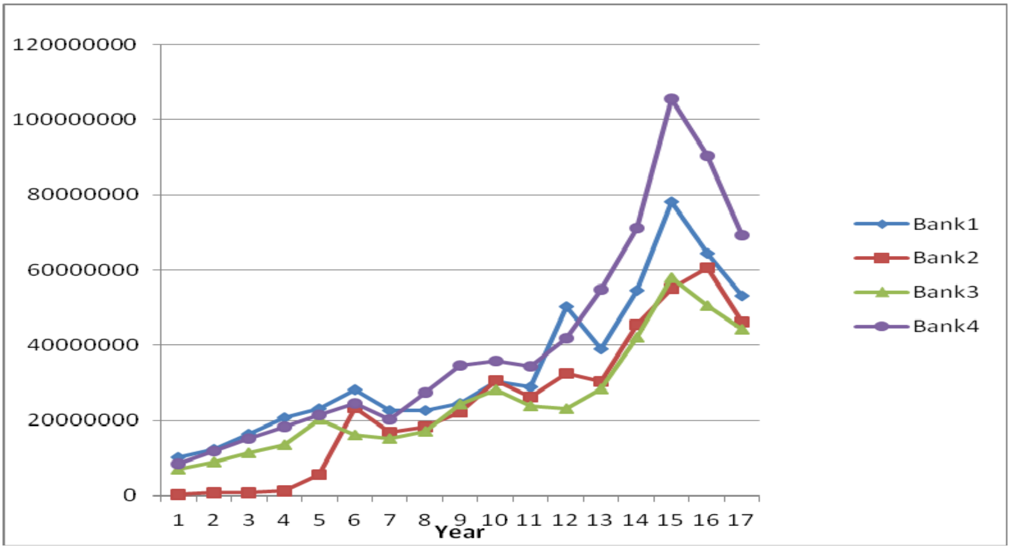
Table 1: Descriptive statistics for variables
for the four largest South African banks (R1,000)

Variable	Mean	Std dev	Minimum	Maximum
Interest income	31,087,070	21,660,533	374,250	105,589,000
Noninterest income	9,859,125	7,647,541	1,370,000	31,756,000
Labour costs	6,245,776	4,430,003	1,242,000	19,542,000
Capital costs	10,082,539	8,789,233	1,231,680	45,659,000
Operating costs	5,439,322	4,075,651	759,871	18,093,000
Deposits	256,443,356	193,776,375	3,567,576	843,815,000
Loans & investments	246,892,110	197,473,065	9,475,000	710,523,000
Interest costs	16,269,254	10,519,085	6,360	54,983,000
Financial capital	5,439,322	4,075,651	759,871	18,093,000

Source: Own calculation

Table 1 indicates that interest income is the dominant form of bank income relative to noninterest income, the latter being about one-quarter of the total of the two incomes. Of the first three input variables in our production function, on average, capital expenditures are the greatest, followed by labour expenses and operating costs, in order of magnitude. The size of deposits and loans & investments are of similar magnitude, as is seen from the averages and the standard deviations of these variables.

