



FINANCIAL INNOVATION AND EFFICIENCY IN THE BARBADIAN BANKING INDUSTRY

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This study estimates efficiency scores for Barbadian commercial banks for the period 1979 to 1999 using data envelopment analysis and the stochastic cost frontier methodology and, then, utilises these to examine the impact of financial innovation. The computed efficiency scores suggest that the average bank in Barbados is relatively efficient when compared to the results of similar studies, while the panel regression findings show that financial innovation is a significant determinant of bank efficiency along with bank size, loan-to-asset ratio and national income growth. (JEL C43, G21, O31)

I. INTRODUCTION*

Financial innovation can be defined as any new financial service or product which changes the way in which financial transactions are completed or delivered. Financial innovations in the Barbadian banking industry are not a recent phenomenon (Zephirin and Seerattan, 1997). The 1980s witnessed the inauguration of the Securities Exchange of Barbados, venture capital investments and mutual fund instruments, while during the 1990s, electronic technologies transformed how people transact business at commercial banks in Barbados. Most of the innovations that have occurred have been occasioned by new distributional channel systems such as automatic teller machines (ATMs) and debit card technologies, which have allowed banks to diversify the way in which customers transfer funds, pay bills and buy goods and services without using cash or cheques. In essence, technological innovation in the banking system has lowered costs per transaction and realised processing efficiencies by shortening the time taken

ABBREVIATIONS

SCF: Stochastic Cost Frontier
DEA: Data Envelopment Analysis
TE: Technical Efficiency
AE: Allocative Efficiency
CE: Cost Efficiency

for completing a transaction and reducing the possibility of human errors (see Parris, 2002 for more details). This proposition can be supported by observing that banks' total costs as a percent of total assets has declined from 8.8% in the 1979-1983 period to 6.8% in the 1994-1999 period.

Given the potential importance of financial innovation to bank behaviour, the recent focus of empirical work has been on its impact on productivity. Wilson (1995), in his survey, concludes that the majority of the studies are in agreement with what has come to be known as the "IT Paradox", where information technology (IT) investment has an insignificant impact on productivity.

One drawback of examining the effect of innovation on productivity in the banking industry is that there is no clearly identifiable output. For example, Haynes and Thompson (2000) use real earning assets as the output variable while Frei, Harker and Hunter (1997) utilise total loans plus total deposits. However, the output of the banking firm should not be linked to a single variable but to a multiplicity of variables that capture the many services offered by a commercial bank. In addition, linking innovations to productivity ignores an important factor firms consider when investing in product or process innovations, namely, efficiency. Productivity is concerned with the relationships between outputs and inputs while efficiency shows if a firm is using its inputs optimally to generate the greatest possible output.

This study therefore employs Data Envelopment Analysis (DEA) and stochastic cost frontier (SCF) techniques to compute the level of efficiency in the Barbadian banking system over the period 1979 to 1999, and then utilises these estimates to investigate the relationship between efficiency and financial innovation. DEA allows one to specify the banking firm as a producer of multiple outputs and a user of multiple inputs. In addition, it generates productivity-related statistics such as technical efficiency, which show the ability of a firm to obtain maximum outputs with a given set of inputs. One caveat that must be borne in mind is that Barbados has an underdeveloped capital market. As a result, banks have not faced any serious competition from other players in the financial arena in terms of their outputs. It is therefore possible that one could obtain the perverse situation that a bank's operating cost, as a proportion of total assets is very high, but its revenue is even higher. This would suggest that an

approach which focuses more on cost inefficiencies, might give different results. Consequently, a stochastic cost frontier model is also estimated to examine whether the efficiency scores differ significantly from those obtained from the DEA approach.

This research adds to the literature in developing countries, since most of the work on efficiency and productivity has been undertaken on developed economies. Certainly in Barbados, only two studies are available and both are rather narrow in scope. Langrin (1995) estimates a translog cost function for Barbadian commercial banks using data over the period 1984 to 1990, and concludes that banks seem to be more efficient in their role as a financial intermediary than a producer of financial funds. However, no efficiency scores are derived in the study. Howard and Haynes (2001) also examine the issue of bank efficiency in Barbados but their study is restricted to ratio analysis, for example, interest, labour and operating costs to total assets.

This paper is divided into five sections. Following the introduction, Section 2 outlines the methodology and describes the data. Section 3 presents the empirical estimates of commercial bank inefficiency while Section 4 explores the relationship between efficiency and financial innovation. Section 5 concludes.

