“Deposit money banks’ efficiency in three years after, during and before the 2004–2005 consolidation in Nigeria: the puzzle on size”

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DEPOSIT MONEY BANKS' EFFICIENCY IN THREE YEARS AFTER, DURING AND BEFORE THE 2004–2005 CONSOLIDATION IN NIGERIA: THE PUZZLE ON SIZE

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Abstract

In this paper, the authors examined the efficiency of deposit money banks (DMBs) in Nigeria in three years after, during and before the 2004–2005 capital consolidation in Nigeria. This consolidation period was the last period the Central Bank of Nigeria implemented an official recapitalization policy of the deposit money banks in the country. The authors predicated the study on a modified intermediation and efficiency measurement frameworks. It utilizes deposits, fixed assets and employees as inputs, whose costs are interest payments, depreciation and staff expenses. Performing loans and advances, investments and liquid assets constituted the output variables. The authors computed the efficiency scores, using the Data Envelopment Analysis (DEA) approach. The data used were obtained from the DMBs that retained their identities and controlled over 75% of the banking industry's total assets. They were purposively selected to maintain data consistency, and were size-classified by total assets. The findings show that small banks tend to be more cost efficient than medium and big banks. More so, medium sized banks tend to be more cost efficient than big banks, while big banks take the lead in cost efficiency score in post consolidation period. Cost efficiency of the banks was the highest during consolidation, followed by pre-consolidation and least in three years after consolidation.

Keywords bank efficiency, deposit money banks, bank size, consolidation, data envelopment analysis, Nigeria

JEL Classification C61, G18, G21

INTRODUCTION

The report of an investigation carried out by the Central Bank of Nigeria (CBN) on the deposit money banks operating in Nigeria in mid and late 2009 post-consolidation period showed that ten banks out of the twenty-four banks in the country during this period had varying problems which included illiquidity, capital inadequacy and poor corporate governance. One quick response of the banks' management was drastic cost-cutting and 'fat' trimming, which often constitutes part of the immediate policies of management to address an x-inefficiency problem. However, it is not all the time that cost-cutting exercises are due to x-inefficiency. Perhaps, the need for re-optimization may call for such exercises. This involves input and/or output responses to alterations in some factors, such as input and output prices which are exogenous in nature. There are also situations where costs are cut due to reductions in profits.

The use of modern technologies to match the products of the banks is one key challenge in the banking industry in the 21st century. There was a lot of branding and re-branding of products especially among those banks that were products of merger and acquisition. This was accompanied with excessive marketing activities, which were not really sound for the banks. In fact, there was an acute competition for deposit mobilization (see Oke, 2016).

One way to completely assess the long-term stability of banks is by analyzing their efficiency level. Financial ratios have been said to be grossly inadequate in examining efficiency level (see Deng et al., 2007). Efficiency is an in-depth evaluation index of achievements. Studies on bank efficiency therefore do inform major banking sector stakeholders on in-depth performance of their banks and can help the management in adopting measures for improvement of the banks. Also, foreign investors can have intuition on the nature and performance of the banking industry and this can guide them in undertaking investment in the country.

One gap in the past studies is that available evidence on efficiency of banks in terms of size is mixed, probably due to differences in methodology and the workings of the economies. For instance, Berger and Humphrey (1992), Kwan and Eisenbeis (1996), Sensarma (2006), Raphael (2012) and Hughes et al. (2016) found higher efficiency for large banks over small banks, while the contrary was found by Altunbas et al. (2000), Jemric and Vjucic (2002), Rao (2002) and Aiello and Bonanno (2016). Thus, there is a need for further investigation on bank efficiency in this regard. More importantly, studies on changes in efficiency of small, medium, and big banks in period shortly after, during and before consolidation are scanty in the literature. This study therefore fills these gaps. Following this introduction is the literature review in section one; theoretical framework and methodology in section two; discussion of findings in section three and the concluding remarks and recommendations in the last section.

