Zimbabwe commercials banks efficiency and productivity analysis through DEA Malmquist approach: 2002-2012

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Abstract
Majority of data envelopment analysis studies have been focused on developed economies and economies in Asia, and very few studies on developing economies particularly African economies. This research aims to determine bank efficiency and productivity change of Zimbabwean commercial banks. The DEA model was used to measure the efficiency of 10 commercial banks working in Zimbabwe. The intermediation approach was used to specify variables. The average scores of technical efficiency under the Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS) assumptions for the commercial banking sector as a whole are 70.95% and 81.5% respectively. The average scale efficiency for commercial banks operating in Zimbabwe was found to be 73.7%. Through applying the Malmquist Productivity Index (MPI) method; it was found that the mean total factor productivity increase for Zimbabwean commercial banks from 2003 to 2012 is 13.8%. The results also showed that the total factor productivity index peaked in 2009 where it reached a value of 121.1% and reached the lowest point in 2005 were it went down to (-52%).

Keywords: Efficiency, Productivity, DEA, Malmquist, Commercial Banks; Zimbabwe.

1 Introduction

Commercial banks play important role to the economy of a country as it serves as an intermediation between the households and the financial sector. Therefore, the best financial system is that in which financial intermediaries perform efficiently. Such a system limits, quantifies, gathers and negotiates all operational risks and incites the savers to invest by offering them a proportional payment to the scale of the risk incurred. The risk and return therefore cannot be the same with different economies and banks (Kablan, 2007) [17].

The banking sector in Zimbabwe is currently confronted with liquidity challenges which are manifesting themselves through constrained banking sector lending capabilities, high lending rates and failure to meet customer withdrawal requirements experienced by a few banking institutions (RBZ,2014) [22]. The predominance of short-term deposits are constraining the banking sector’s potential to provide effective financial intermediation to productive sectors of the economy (RBZ, 2014) [22].
Most of the studies on bank efficiency are focussed on the developed economies. (Berger and Humphrey, 1997) [4] surveyed 130 studies that have employed DEA, only 8 were done in the developing countries and according to the researcher’s knowledge none of them was conducted in Zimbabwe. This study therefore seeks to assess the efficiency and productivity of commercial banks in Zimbabwe for the period ranging from 2002 to 2012.

2 Literature review

According to (Koopmans, 1951) [18], 100% efficiency is attained by any DMU if and only if; none of its inputs or outputs can be improved without worsening some of its other inputs or outputs. In most management or social science applications the theoretically possible levels of efficiency will not be known. According to (Cooper, 2004) [13] the relative efficiency is attained when a DMU is fully (100%) efficient on the basis of available evidence if and only if the performances of other DMUs does not show that some of its inputs or outputs can be improved without worsening some of its other inputs or outputs (Cooper, 2004) [13].

Approaches to Identification of Input-Output Variables

Intermediation Approach
The Intermediation Approach was introduced by (Sealey and Lindley, 1977) [23] and it assumes that the banks’ main aim is to transform liabilities (deposits) into loans (assets). Three categories of services, which are payment transfers, services to depositors and borrowers, and other services were identified. However, they argued that only the second activity regarding earning assets generates income. The services received by depositors of financial firms are more appropriately associated with the acquisition of economic inputs since these services require the financial firm to incur positive costs without yielding any direct revenue. The intermediation approach considers a bank’s production process to be financial intermediation behaviour related to borrowing funds from depositors and subsequently lending them to others. According to this approach, inputs include various costs of funds purchased, for instance, labour, capital, operating costs and interest expenses, while outputs are measured by monetary values of varied earning assets such as loans and investments.

Production Approach
The Production Approach (PA), which can also be referred to as value-added or service-oriented approach focuses on the services banks provide to their clients. It assumes that the banks’ aim is to produce liabilities (deposits) as well as loans (assets) and other services. One of the first studies under this approach was (Benston, 1965) [3]. His aim was to investigate which bank can produce services at the lowest cost.