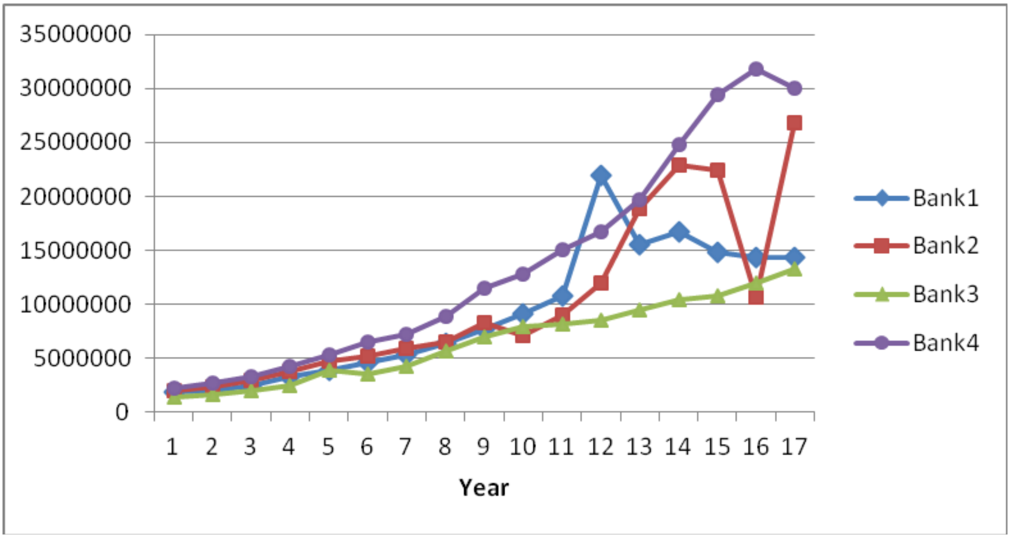
Figure 1: Interest Income of the Four South African Banks during 1994 to 2010 (Years 1 to 17).



Source: Own projection

The graphs of Figures 1 and 2 clearly indicate that the variability in the values of both types of bank incomes increased in amplitude over the years of the study, but especially in the last half of the sample period.

Figure 2: Noninterest Income of the Four South African Banks during 1994 to 2010 (Years 1 to 17).



Source: Own projection

5. Empirical Analysis

5.1: SFA Models for Interest and Noninterest Incomes

5.1.1 Tests of Hypotheses

We estimated the translog SFA model, defined by equations (1) and (2), together with various sub-models of interest for both interest and noninterest incomes of the banks. The empirical results were generated using mean-corrected data for the input variables so that the first-order coefficients of the input variables for the translog model can be interpreted as elasticities of the inputs at mean input levels. Before considering the empirical estimates obtained for the SFA models, we consider some tests of hypotheses about whether simpler models are adequate representations of the data, given the translog SFA production frontier model involved. These tests of hypotheses are presented in Table 2, together with the values of the loglikelihood function (LLF) for each SFA model that is estimated to obtain the values of the test statistic for testing the null hypotheses involved.

Table 2: Tests of hypotheses for SFA models for interest and noninterest incomes of the banks

Null Hypothesis	LLF	Test Statistic, λ	Critical Value[3]	Decision
Interest Income	45.6759			
H_0:$\gamma=\delta_0=\delta_1=\ldots=\delta_{03}=0$	32.4766	26.399	16.274	Reject H_0
H_0: $\beta_{jk}=0$, j, k=1,2,3,4	26.9263	37.499	18.307	Reject H_0
H_0: $\beta_4=\beta_{4kj}=0$, k=1,2,3,4	41.8103	7.731	11.071	Accept H_0
H_0: $\delta_1=\delta_2=\delta_3=0$	11.1665	61.288	15.507	Reject H_0
Noninterest Income	83.8484			
H_0:$\gamma=\delta_0=\delta_1=\ldots=\delta_{03}=0$	47.3905	72.916	16.274	Reject H_0
H_0: $\beta_{jk}=0$, j,k=1,2,3,4	50.4289	66.839	18.307	Reject H_0
H_0: $\beta_4=\beta_{4k}=0$, k=1,2,3,4	80.1925	7.448	11.071	Accept H_0
H_0: $\delta_1=\delta_2=\delta_3=0$	74.3230	11.739[4]	15.507	Accept H_0

Source: Own calculation

The first null hypothesis considered is that the inefficiency effects are not present. This hypothesis is strongly rejected for both interest income and noninterest income so that we conclude that ignoring the presence of inefficiency effects is not satisfactory for describing the relationship between the two sources of bank income

[3] All critical values given are the upper 5% points for the appropriate Chi-square distributions. The first is obtained from Table 1 of Kodde and Palm (1986) because the non-central Chi-square distribution is involved.