1. THEORETICAL AND EMPIRICAL REVIEW

There are five basic approaches used in the literature for classifying the inputs and outputs. These include the production, intermediation, asset, value added and user cost approaches. These approaches are based on the application of production theory in economics to the behavior of banking firms, where they produce one or more outputs using some inputs. What some authors have called modern approach is actually not an approach of inputs and outputs identification, but merely another way of accounting for efficiency. This ratio-based method has to do with integrating information processing and risk management into the classical theory of firm. It is shown by the CAMEL method, an acronym for capital adequacy, asset quality, management, earnings and liquidity. Again, ratio analysis of efficiency has been criticized for its inadequacy in efficiency analysis compared to frontier analysis which this study and most past and recent studies have adopted (see Chen, 2001; Yeh, 1996; Sherman & Gold, 1985, Omankhanlen, 2013).

Efficiency is three fold which comprises productive or technical efficiency, allocative efficiency and cost or price or economic efficiency (see Debreu, 1951; Koopmans, 1951; Farrell, 1957; Coelli, Rao, O'Donnell, & Battese, 2005). In computing technical efficiency score, single or multiple inputs and outputs are required (Coelli et al., 2005). In addition, input price or inputs' prices are needed to compute the allocative efficiency. A multiplication of technical efficiency with allocative efficiency is what yields the economic efficiency. The foregoing efficiency is a frontier efficiency where a best performing firm is identified and its efficiency value is one. A deviation from the best performing or inputs is what gives the inefficiency level. Therefore, the frontier efficiency is a relative efficiency. When maximum output is obtained from a given input or inputs used, the efficiency is technical. On the other hand, when inputs are used in optimal ratios, allocative efficiency is determined. Where inputs are reduced to produce a given output, the technical efficiency is input-oriented. But where given inputs are employed to raise output level, technical efficiency is output-oriented (Coelli et al., 2005).

Previous researches on bank efficiency as regards to size are mixed. Berger and Humphrey (1991) found that a substantial portion of the dispersion in United States of America (USA) banks' costs were due to inefficiencies. In their findings, they reported that overall, inefficiency accounted for 25% or more of average costs. Using the Thick Frontier Analysis (TFA), Berger and Humphrey (1992) relate cost efficiency of banks with changes in costs of best-practice in 1980–1984 and 1984–1988. They employed data covering all the USA banks. Without making adjustment for business conditions in the cost of best practice changes, they found that all the banks had their average costs increased in 1980–1984, but with a decrease in 1984–1988. The smaller banks were the worst hit in the average costs increment in 1980–1984. This might be due to their heavy reliance on deposits compared with larger banks coupled with deposit rates deregulation in 1980–1984. Consequent decrease in average costs in 1984-1988 could be attributed to reduction in markets rates in the post-deregulation period that affected deposit and lending rates contemporaneously. Average costs of the banks increased in both periods when adjustments of business conditions in best-practice cost changes were made. Similarly, Sobodu and Akiode's (1995) study found bank efficiency to be declining during the period of deregulation in Nigeria using the Data Envelopment Analysis (DEA) on 1983-1993 data. Their findings contrasted with Obafemi's (2008, 2012, 2013) study whose similar approach revealed that liberalization improves bank efficiency in Nigeria, though such improvement is not sustained over time.

Tannewald (1995) also used the TFA, as well as a hybrid of Stochastic Frontier Analysis (SFA), to investigate the difference in operational efficiency among the banks in a Federal Reserve District in the US. He found a substantial dispersion in x-efficiency among the sampled banks with the peak of 51%. In Nigeria, Fadiran (2006) using the DEA also found substantial inefficiency in the country's banking sector. According to this study, there is poor quality of management in the banking industry. Omankhanlan (2013) using the DEA, however, found that the Guaranty Trust Bank Plc was the most efficient bank in Nigeria in the 2005-2009 post-consolidation era, while Oluitan (2010) employing the SFA reported bank inefficiency in Africa to have ranged between 24 percent and 26 percent of the banks' cost incurred which could be avoided if the sector operated along the efficient frontier. Besides, Kwan and Eisenbeis (1996) used SFA to examine inefficiencies among US banks. Their study found inefficiency to be more prominent among small banks. In addition, they found that inefficient firms tended to stay inefficient over time. This is similar to the study by Hughes, Jagtiani, and Mester (2016) which found large community banks to be more efficient than their small counterparts in monitoring and evaluating their credit risks. Contrary to this, Jemric and Vujcic (2002), Rao (2002) and Aiello and Bonanno (2016) found small banks to be most efficient. In the same vein, Altunbas, Liu, Molyneux, and Seth (2000) used the SFA to assess x-efficiency of Japanese banks while controlling risk. They found that x-inefficiency scores were not sensitive to risk. Larger banks were found to be more x-inefficient in Japan. Similarly, a study of Ncube (2009) showed a delimiting effect of bank size on cost efficiency of South African banks. In the same vein, a study by Saha and Dash (2016) found that bank size is irrelevant in determining whether or not the bank is efficient in India.