II. METHODOLOGY AND DATA

A. Estimating Efficiency

DEA and an SCF model are utilised to derive estimates of efficiency in Barbados. The DEA approach assumes that each bank uses the same inputs, in differing combinations, to produce various outputs. Assuming that there exists data on K inputs, M outputs, N firms and constant returns to scale, the formal linear programming problem can be specified as:

$$(1) \quad \begin{aligned} & \min_{\theta, \lambda} \theta \\ & st \quad -y_i + Y\lambda \geq 0, \\ & \quad \theta x_i - X\lambda \geq 0, \\ & \quad \lambda \geq 0 \end{aligned}$$

where θ is a scalar, y_i is a vector of output prices for the i^{th} firm, x_i is a vector of input prices for the i^{th} firm, Y is an $M \times N$ output matrix, X is a $K \times N$ input matrix, λ is an $N \times 1$ vector of constants. The linear programming problem above constructs a piece-wise external production surface, which represents the revealed optimal production frontier. The value of θ obtained provides the efficiency score of the i^{th} firm, with a value of 1 indicating a point on the frontier and a technically efficient firm (TE). This index shows the ability of a bank to obtain the greatest possible output with a given set of inputs.

To obtain an estimate of minimum cost efficiency, Equation (1) and the following cost minimising problem must be solved simultaneously:

$$(2) \quad \begin{aligned} & \min_{\lambda, x_i^*} w_i' x_i^* \\ & st \quad -y_i + Y\lambda \geq 0, \\ & \quad x_i^* - X\lambda \geq 0, \\ & \quad \lambda \geq 0 \end{aligned}$$

where w_i is a vector of input prices for the i^{th} firm and x_i^* is the cost minimising vector of input quantities. Total cost efficiency (CE) can then be computed from the ratio of minimum cost to observed cost:

$$(3) \quad w_i' x_i^* / w_i' x_i.$$

Allocative efficiency (AE), which reflects the ability of the firm to use inputs in optimal proportions given input prices, is then derived from the ratio of CE and TE. For a more technical introduction to the approach see Fried, Lovell and Schmidt (1993) and Coelli, Rao and Battese (2001).

In order to control for the impact of method choice on the inferences derived, results from the alternative SCF approach are calculated. This approach determines the level of efficiency of a bank by comparing it to an idealised cost frontier. The SCF function is specified as:

$$(4) \quad c_i = c(q_i, w_i) + \varepsilon_i$$

where c_i are the total expenses observed for the i^{th} bank, q_i is a vector of outputs, w_i is a $K \times 1$ vector of input prices and ε_i is an error term. As in Aigner, Lovell and Schmidt (1977) and Meeusen and van der Broeck (1977) the error term of the SCF is assumed to be of the following form:

$$(5) \quad \varepsilon_i = u_i + v_i$$

where u_i and v_i are independently distributed. The u_i s denote the effects of inefficiency and are assumed to have a half-normal random distribution. On the other hand, the v_i s are random variables postulated to have a two-sided normal distribution with mean zero and variance σ_v^2 , which captures statistical noise.

Given the above model, estimates of technical inefficiency, u_i , can be derived as the ratio of the frontier minimum cost to observed cost, which is also equal to:

$$(6) \quad CE_i = \exp(-u_i).$$

The score is bounded between zero and one, with a score of 0.7, for example, suggesting that the bank can produce the same level of outputs using 30% less overheads.

B. Specification of Inputs, Input Prices and Outputs

An important aspect of obtaining accurate efficiency estimates is the specification of outputs and inputs. Within the banking literature, there are three main approaches to the specification of what constitutes inputs and outputs. These are the production approach (see Fried, Lovell and Schmidt, 1993), the intermediation approach and the asset approach (see Favero and Papi, 1995). Following other studies

on bank efficiency such as Berger and Mester (1997), DeYoung and Hasan (1998) and Isik and Hassan (2002), the intermediation method is chosen over other empirical specifications since it most closely captures what financial institutions do, that is, convert and transfer financial assets from surplus economic units to deficit units. Therefore, commercial banks are assumed to be multi-product firms that produce four outputs and employ three inputs.