[4] This test statistic is obtained by comparing the TL3 model without the three Z-variables with the TL3 model with the Z-variables included. If the TL3 model without the three Z-variables is compared with the TL4 model with the Z-variables included, the test statistic is 19.051, which is also not significant at the 5% level.

and the various levels of input variables for the South African banks, given the specifications of the translog SFA model of equations (1) and (2).

The second null hypothesis considered in Table 2 is that the second-order coefficients of the translog production function for the income variables are all zero and so the Cobb-Douglas model would be an adequate representation of the data. This hypothesis is again strongly rejected for both interest income and noninterest income for the South African banks.

The third null hypothesis considered in Table 2 is that deposits do not have any significant effect on the levels of interest income and noninterest income of the four banks. This is specified in terms of the coefficients of the translog model of equation (1) having zero coefficients associated with the deposit input, X_4, namely, $\beta_4=\beta_{4k}=0$, k=1,2,3,4. For both interest income and noninterest income of the banks, this null hypothesis is accepted. The fact that deposits do not have a significant influence on both interest income and noninterest income of the banks is an important result that is discussed in more length in Section 6.

The fourth null hypothesis involved in Table 2 is that the coefficients of the three Z-variables in the inefficiency effects model of equation (2) for the translog production function (*with the three input variables, excluding deposits)* are simultaneously zero (H_0: $\delta_1=\delta_2=\delta_3=0$). This null hypothesis is rejected for interest income but accepted for noninterest income for the banks. The finding that loans & investments, interest costs and financial capital significantly affect the inefficiency of generation of interest income only is perhaps not surprising.

5.1.2 Estimated SFA Frontiers

The maximum-likelihood estimates for the first-order parameters of the production functions of the preferred SFA models for interest and noninterest incomes, together with the coefficients of the inefficiency model are presented in Table 3 for interest and noninterest incomes.[5] These estimates are obtained by using the FRONTIER 4.1 program, developed by Coelli (1992, 1996).

For interest income, the SFA model we prefer is the translog model without deposits but with all three inefficiency variables, together with the dummy variables to account for different mean inefficiencies for the four banks. This model for interest income also accounts for neutral technical change and technical inefficiency change over the years observed. This model for interest income has elasticity of labour of 0.57 at mean input levels but the elasticity of capital is estimated to be negative, but not significantly different from zero. There was significant technical progress for interest income for the banks over the 17 years of the study period.

The inefficiency effects in the generation of interest income are estimated to decrease as loans & investments and interest costs increase but to decrease as financial capital increases. The inefficiency effects tended to increase over the years of the study period, as shown by the positive estimate for the coefficient of year of observation. The inefficiency effects for interest income were significantly

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[5] The estimates of the second-order coefficients of the translog SFA models are not given for brevity of presentation.

different for the four banks in the study, as expected. The γ-parameter, associated with the presence of inefficiencies in generating interest income, was highly significant.

Table 3: Maximum-likelihood estimates for the preferred SFA models for interest and noninterest incomes[6]

Variable	*Parameter*	*Interest Income*	*Noninterest Income*
Production function			
Labour	β_1	0.57 (0.24)	0.66 (0.21)
Capital costs	β_2	-0.090 (0.087)	-0.103 (0.052)
Operating Costs	β_3	0.14 (0.15)	-0.02 (0.17)
Deposits	β_4	0	0
Year	β_5	0.054 (0.020)	0.1039 (0.0071)
Inefficiency Model			
Constant	δ_0	5.6 (1.2)	-0.84 (0.15)
Loans & Investments	δ_1	-0.162 (0.069)	0
Interest Costs	δ_2	-0.434 (0.039)	0
Financial Capital	δ_3	0.24 (0.12)	0
Year	δ_4	0.061 (0.019)	0.059 (0.010)
Dummy for Bank 1	δ_{01}	0.65 (0.17)	0.28 (0.15)
Dummy for Bank 2	δ_{02}	0.66 (0.15)	0.25 (0.13)
Dummy for Bank 3	δ_{03}	0.71 (0.19)	0.57 (0.14)
	$\sigma_V^2 + \sigma_U^2 \equiv \sigma^2$	0.0186 (0.0052)	0.0277 (0.0058)
	$\gamma = \sigma_U^2 / \sigma^2$	0.439 (0.088)	1.0000 (0.0094)
	LLF	41.8103	74.3230