The results of Maudos, Pastor, Perez, and Quesada (2002) showed that in comparison with large and small European banks, only the medium banks were both profit- and cost-efficient. Their study involved banks in ten European countries over the period 1993-1996 and multiple regression-cum-DEA were employed. Kwan and Eisenbeis (1996) analyzed the x-inefficiency of USA banks in connection to their risk factors and stock returns using SFA on 1986-1991 data. They found small banks to be on average less efficient than big banks. Also, x-inefficiency of large banks varied less significantly compared with that of small banks. Besides, x-inefficiency dropped consistently. In addition, the less efficient banks took more risks and stock returns of the small banks had a significant contemporaneous relationship with their x-inefficiency level.

Jemric and Vujcic (2002) estimated efficiency of Croatian banks over the period 1995-2000 using DEA. They found that in terms of global efficiency, smaller banks fared better. However, on the basis of variable returns to scale, the large banks were seemingly efficient. Bwala (2003) investigated the relative operational efficiency of insured banks in Nigeria using TFA on quarterly data of the insured banks for 2000–2002. This analysis revealed that the least efficient banks' average costs were 262% more than those of the most efficient ones. While 92% of this difference was due to difference in the exogenous variables, the remaining 170% was due to inefficiency in the use of inputs (x-inefficiency).

2. THEORETICAL FRAMEWORK AND METHODOLOGY

This study adopted modified intermediation method credited to Drake (2003) in which performing loans and advances, investments and liquid assets are the outputs; deposits, labor, fixed assets and equity capital are inputs; interest paid on deposits and other funds, personnel expenses, depreciation of fixed assets and earnings per share are price of the inputs, respectively. The loans and advances adopted were those performing because of the huge bad debts in the Nigerian banking system. The non-parametric approach DEA modeling was employed because of the few data points, especially given the categorization of the banks into large, medium and small sizes. The samples used include deposit money banks (DMBs) that did not change their names after the 2004–2005 consolidation of banks in Nigeria. The 15 identity-retained banks out of the 24 banks operating in the country as of 2012 are listed in Appendix A. The empirical analysis covered 2001–2008 period. The year 2001 is the starting period because it was in that year that the banks became deposit money banks since the universal banking policy was abolished in the previous year, which led to the separation of commercial banks from merchant banks. In fact, all the merchant banks in the country that period opted for commercial banking. Therefore, a three-year pre-consolidation period covering 2001–2003 is used. The consolidation exercises took eighteen months which was July 2004–December 2005. Banks in the country had two financial years in this period, hence, the consolidation period for the study is 2004–2005. The period 2004–2005 was chosen because it was the period the Central Bank of Nigeria conducted official bank consolidation policy. In order to ensure a consistent basis of comparison with the pre-consolidation period, three years after the consolidation are selected as post-consolidation era which is 2006–2008. Since each of both periods cover three years, they are short-time. Also, the eighteen months' consolidation exercise is a short period, hence, the analysis is a short-time comparison. The banks were classified into small, medium and large banks based on total asset. The DEA methodology is shown in Appendix B.

3. DISCUSSION OF RESULTS

Tables 1-4 present the summaries of measured mean efficiency of the deposit money banks for the period 2001–2003. The results in Table 4 reveal that in the pre-consolidation era of 2001–2003, the technical efficiency of the big banks is 0.852, while their allocative and cost efficiencies are 0.883 and 0.741, respectively. The respective technical, allocative and cost efficiencies of the medium banks are 0.888, 0.975 and 0.867. For small banks, the technical, allocative and cost efficiencies are 0.863, 0.978 and 0.844, respectively.

Thus, the x-inefficiency of the banks in these periods is 0.259, 0.133 and 0.156, respectively, on average for big, medium and small banks. These results imply that on average, medium size banks are more technically, allocatively and cost efficient than big and small banks in Nigeria during the pre-consolidation periods. Also, the small banks exhibit higher technical, allocative and cost efficiencies compared to the big banks in the pe-

Table 1. Measured mean efficiency of the deposit money banks in 2001

Source: authors' computation.