Starting with inputs, LABOUR, is given by the number of persons employed; CAPITAL, is measured as the book value of premises and fixed assets, and; FUNDS represent total resources available to the bank and is defined as the sum of deposit and non-deposit funds (non-deposit funds includes monies due to other banks, the head office, the Central Bank and other branches). These three inputs are the main resources needed to operate a bank. The output variables, which primarily reflect desired outcomes, include: TLOANS, measured by total loans outstanding; other earning assets, OASSETS, which incorporates investments and securities (treasury bills, government bonds and other securities); interest income, INTINCOME, given by total interest income from loans and other investments, and; FEEINCOME, which includes incomes obtained from fees and other services provided by the bank.

C. Sample Statistics

Table 1 presents the variable definitions while Table 2 gives the means and standard deviations for the inputs, input prices and outputs for four periods on the seven commercial banks operating in Barbados. Employment at commercial banks fluctuated significantly over the period. During the mid-1980s banks reduced their complement of workers, from 224 between 1979-1983 to 194 during 1984-1988. This fall might be related to the almost doubling in the price of labour registered over the period of analysis. However, with the expansion in bank business during the 1990s, mainly due to the booming economy, banks raised employment levels above those reported in the 1979-1983 period. Another trend observed from Table 2 is that banks have significantly increased their stock of fixed capital during the latter half of the 1990s. While in the 1979-1983 period the average bank held \$4.5 million in capital

assets, by 1989-1993 the stock had risen to \$10.5 million and exploded to just under \$18 million in 1994-1999. Banks have also benefited from a significant expansion in loanable funds since the 1984-1988 period. The growth in loanable funds registered in 1989-1993 over the 1979-1983 era almost doubled that recorded in the previous period while loanable funds in 1994-1999 was more than 50% greater than in the preceding period. This increase in resources was obtained in spite of a decline in the rate of return offered to customers from 4.9% in the 1979-1983 period to 3.6% by 1994-1999.

Turning attention now to the outputs, two key trends are evident. First, over the period under investigation, banks have reduced their reliance on retail banking in favour of investments and other interest earning assets. For example, in the 1979-1983 period the average bank held 61% of its assets in loans compared to 51% in the 1994-1999 period. This decline could imply that commercial banks are obtaining greater returns from their investment portfolios relative to that obtained on loans. The second key trend obtained from the sample statistics is the growing importance of FEEINCOME as a source of bank income. In the 1979-1983 the average bank obtained 20% of its total income from fees and other income, however by the 1994-1999 period the contribution had risen to approximately 24% of bank's revenues.

D. Econometric Model

To examine the relationship between financial innovation and bank efficiency, the following random effects panel data regression is estimated:

$$(7) \quad u_{it} = u(FINOV_{it}, x_{it}^1, \dots, x_{it}^n)$$

where $FINOV$ is an indicator of financial innovation and $(x_{it}^1, \dots, x_{it}^n)$ is a vector of variables used to account for other factors that might influence bank efficiency (see Table 3 for the definitions and sample statistics of the control variables employed).

Two indicators of financial innovation are used. The first of these, $INOV$, is an index which seeks to measure the number and availability of financial products in a given year (Bynoe-Mayers and Craigwell, 2002). It is based on Gelbard and Leite's (1999) index of financial development and begins by asking several questions about the development of commercial banks financial products; for example, do banks issue debt or credit cards? Then it converts the answers to the questions into an index, by assigning a value of 0 or 100, to 'yes or no' answers, and also by using the following equation:

$$(8) \quad d_j = \frac{k_j - \min}{\max - \min} \times 100$$

where j is the p^{th} attribute, d_j is an index between 0 and 100 of the p^{th} attribute, k_j is the value of attribute j , \min is the minimum value of the p^{th} attribute and \max is the maximum value of the p^{th} attribute. Therefore the index accounts for the existence of a wide range of new financial products and practices overtime. It is expected that this variable will positively impact on efficiency since innovations offer customers a greater level of products to purchase and therefore opportunities to increase the output of the given bank.

The second indicator of financial innovation, ATM , is a dummy variable that represents the introduction of automatic teller machines (ATMs) in the banking system. This variable is also expected to be positively related to efficiency, since ATMs reduce the need for a large complement of bank tellers and a number of branches.