Source: Own calculation

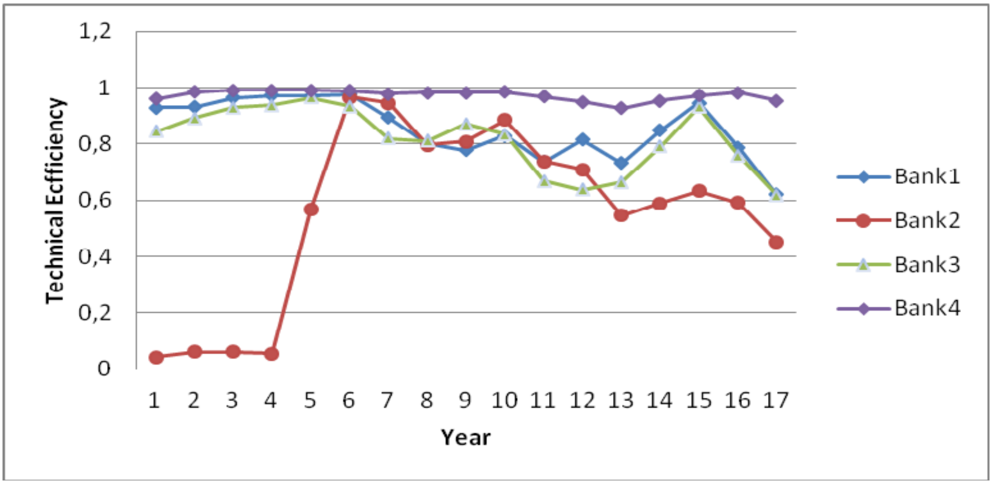
[6] The standard errors, correct to two-significant digits, are presented under the parameter estimates such that the latter are given to the same number of digits behind the decimal points as the corresponding standard errors.

The preferred SFA model for noninterest income is the translog model without deposits or the three Z-variables defined in equation (2) for explaining the inefficiency of generation of the noninterest incomes (loans & investments, interest costs and financial capital). The labour elasticity at the mean input values is estimated to be 0.66 but those for capital and operating expenses are estimated to be slightly negative[7] (but not significantly different from zero). There was significant technical progress in the level of noninterest income over the 17 years of the study, but there was also a significant increase in the level of technical inefficiency in the generation of noninterest income over time. The significance of the technical inefficiency effects in the generation of noninterest income is shown by the fact that the γ-parameter is estimated to be very close to one (equal to one, correct to four-digits behind the decimal point).

5.1.3 Technical Efficiencies

Using the preferred SFA models for interest income and noninterest income, presented in Table 3, the technical efficiencies of the banks generating interest and noninterest incomes for the 17 years of our sample period (1994-2010) are estimated using FRONTIER 4.1. These predicted values are graphed in Figures 3 and 4 for interest income and non-interest income, respectively.

Figure 3: Technical Efficiencies of Four South African Banks Generating Interest Income, 1994-2010 (Years 1 to 17).



Source: Own projection

The mean technical efficiencies of generating interest income were estimated to be 0.854, 0.555, 0.817 and 0.972 for Banks 1, 2, 3 and 4, respectively, with the overall mean technical efficiency of 0.800. Bank 4 consistently had the largest technical