Classification	Total assets size (N' billion)	Frequency	Technical efficiency (TE)	Allocative efficiency (AE)	Cost efficiency (CE)
Big	≥150	3	0.884	0.703	0.603
Medium	50 to < 150	2	0.852	0.981	0.839
Small	< 50	10	0.890	0.980	0.870

Table 2. Measured mean efficiency of the deposit money banks in 2002

Source: authors' computation.

Classification	Total assets size (N' billion)	Frequency	Technical efficiency (TE)	Allocative efficiency (AE)	Cost efficiency (CE)
Big	≥150	3	0.806	0.958	0.765
Medium	50 to < 150	6	0.924	0.988	0.914
Small	< 50	6	0.848	0.979	0.830

Table 3. Measured mean efficiency of the deposit money banks in 2003

Source: authors' computation.

Classification	Total assets size (N' billion)	Frequency	Technical efficiency (TE)	Allocative efficiency (AE)	Cost efficiency (CE)
Big	≥150	3	0.865	0.988	0.855
Medium	50 to < 150	7	0.889	0.956	0.848
Small	< 50	5	0.851	0.975	0.832

riods. This could be alluded to by increasing research into new banking products and services, as well as better welfare packages for the employees by the medium- and small-sized banks. In addition, the medium-sized banks had core competencies and were more focused. Most of the medium-sized banks were mainly investment banks and this gave them leverage in the industry. Only few of these medium-sized banks had subsidiaries and attracted high quality staff to drive their businesses.

The measured average efficiency scores of the banks during the period of consolidation (2004–2005) are presented in Tables 5-7. Although the trend of the efficiency scores for the two years alternated due to the peculiarity of each year, on average, big sized banks tended to be technically more efficient than medium and small banks. Also, averagely, small banks exhibited more allocative and cost efficiencies than their big- and medium-sized counterparts in the reference period. Specifically, on average, the big banks recorded technical, allocative and cost efficiencies of 0.923, 0.924 and 0.855 while the medium banks' efficiencies are 0.901, 0.979 and 0.883, respectively. The small banks' respective efficiencies, on the other hand, are 0.904, 0.989 and 0.895. The average x-inefficiencies of the big, medium and small banks are 0.145, 0.117 and 0.105, respectively. The results could be due to the fact that restructuring of big and medium sized-banks came with a lot of challenges during consolidation. Because of their large capital base, they needed to do a lot of works in terms of defining their growth pattern. There was need to restructure the perceived inefficient aspects of their operations as opposed to initiating a direct growth. They had to restructure first before growth could

Table 4. A 3-year measured average efficiency of the deposit money banks in 2001–2003 pre-consolidation period

Source: authors' computation.

Classification	Total assets size (N' billion)	Pooled frequency	Technical efficiency (TE)	Allocative efficiency (AE)	Cost efficiency (CE)
Big	≥150	9	0.852	0.883	0.741
Medium	50 to < 150	15	0.888	0.975	0.867
Small	< 50	21	0.863	0.978	0.844

Table 5. Measured mean efficiency of the deposit money banks in 2004

Source: authors' computation.

Classification	Total assets size (N' billion)	Frequency	Technical efficiency (TE)	Allocative efficiency (AE)	Cost efficiency (CE)
Big	≥200	3	0.964	0.990	0.954
Medium	100 to < 200	2	0.966	0.975	0.943
Small	< 100	10	0.887	0.982	0.873

Table 6. Measured mean efficiency of the deposit money banks in 2005

Source: authors' computation.

Classification	Total assets size (N' billion)	Frequency	Technical efficiency (TE)	Allocative efficiency (AE)	Cost efficiency (CE)
Big	≥200	5	0.882	0.857	0.755
Medium	100 to < 200	3	0.835	0.983	0.822
Small	< 100	7	0.920	0.995	0.916

Table 7. A 2-year measured mean efficiency of the deposit money banks in 2004–2005 consolidation period

Source: authors' computation.

Classification	Total assets size (N' billion)	Pooled frequency	Technical efficiency (TE)	Allocative efficiency (AE)	Cost efficiency (CE)
Big	≥200	8	0.923	0.924	0.855
Medium	100 to < 200	5	0.901	0.979	0.883
Small	< 100	17	0.904	0.989	0.895

Table 8. Measured mean efficiency of the deposit money banks in 2006

Source: authors' computation.