Several control variables are employed. $SIZE$, is used to test whether banks of various scales of operations have differing levels of efficiencies. If the coefficient on this variable is negative it would support the hypothesis put forward by authors such as Nakamura (1993) and Mester, Nakamura and Renault (1998) that small firms have greater access to credit information and less agency problems since management might be closer to both the customer and the loans officer. On the other hand, if the sign of the coefficient is positive it would be in agreement with the expense preference hypothesis postulated by Rhoades and Rutz (1982) and Clark (1986). This approach contends that managers at small banks may

invest in less risky loans and investments so as to enjoy a ‘quiet life’ and in the process reject loans that could have generated additional profits for the bank. LOANTA captures the risk averseness of the bank and is expected to be positively related to efficiency as banks in Barbados have a greater degree of market power over their loan portfolio relative to other components of their asset holdings. The inclusion of the variable FUNDTA tests whether banks with greater deposit bases have differing levels of efficiency. The coefficient on this variable is expected to be positive since, banks with larger stocks of loanable funds should produce relatively more outputs relative to their peers, holding all other factors constant, due to financial economies of scale. In Barbados, banks are subject to both cash and securities requirements (RREQ), which acts as a cost to the commercial bank, as these funds could have been used to provide loans or make other interest earning investments to generate income. Therefore it is likely that RREQ will impact negatively on bank efficiency. The variable $\sigma(ROA)$ is included to capture an aspect of profit risk. Riskier banks may have higher levels of efficiency since they are trading low levels of risk for possibly greater returns. However, if the expected returns from taking on additional risk do not materialise then bank efficiency could decline. The coefficient on the variable $\sigma(ROA)$ is therefore ambiguous. Income growth (INCGROWTH) proxies for the growth in demand for financial services and is expected to be positively related to efficiency since an increase in income would likely lead to greater demand for bank services and by extension more opportunities to make profits. Two dummy variables are also included in the model to test whether efficiency varies between foreign and domestic banks (FRBANK) and public and private commercial banks (STBANK).

III. EMPIRICAL ESTIMATES OF EFFICIENCY

Table 4 shows the efficiency estimates derived from the DEA and the SCF models for four periods. The average standard deviations of the difference in efficiency between banks for a given year

are also reported in the table. The estimates produced by the DEA suggest that the average bank in Barbados has an efficiency score of 0.952 for the period 1979-1999. In economic terms this means that the average bank could have produced the same level of outputs using 4.8% less inputs. In addition, there appears to be an upward trend in cost efficiency with the average score rising from 0.940 in the 1979-1983 period to 0.968 in the 1994-1999 period. Apparently banks in Barbados have been streamlining their management techniques over time and possibly benefiting from technological innovations within the industry.

The resource wastage found in this study is relatively low when compared to the level of inefficiency of banks of both developing and developed countries. Isik and Hassan (2002) estimates inefficiency of Turkish banks at 40%, Altunbas, Evans and Molyneux (1994) 24% for German universal banks, for the US banking industry the estimate is 13.2% (Berger and Mester, 1997) and 5-10% for English banks (Altunbas, Maude and Molyneux, 1995). These efficiency scores certainly explain the higher rates of profitability experienced by Barbadian commercial banks (approximately 2.1% compared to 0.4% for industrial countries (Demircuc-Kunt and Hizinga, 1998)). One of the main explanations for this finding is the relatively high interest margins (4.3%) the average bank in Barbados was able to maintain during the period under investigation. This situation is amplified even further when fee and other income is added to the analysis. Given the concentration of the market amongst seven commercial banks, this result is not surprising.

The results presented in Table 4 also show the technical and allocative efficiencies for four periods. These scores reveal that average technical inefficiency is 1.3% where as the average allocative inefficiency is 3.7%. This suggests that allocative inefficiency is the dominant source of bank inefficiencies. Therefore, Barbadian banks appear to utilise inputs in the improper mixes but are relatively good at getting the most output from their given resources. This inability to choose the correct input mix seems to be declining over time, evidenced by the rising efficiency score. One possible explanation is the delegation of input management to branch managers who may not be using inputs in the correct proportions.

Regarding the relatively low level of technical inefficiency, one possible explanation is that commercial banks may be getting high returns on their computerisation and other innovative product investments undertaken during the late 1980s and early 1990s. As mentioned earlier, the 1990s saw the growth of debit card utilisation, ATM technologies, credit cards and the establishment of the a system known as CARIFS, which allowed users to access cash from any bank ATM even if they are not a customer of that bank.

The authors also estimated a stochastic cost frontier model to examine whether the efficiency estimate differs significantly from those obtained from the DEA and these results are reported in the final row of Table 4. The efficiency estimates are in broad agreement with those from the DEA. The SCF results show that the average bank in Barbados has costs 11% higher than those obtained on the efficient frontier.