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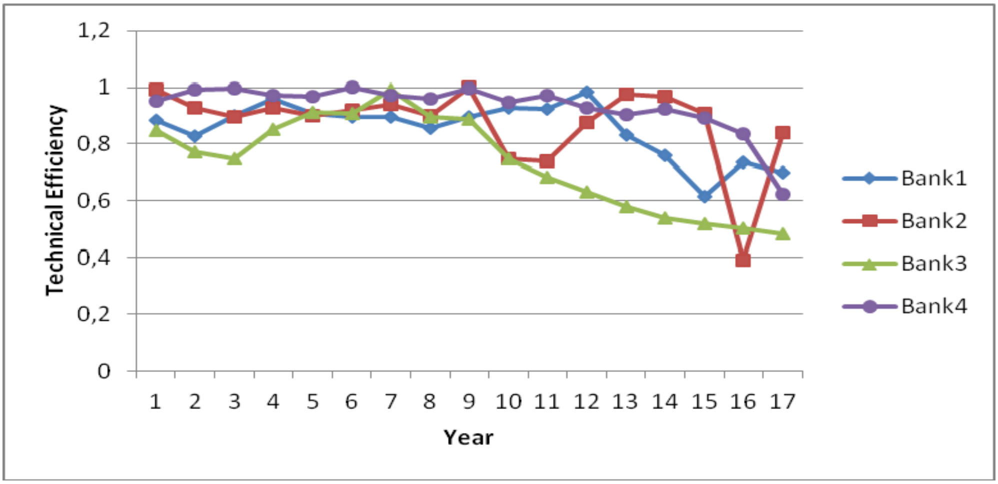
[7] These negative elasticities for the SFA model for noninterest income (and that for capital for interest income) indicate that the estimated translog SFA production functions do not satisfy the regularity conditions for production functions (see, e.g., Coelli, et al., 2005, p. 12). These are issues that merit future research.

efficiency of generating interest income of the four banks in every year of the sample period. However, it is evident from Figure 3 that Bank 2 had very low technical efficiencies in the first five years, but thereafter its technical efficiency was quite comparable with those of the other three banks until the last four years when it dropped to again have the lowest levels of technical efficiencies of generating interest income among the four banks.

Figure 4: Technical Efficiencies of Four South African Banks Generating Noninterest Income, 1994-2010 (Years 1 to 17).



Source: Own projection

The mean technical efficiencies of the four banks generating noninterest incomes were estimated to be 0.853, 0.873, 0.736 and 0.932 for Banks 1, 2, 3 and 4, respectively, with the overall mean technical efficiency of 0.848. Bank 4 was almost always the best performing bank for generating noninterest income but it is evident that its efficiency declined quite systematically in the last 10 years (since 2000) and dramatically declined in the last year to have the second lowest technical efficiency of the four banks. It is noted that Bank 2 had greater variability of its technical efficiencies in the last half of the sample period. Its technical efficiency dropped dramatically in 2009 but recovered in 2010 to be the highest of the four banks.

5.2: SFA Output Distance Function for Interest and Noninterest Incomes

We estimate the unrestricted translog output distance function with the two outputs and four outputs, defined by equation (4), together with the separable model without the interactions between the inputs and outputs. Before presenting the estimates obtained, we test some hypotheses about the output distance function and the results are given in Table 4.

Table 4: Tests of hypotheses for SFA translog output distance functions

Null Hypothesis	LLF	Test Statistic, λ	Critical Value	Decision
$H_0: \gamma = \delta_0 = \delta_1 = \ldots = \delta_{03} = 0$	83.1824	41.486	7.045	Reject H_0
$H_0: \beta_4 = \beta_{4k} = \delta_{41} = 0$, k=1,2,3,4	76.0496	55.752	12.592	Reject H_0
$H_0: \delta_{k1} = 0$, k=1,2,3,4	96.6755	14.500	9.488	Reject H_0
$H_0: \delta_1 = \delta_2 = \ldots = \delta_{03} = 0$	84.8548	38.142	14.067	Reject H_0