Classification	Total assets size (N' billion)	Frequency	Technical efficiency (TE)	Allocative efficiency (AE)	Cost efficiency (CE)
Big	≥500	4	0.868	0.953	0.825
Medium	200 to < 500	3	0.802	0.943	0.753
Small	< 200	8	0.859	0.949	0.818

Table 9. Measured mean efficiency of the deposit money banks in 2007

Source: authors' computation.

Classification	Total assets size (N' billion)	Frequency	Technical efficiency (TE)	Allocative efficiency (AE)	Cost efficiency (CE)
Big	≥500	5	0.902	0.897	0.805
Medium	200 to < 500	5	0.822	0.929	0.767
Small	< 200	5	0.829	0.975	0.805

Table 10. Measured mean efficiency of the deposit money banks in 2008

Source: authors' computation.

Classification	Total assets size (N' billion)	Frequency	Technical efficiency (TE)	Allocative efficiency (AE)	Cost efficiency (CE)
Big	≥500	9	0.816	0.991	0.810
Medium	200 to < 500	2	0.506	0.998	0.505
Small	< 200	4	0.833	0.894	0.736

Table 11. 3-year measured mean efficiency of the deposit money banks (2006–2008)

Source: authors' computation.

Classification	Total assets size (N' billion)	Pooled frequency	Technical efficiency (TE)	Allocative efficiency (AE)	Cost efficiency (CE)
Big	≥500	18	0.862	0.947	0.813
Medium	200 to < 500	10	0.710	0.957	0.675
Small	< 200	17	0.840	0.939	0.786

arise. To the small-sized banks, restructuring represents a well-focused organic growth.

Tables 8-11 show the measured mean efficiency of the banks in the 2006–2008 post consolidation period. The results in Table 11 show that the technical, allocative and cost efficiencies of the big banks are 0.862, 0.947 and 0.813, respectively.

For medium banks, the technical, allocative and cost efficiencies are 0.710, 0.957 and 0.675, respectively. But the respective technical, allocative and cost efficiencies of the small banks are 0.840, 0.939 and 0.786. So, the x-inefficiencies of the big, medium and small banks are 0.197, 0.325 and 0.214, respectively. This means that on average, the big banks are more technically and cost efficient than medium and small banks in the period after recapitalization. However, the medium banks are more allocatively efficient than big and small banks on average. This could be largely accounted for by the outcome of restructuring in the big-sized banks. The medium-sized banks continually invested in information technology, committed themselves to professionalism and had renewed loyalty to their customers.

Generally, the results in Tables 1-11 can be summarized as largely showing small banks to be more cost efficient than medium and big banks, and medium banks to be more cost efficient than big banks, but big banks take the lead in post-consolidation period efficiency. These results are similar with those obtained in the literature such as Kwan and Eisenbeis (1996), Sensarma (2006), Raphael (2012) and Hughes et al. (2016) for argument in favor of big banks, while those in favor of small banks are Rao (2002), Jemric and Vujcic (2002) and Aiello and Bonanno (2016). However, most past studies did not consider pre-, during and post-consolidation periods simultaneously. Our findings could be attributed to specialization characteristics of the small banks over the medium and big-sized banks. It was observed that big-sized banks, apart from having subsidiaries had a lot of commitments which could have made them to lose focus. The big banks were also seen to have problems with management of their credit portfolio, as well as lacking sound corporate governance. In the post-consolidation period, it was observed that there was a lot of investments by the big sized banks in the areas of technology and scale of operations, with major focus on efficiency. Emphasis was placed on employing specialists to man the business lines and investments were made based on strong management decisions. Some of the investments paid up in the short run, hence probable reason for the improvement in their efficiency after consolidation.

CONCLUSION AND RECOMMENDATIONS

This paper examined efficiency of deposit money banks in Nigeria in three years after, during and before the 2004–2005 consolidation while addressing the issue of size. Based on the study, the deposit money banks in Nigeria were more efficient during the 2004–2005 period of consolidation than in the pre-consolidation and post-consolidation periods. This suggests that internal issues such as corporate governance, management style and quality, as well as sharp practices in the banks must be paramount to regulators in making policies that would guarantee robust health of the banks. Improved corporate governance and best practice management style are critical to the banks in Nigeria in recent times because of the challenging macroeconomic environment they are operating in, which have to do with high inflation and negative growth. Some of the banks have also been confronted with harsh exposures to the downstream and upstream oil and gas sectors, as well as the power sector, hence, they need to strengthen their internal mechanisms to remain efficient. Since the small banks were the most efficient deposit money banks in Nigeria during the 2004–2005 consolidation period, there is a need to have banks categorized into small-, medium- or big-sized to meet different needs of the society such as small scale financing of businesses and mobilization of small savings. This will complement the activities of the microfinance banks in Nigeria or better still face them out of the banking sector. This is because microfinance banks in the country have not been stable since their winding up rate has remained very high.