Table 5 reports the correlation ratios among the different efficiency measures and three common accounting ratios that may be considered alternative measures of efficiency. The first of these is return on assets (ROA), which attempts to capture the productivity of the asset base, while total expenses divided by total assets (COSTTA) proxies cost inefficiency. The final performance variable is total assets divided by total labour employed (TALABOUR) and attempts to measure employee productivity. There is a positive relationship between ROA and TALABOUR and all the efficiency scores. These results suggest that more profitable and productive banks are usually more efficient than their peers. Similarly, COSTTA, a proxy for inefficiency is negatively correlated with all of the efficiency scores and the other performance indicators. These results show that all the efficiency scores generated are associated with more simple estimates of financial performance. This finding illustrates the usefulness of the calculated efficiency scores and also acts as a check on the consistency of the efficiency scores obtained.

V. FINANCIAL INNOVATION AND EFFICIENCY

Table 6 presents the results of estimating the model given in Equation 7. The coefficients on the control variables are considered first. *SIZE* is negatively and significantly related to bank efficiency. This finding suggest that efficiency at larger banks is lower than their peers and agrees with the results of Akhigbe and McNulty (2003) and supports the information advantage hypothesis of Nakamura (1993) and Mester, Nakamura and Renault (1998), which proposes that there would be less agency problems between the bank and the loan officer since senior management is closer. Banks with higher loan-to-asset ratios (*LOANTA*) tend to have higher efficiency scores. Thus, bank loans seem to be more highly valued than alternative bank outputs, say for example, securities. However, the variable is only significant in the allocative and cost efficiency models, but not the technical efficiency models. Another factor, which explains the growth in efficiency, is the relatively high rates of national income growth recorded during the period under analysis. During the period, the Barbadian economy grew at an average rate of 2.9% per year, which was reflected by an increase in GDP per capita from US\$2697 in 1979 to US\$9222 by 1999. This economic expansion allowed banks to benefit from higher demand for their financial services and thus greater output. The remaining control variables $\sigma(ROA)$, *RREQ*, *FRBANK* and *STBANK* are insignificant in all three-regression equations.

Focussing now on the financial innovation variable (*INOV*), the results presented in Table 6 show that this variable is positively related to all the efficiency measures. However, it only manifests as a significant factor in the *AE* and *CE* models. The finding that innovation is an insignificant variable in the *TE* and *SFCE* models is not surprising since these measures of efficiency are more related to managerial ability and experience than the new products and services available to the bank. The results do reveal, however, that banks have used new financial services and products to maximise their ability to use inputs in optimal proportions (reflected by the significance of *INOV* in the *AE* and *CE* models). Calculating the elasticity of financial innovation with respect to cost efficiency shows that for every 1% increase in the innovation indicator, bank efficiency rises by approximately 0.076%. This estimate is consistent with the productivity gains reported by Haynes and Thompson (2000) for the introduction of ATM technologies

among UK building societies. This finding is especially important, since Table 4 reveals that allocative inefficiencies have been the main area in which there have been shortcomings. It therefore suggests that innovations should continue if banks are to reduce their levels of allocative inefficiencies overtime. This can be achieved if banks diversify their activities from basic retail banking activities into other areas of financial services.

The financial innovation index accumulates a number of innovations introduced by banks. However, by examining a particular innovation one can directly measure its impact on efficiency. As noted earlier, the innovation chosen is the introduction of the ATM technology. The same efficiency model is estimated but a dummy variable, taking on the value 1 for all periods after the ATM is introduced and 0 otherwise, is included in the model and the results are presented in Table 7. Most of the coefficients on the control variables maintain similar signs to those observed in Table 6, although their magnitudes are somewhat different. These outcomes also show that the introduction of ATMs increases firm efficiency by approximately 3.5% for the average bank, while allocative efficiencies rise by 2.8%. These results imply that the introduction of ATM technologies is usually accompanied by efficiency gains, such that adopters enjoy a significant advantage over non-adopters.