Source: Own calculation

The first null hypothesis of Table 4, that there are no inefficiency effects in the unrestricted output distance function, is strongly rejected. The second null hypothesis is that the coefficients associated with deposits (X_4) in the output distance function have zero coefficients, so that deposits do not contribute to the explanation of the generation of interest or noninterest incomes, as found in the single output SFA approach in the earlier analysis. The results obtained by estimating the output distance function with the first three input variables (excluding deposits) yields a highly significant test statistic so we reject the null hypothesis that deposits are not relevant as an input variable for the generation of interest and noninterest incomes. The third null hypothesis of Table 4, that the separable output distance function is an adequate representation of the data (so that the coefficients of the interactions between the inputs and outputs in the output distance function of equation (4) are zero), is also strongly rejected. The fourth null hypothesis is that the coefficients of the explanatory variables in the inefficiency model (loans & expenses, interest costs, financial capital, year effect and three bank dummy variables) are zero. This null hypothesis is also rejected by the data. On the basis of the above tests of hypotheses, we judge that the unrestricted output distance function with the inefficiency variables is the preferred model. Estimates for the parameters of the unrestricted output distance function are given in Table 5, together with those for two submodels[8] that are estimated and tested for adequacy of fit, given the specifications of the output distance function model, defined by equation (4).

Table 5: Maximum-likelihood estimates for parameters in SFA output distance functions for banks generating interest and noninterest incomes[9]

Variables	Para-meters	Unrestricted	Separable	No Ineff Variables
<u>*Output Variables*</u>				
Constant	α_0	-16.299 (0.056)	-15.941 (0.065)	-16.28 (0.48)
$Y_1^* \equiv Y_1 - Y_2$	α_1	0.35	-0.31	0.29

[8] We do not present results for the output distance function with the three inputs excluding deposits in Table 5.

[9] The maximum-likelihood estimates of the output distance function are obtained by using the "cost function" option of FRONTIER 4.1 to account for the *addition* of the non-negative error, U_i, in the model of equation (4).

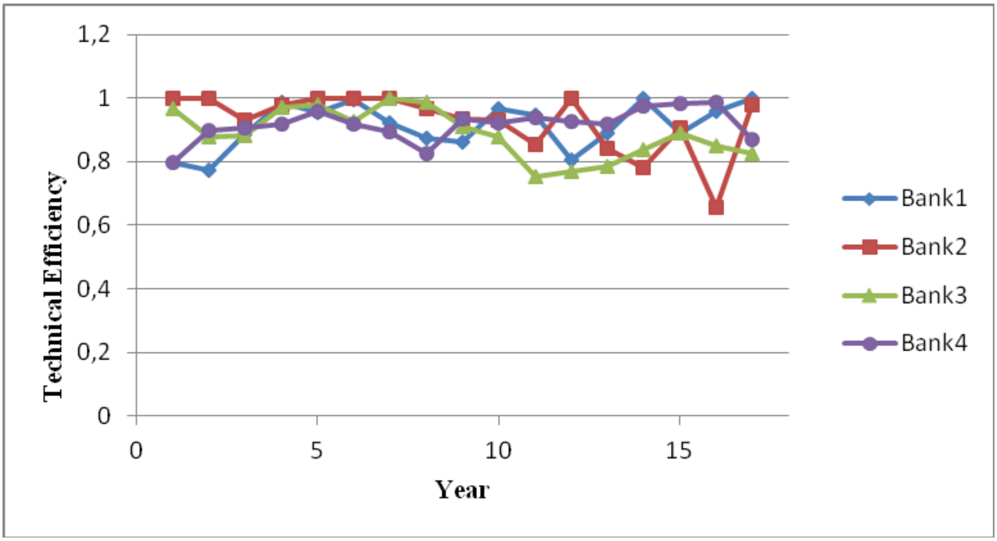
Variables	Para-meters	Unrestricted	Separable	No Ineff Variables
		(0.12)	(0.11)	(0.54)
$0.5(Y_1^*)^2$	α11	-0.047 (0.096)	-0.85 (0.087)	0.01 (0.56)
Input Variables				
$X_1 \equiv \ln(Labour)$	β1	0.18 (0.25)	-0.85 (0.12)	0.19 (0.67)
$X_2 \equiv \ln(Capital)$	β2	0.20 (0.27)	0.032 (0.021)	0.06 (0.57)
$X_3 \equiv \ln(Expenses)$	β3	-1.22 (0.35)	0.11 (0.11)	-1.12 (0.70)
$X_4 \equiv \ln(Deposits)$	β4	-0.37 (0.40)	-0.964 (0.052)	-0.27 (0.87)
$(X_1)^2$	β11	2.0 (1.1)	1.27 (0.67)	1.64 (0.97)
$(X_2)^2$	β22	-0.21 (0.70)	0.23 (0.19)	-0.08 (0.90)
$(X_3)^2$	β33	1.16 (0.29)	0.67 (0.69)	1.22 (0.87)
$(X_4)^2$	β44	1.1 (1.3)	-3.95 (0.43)	1.19 (0.97)
$X_1 \times X_2$	β12	-0.22 (0.65)	-0.14 (0.14)	-0.11 (0.78)
$X_1 \times X_3$	β13	-1.9 (1.7)	-0.93 (0.63)	-1.75 (0.75)
$X_1 \times X_4$	β14	1.2 (1.2)	0.84 (0.28)	1.28 (0.94)
$X_2 \times X_3$	β23	0.69 (0.49)	-0.185 (0.092)	0.53 (0.82)
$X_2 \times X_4$	β24	-0.86 (0.24)	0.73 (0.13)	-1.00 (0.89)
$X_3 \times X_4$	β34	-0.40 (0.30)	-0.04 (0.49)	-0.40 (0.89)
Inputs×Outputs				
$X_1 \times Y_1^*$	δ11	-0.69 (0.21)	0	-0.74 (0.66)
$X_2 \times Y_1^*$	δ21	-0.17 (0.25)	0	-0.10 (0.48)
$X_3 \times Y_1^*$	δ31	1.01 (0.14)	0	1.01 (0.51)
$X_4 \times Y_1^*$	δ41	-0.52 (0.76)	0	-0.56 (0.84)
Inefficiency Model				
Constant	δ0	-7.2	-1.8	0.02 (0.93)