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APPENDIX A

Banks used

1. Access Bank Plc
2. Afribank Plc
3. Citibank Nigeria Limited
4. Diamond Bank Plc
5. Ecobank Nigeria Plc
6. Equitorial Trust Bank Limited
7. First City Monument Bank Plc
8. Fidelity Bank Plc
9. First Bank of Nigeria Plc
10. Guaranty Trust Bank Plc
11. Standard Chartered Bank Nigeria Ltd
12. United Bank of Africa Plc
13. Union Bank of Nigeria Plc
14. Wema Bank Plc
15. Zenith International Bank Plc

APPENDIX B

DEA methodology

By assumption, there are *J* inputs and *K* outputs for each of *I* banks. For the *i*-th bank, these are represented by the column vector x_i and q_i, respectively. The $J \times I$ input matrix, *X*, and the $K \times I$ output matrix, *Q*, represent the data for all *I* banks. Based on the duality principle of Linear Programming (LP) approach, an envelopment form of the DEA model based on Coelli et al. (2005) is given as:

$$\begin{aligned} & Min_{\varnothing,\lambda} \varnothing, \\ & Subject\ to\ -q_i + Q\lambda \geq 0, \\ & \varnothing x_i - X\lambda \geq 0, \\ & \lambda \geq 0, \end{aligned} \tag{1}$$

The variables are inputs (x_i) and outputs (q_i). Parameters are (efficiency factor Ø and λ weights). All non-parametric methods often use weighted data which are ranked data set. Therefore, λ is used for the ranking of the data set. This approach involves using minimum inputs to produce a given output, hence it is input-oriented. This is why "Min" representing minimization is used. The projected output vector is given as $Q\lambda$ while the projected input vector is $X\lambda$. Notice that $-q_i + Q\lambda \geq 0$ implies $Q\lambda \geq q_i$ which means that projected output should be at least equal to output. In the same vein, $\varnothing x_i - X\lambda \geq 0$ connotes $\varnothing x_i \geq X\lambda$ meaning that the minimum input should be at least equal to the projected input (see Farrel, 1957; Fare et al., 1994; Coelli et al., 2005). Equation 1 which is based on Constant Returns to Scale technology is for different bank size comparison, while equation 2 that is hinged on Variable Returns to Scale technology is for same size comparison. Interpretation of this study's results on technical efficiency is therefore based on equation 1.

$$\begin{aligned}
&Min_{\emptyset,\lambda}\emptyset,\\
&Subject\ to\ -q_i + Q\lambda \geq 0,\\
&\emptyset x_i - X\lambda \geq 0,\\
&I1'\lambda = 1,\\
&\lambda \geq 0,
\end{aligned} \tag{2}$$

where I1 is an I × 1 vector of ones.

$$\begin{aligned}
&Min_{\lambda, x_{i^*}}\ p_i' x_{i^*}\\
&Subject\ to\ -q_i + Q\lambda \geq 0,\\
&x_{i^*} - X\lambda \geq 0,\\
&\lambda \geq 0,
\end{aligned} \tag{3}$$

where pi is a J × 1 vector of input prices for the i-th bank and xi* (which is calculated by the LP) is the cost. The total cost efficiency (CE) of the i-th bank is calculated as

$$CE = \frac{p_i' x_{i^*}}{p_i' x_i}. \tag{4}$$

Equation 4 implies that cost efficiency is the ratio of minimum cost to observed cost, for the i-th bank.

The (input-mix) allocative efficiency (AE) is then calculated residually as

$$AE = \frac{CE}{TE}. \tag{5}$$

The step implicitly includes any slacks in the computation of allocative efficiency. This is frequently vindicated by the fact that the slacks reveal incongruous input combination (Ferrier & Lovell, 1990).