V. CONCLUSIONS

This study employs DEA and stochastic frontier analysis to estimate the level of efficiency amongst commercial banks in Barbados over the period 1979 to 1999. The results show that Barbadian banks have relatively low levels of inefficiencies, wasting only 4.8% of inputs, when compared to their international counterparts. The study then estimates an econometric model to derive estimates of the relationship between efficiency and financial innovation and other control variables. These results show that bank size, loan-to-asset ratio, national income growth and financial innovation are the most significant determinants of efficiency in Barbados. Moreover, the coefficient estimate obtained for the

innovation variable indicates that for every 1% increase in the index of financial innovation, efficiency rises by 0.076%. To provide an analysis of the impact of a recent innovation, an ATM dummy is included in the model. The econometric results show that this development increased bank efficiency by approximately 3.5%.

Although overall bank inefficiencies are rather low, one area that could be improved is the allocative inefficiencies of banks. This variable shows the ability of firms to use inputs in optimal proportions. From the results presented in the study, it seems that financial innovations could be one area in which allocative inefficiencies can be reduced. However, the introduction of new technologies must be accompanied with greater training for employees in how best to use these technologies.

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TABLE 1
Definition of Variables

Variables	Definition
<i>Inputs</i>	
LABOUR	Total number of employees
CAPITAL	Book value of premises and fixed assets
FUNDS	Sum of deposit and non-deposit funds
<i>Input Prices</i>	
P_l	Total expenditure on employees divided by the total number of employees
P_c	Total expenditure on premises and fixed assets divided by the book value of premises and fixed assets
P_f	Total interest expenses on deposit and non-deposit funds divided by the sum of deposit and non-deposit funds
<i>Outputs</i>	
TLOANS	Total loans
OASSETS	Other earning assets (such as investments, etc.)
INTINCOME	Total interest income
FEEINCOME	Total fee and other income

TABLE 2
Sample Statistics of Inputs and Outputs (BD\$\$ '000)*

Variables	Years							
	1979-1983		1984-1988		1989-1993		1994-1999	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
<i>Inputs</i>								
LABOUR	224	161	194	161	248	176	283	155
CAPITAL	4,525	5,243	6,213	5,535	10,466	8,956	17,935	11,611
FUNDS	138,458	63,665	198,443	94,295	278,094	135,384	471,073	246,185
<i>Input Prices</i>								
P _l	16.402	5.083	28.256	8.960	28.669	5.918	38.154	5.453
P _c	0.025	0.021	0.052	0.076	0.037	0.026	0.048	0.037
P _f	0.049	0.016	0.041	0.017	0.049	0.013	0.036	0.010
<i>Outputs</i>								
TLOANS	92,799	40,565	130,931	63,107	175,340	80,030	272,542	135,453
OASSETS	25,292	14,241	43,882	22,878	67,084	34,726	114,647	74,618
INTINCOME	13,135	5,702	15,767	7,259	26,124	11,403	38,706	16,921
FEEINCOME	3,377	2,151	4,947	3,356	7,077	5,105	12,372	7,393
<i>Memo</i>								
Total	13,317	6,036	17,311	8,719	26,695	12,949	36,638	16,543
Expense								
Total Assets	151,362	68,314	221,721	101,725	311,301	142,496	535,657	258,423

* : Two Barbados Dollars = One US Dollar (Fixed)

TABLE 3
Summary Statistics for Explanatory Variables

Variables	Definition	Mean	St. Dev
SIZE	Total assets of the i^{th} bank divided by total industry assets	0.147	0.064
LOANTA	Total loans divided by total assets	0.568	0.113
FUNDTA	Total loanable funds divided by total assets	0.880	0.078
RREQ	Total reserve requirements	27.699	0.136
INCGROWTH	Percentage change in real gross domestic product at factor cost	1.491	3.667
$\sigma(ROA)$	Standard deviation of return on assets	0.010	0.005
FRBANK	Dummy variable indicating that the bank's head office is located overseas	0.692	0.463
STBANK	Dummy variable indicating that the bank is owned by the state	0.147	0.355
INOV	Index of financial innovation	0.566	0.145
ATM	Dummy variable which takes the value 1 if ATM technologies are being used by the bank and 0 otherwise	0.364	0.483

TABLE 4
Estimates of Commercial Bank Efficiency

Variables	Years							
	1979-1983		1984-1988		1989-1993		1994-1999	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
<i>DEA Estimates</i>								
TE ^a	0.993	0.014	0.985	0.029	0.975	0.036	0.997	0.020
AE ^a	0.946	0.094	0.955	0.068	0.980	0.035	0.971	0.049
CE ^a	0.940	0.102	0.941	0.085	0.960	0.055	0.968	0.059
<i>Stochastic Frontier Estimates</i>								
SFCE ^a	0.894	0.007	0.895	0.006	0.895	0.006	0.895	0.006