Variables	Para- meters	Unrestricted	Separable	No Ineff Variables
		(2.1)	(1.1)	
Loans & Expenses	δ_1	-0.10 (0.21)	-0.210 (0.060)	0
Interest Costs	δ_2	-0.027 (0.022)	0.025 (0.034)	0
Financial Capital	δ_3	0.650 (0.085)	0.30 (0.10)	0
Year	δ_4	-0.0666 (0.0097)	0.037 (0.013)	0
Bank 1 Dummy	δ_{01}	0.08 (0.35)	0.26 (0.14)	0
Bank 2 Dummy	δ_{02}	0.07 (0.38)	0.005 (0.099)	0
Bank 3 Dummy	δ_{03}	0.43 (0.41)	0.59 (0.14)	0
<u>*Variance Parameters*</u>	$\sigma_V^2 + \sigma_U^2$	0.0135 (0.0037)	0.0308 (0.0040)	0.010 (0.035)
	$\gamma = \sigma_U^2 /$	0.99999 (0.00045)	0.999992 (0.000038)	0.89 (0.96)
<u>*Loglikelihood*</u>	LLF	103.9256	96.6755	84.8548

Source: Own calculation

The output distances obtained for the banks in the 17 years involved are graphed in Figure 5. These are interpreted as technical efficiencies of the generation of outputs (i.e., interest and noninterest incomes) of the banks involved. The mean technical efficiencies of the banks are estimated to be 0.913, 0.927, 0.887 and 0.916 for Banks 1, 2, 3 and 4, respectively, with average of 0.911. The yearly technical efficiencies varied by between about 5% and 10% for the four banks, with Bank 4 having the smallest variation (from about 0.799 to 0.988) and Bank 2 having the largest variation (varying from about 0.656 to 0.999 which were the minimum (in 2009, Year 16) and maximum technical efficiencies (in 2005, year 12). All four banks had technical efficiencies greater than 0.90 in more than one year, and over 60% of the yearly observations exceeded 0.90. These statistics indicate that there was a high level of technical efficiency in the generation of income by the four banks according to the inference from the output distance function involving the two outputs of interest and noninterest incomes. In general, the output distance function technical efficiencies for the banks are greater than those obtained by the analysis involving interest income and noninterest income separately.

Figure 5: Output Distances for Four South African Banks Generating Interest and Noninterest Incomes during 1994 to 2010 (Years 1 to 17).



Source: Own projection

6. Discussion of results

The South African banking sector experienced considerable changes during the years, 1994 to 2010. Over the last decade, the banks saw the first substantial rewrite of the Banks' Act and Regulations since 1990, after the adoption of the international guidelines, called Basel II, which took effect on 1 January, 2008. Banks also saw the introduction of the National Credit Act, as well as the Financial Sector Charter. These changes affected the profitability of the banks and forced them to rethink their marketing strategies. The banks became more services driven and, to a large extent, not primarily interest-rate driven.

Tests of four null hypotheses were considered for the SFA model, defined in equations (1) and (2), for interest and noninterest incomes considered separately, to see if simpler models were adequate representations of the data on income variables for the four banks. The first two null hypotheses considered were strongly rejected for both interest income and noninterest income, indicating that there were significant inefficiencies in the generation of both types of incomes by the banks and that there were not constant elasticities associated with the inputs, labour, capital and operating costs (as specified by the Cobb-Douglas production function).

The third null hypothesis that deposits do not have any effect on the levels of interest income and noninterest income was accepted. We know that deposits only have an influence on interest income once they become available as loans. Interest income is related to interest rate changes. Short-term deposits and bank accounts are volatile deposits and so they are not utilized as loans and make no contribution to interest income. Longer-term deposits and purchased funds are typically the liability accounts that are utilized as loans. The more stable a deposit, the higher the percentage of the deposit that can be made available as loans. With regard to noninterest income, many depositors open bank accounts to reap the benefits they receive from being a bank client. With a large unbanked society, banks attempt to deliver services to these people and various initiatives are used to minimise the cost of holding an account (e.g., keeping a specific minimum balance to pay a minimal service fee). In some cases, banks charge a fixed amount for services rendered, but set a maximum number of services that can be used (e.g., cheques and Internet banking) within a specific period such as a month. In such cases, clients attempt to stay within these margins. However, with a larger number of bank clients, it is expected that there would be an increase in the total amount of noninterest income.

Loans & investments, interest costs and financial capital significantly affect the inefficiency of generation of interest income but not the noninterest incomes of the banks. In South Africa, the prime overdraft rate is 3.5 percentage points higher than the Repo rate set by the Reserve Bank of South Africa. Banks set their own interest rates for their clients, depending on the status of the client and in line with the prevailing interest rates. Because banks, to a large extent, face similar costs of funds, the competition between banks is not interest-rate driven but rather services driven. Although a bank may not be very successful competing on interest income, it may be successful in generating noninterest income (by its service fees). Some banks have even offered new clients an iPad at a discount if they switch banks. The marketing of banks is focused on the various services offered (e.g., one-stop banking). Financial capital is not used to make loans, but is used to finance banking activities. Although the amount of financial capital may increase over time, it does not necessarily mean that the bank will be able to increase its income and, hence, its profits. Financial capital is used to absorb losses that are generated by all types of risks, and is a hedge against solvency risk.

The alternative analysis of interest income and noninterest income using an output distance function approach yielded some different results than the single output analysis with the incomes separately. Again, we find significant inefficiencies in the generation of the outputs, interest and noninterest incomes, using an SFA model in which the distance function is associated with the explanatory variables, loans & investments, operating costs and financial capital. It was concluded that deposits, along with labour, capital and other operating costs, are significant in the output distance function associated with the two outputs and inputs. The technical efficiencies obtained by the use of the output distance function were found to be very high for all four banks, ranging from about 0.69 to 0.99, the average being 0.884, and the mean technical efficiencies for the four banks ranging from 0.81 to 0.96. In general, these technical efficiencies obtained from the output distance function were greater than those obtained for the corresponding banks using the SFA models involving interest and noninterest incomes separately.

Results from alternative methods of estimation of the SFA production function models would be helpful to confirm the results obtained in our study involving the maximum-likelihood approach.

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