^a TE: Technical efficiency, AE: Allocative efficiency, CE: Cost efficiency, SFCE: Cost efficiency from the stochastic frontier model

TABLE 5
Correlates with Commercial Bank Efficiency

	TE	AE	CE	SFCE	ROA	COSTTA	TALABOUR
TE	1.000						
AE	0.176	1.000					
CE	0.517	0.920	1.000				
SFCE	-0.013	0.415	0.346	1.000			
ROA	-0.007	0.115	0.101	0.175	1.000		
COSTTA	-0.052	0.006	-0.007	-0.174	-0.385	1.000	
TALABOUR	0.109	0.209	0.218	0.391	-0.017	-0.381	1.000

^a TE: Technical efficiency, AE: Allocative efficiency, CE: Cost efficiency, SFCE: Cost Efficiency from the stochastic frontier model, ROA: Return on assets, COSTTA: Total expenses divided by total assets, TALABOUR: Total assets divided by total number of employees.

TABLE 6
Commercial Bank Efficiency and Financial Innovation

	TE	AE	CE	SFCE
SIZE	-0.112 (0.068)	-0.581 (0.133)***	-0.722 (0.137)***	-0.011 (0.003)***
LOANTA	0.020 (0.029)	0.116 (0.053)**	0.114 (0.058)**	0.000 (0.001)
FUNDTA	-0.021 (0.057)	-0.012 (0.098)	0.004 (0.116)	-0.001 (0.001)
RREQ	-0.002 (0.001)	0.002 (0.002)	0.001 (0.003)	-0.000 (0.000)
INCGROWTH	0.003 (0.001)**	0.001 (0.002)	0.003 (0.002)	0.000 (0.000)
σ (ROA)	0.463 (0.922)	-1.112 (1.671)	-1.801 (1.864)	0.004 (0.020)
FRBANK	0.005 (0.014)	0.029 (0.025)	0.027 (0.029)	-0.000 (0.000)
STBANK	0.004 (0.015)	0.047 (0.029)	0.048 (0.030)	0.003 (0.001)*
INOV	0.011 (0.027)	0.113 (0.047)**	0.127 (0.055)**	0.001 (0.001)
Intercept	1.038 (0.060)***	0.869 (0.105)***	0.877 (0.122)***	0.897 (0.001)***
R-squared	0.151	0.251	0.258	0.971
$\chi^2(9)$	21.730***	32.330***	46.230***	22.920***
Obs	143	143	143	143

Notes: White robust standard errors are reported in parentheses below the coefficients.
***, **, * denotes significance at the 1, 5 and 10 percent level.

TABLE 7
Commercial Bank Efficiency and the Introduction of ATM Technologies

	TE	AE	CE	SFCE
SIZE	-0.117 (0.069)*	-0.579 (0.137)***	-0.742 (0.139)***	-0.010 (0.003)***
LOANTA	0.025 (0.029)	0.126 (0.056)**	0.128 (0.059)**	0.000 (0.001)
FUNDTA	-0.017 (0.058)	-0.006 (0.100)	0.035 (0.117)	-0.000 (0.001)
RREQ	-0.001 (0.001)	0.004 (0.002)*	0.004 (0.003)	-0.000 (0.000)
INCGROWTH	0.003 (0.001)**	0.001 (0.002)	0.003 (0.002)	0.000 (0.000)
σ (ROA)	0.418 (0.918)	-0.929 (1.685)	-1.881 (1.862)	0.005 (0.019)
FRBANK	0.005 (0.014)	0.022 (0.025)	0.019 (0.029)	-0.000 (0.000)
STBANK	0.004 (0.014)	0.042 (0.029)	0.044 (0.029)	0.003 (0.001)*
ATM	0.005 (0.007)	0.028 (0.012)**	0.035 (0.014)**	0.000 (0.000)
Intercept	1.031 (0.062)***	0.835 (0.108)***	0.827 (0.125)***	0.896 (0.001)***
R-squared	0.147	0.244	0.261	0.971
$\chi^2(9)$	22.300***	29.940***	47.090***	22.780***
Obs	143	143	143	143

Notes: White robust standard errors are reported in parentheses below the coefficients.
***, **, * denotes significance at the 1, 5 and 10 percent level.