Profit Approach
The profit approach is based on (Berger and Mester, 1997) [6] who stated that “use of the profit approach may help take into account unmeasured changes in the quality of banking services by including higher revenues paid for the improved quality, and may help capture the profit maximization goal by including both the costs and revenues”. However, such changes are expected to occur following any significant changes in the disposable income of citizens. (Drake, Hall and Simper 2006) [15] used employee expenses, other non-interest expenses and income / expenses from allocations to release of loan loss provisions as inputs and net interest income, net commission income and other income as outputs.
Measuring Bank Efficiency

Efficiency of a firm can be evaluated using financial ratios, the parametric approach and the nonparametric approach. Financial ratios like return on assets or cost-revenue ratios from accounting statements are commonly used by financial institutions, managers, regulators and consultants to measure efficiency of a firm (Bauer, et al. 1998) [2]. Frontier efficiency, on the other hand, measures deviations in performance from that of firms with best performance on the efficient frontier, holding constant a number of exogenous market factors like prices in local markets. It measures how well a firm performs relative to the predicted performance of the best firm in the industry, facing similar market conditions. (Bauer, et al. 1998) [2], stress that frontier efficiency is a more superior measurement than financial ratios because it uses statistical technique to remove the effect of differences in prices and other exogenous market factors affecting the standard performance ratio in order to obtain better estimates.

Data Envelopment Analysis (DEA)

According to (Berger and Humphrey, 1997) [4] DEA is a linear programming technique that is used to develop a set of best practice or frontier observations. DEA uses the piecewise linear cost or production frontier in order to connect the costs or inputs of the efficient firms in the efficiency analysis.

The CCR and the BCC DEA model

There are many extensions of the initial model published by Charnes, Cooper and Rhodes (CCR) in 1978 [12]. The CCR model was modified by Banker, Charnes and Cooper in 1984 [8] and became the BCC model which accommodates variable returns to scale. (Tone, 2001) [25] introduced the additive and slacks-based models which can accommodate both variable and constant returns to scale and take mix efficiencies into account. The return to scale assumption of the latter two models depends on whether the convexity constraint is included or not.

Input and output oriented DEA models

DEA models can either be input oriented or output oriented. The terms input and output-oriented relate to the way in which inefficient DMUs are projected onto the efficient frontier. Input-oriented models aim at reducing the input amounts by as much as possible without reducing present output levels. Output oriented models maximize output levels without increasing input consumption. The Additive Model and the Slack Based Model (SBM) deal with input excesses and output shortfalls simultaneously in a way that jointly maximizes both.

Measuring Productivity Change

The Malmquist index technique was introduced by (Caves, Christensen and Dievert 1982) [10] it became only applicable for the DEA method after the foundation of (Färe and Grosskopf, 1992) [16]. In their research, the non-parametric efficiency theory of (Farrell, 1957) was combined with the Malmquist index of (Caves, Christensen and Dievert, 1982) [10] into a DEA Malmquist index of productivity changes which is now commonly used in evaluating Total Factor Productivity (TFP) changes in the banking industry. After each efficiency score is defined for each year using DEA method, one can follow (Färe, et al, 1992) [16] to calculate the (geometric) distance m0 or TFP change between two indices of the year t and t+1. Thus, if m0 is greater than one then it means there is an improvement in TFP; otherwise the TFP has been decreasing. The Malmquist productivity index has become the standard approach in productivity measurement over time, especially when nonparametric specifications are applied to micro data. (R. Fare, et al, 1995) translated the idea of using the geometric mean of two Malmquist productivity indexes defined for translog technologies in Caves et al [10], to the nonparametric setting. They decomposed it into changes in efficiency, "catching-up", and changes in the frontiers, “technical change".
**Empirical Studies**

(Darrat, et al.2002) [14] examined the efficiency of banks in Kuwait, using the DEA. The balance sheets and income statements of eight banks were examined over the period of 1994 to 1997. The three inputs included were labour, capital, and deposits, and the outputs were loans and investments. The purpose of the results was to indicate that about 47% of the resources of the banks were not used correctly to generate profit. The small banks were found to be more efficient than the larger ones. Finally, there seemed to be a positive relationship between the profitability, capitalization, and efficiency in the Kuwaiti banking system.

(Chansarn, 2008) [11] conducted a study on the efficiency of 13 Thai commercial banks from 2003 to 2006 using the Data Envelopment Analysis technique. His research investigated the performance of Thai commercial banks in both operation and intermediation approaches. The research showed that Thai commercial banks were more efficient in operation approach than intermediation approach during 2003 to 2006. Moreover, while large, medium and small banks were all efficient in operation approach, this research also discovered that small banks were most efficient in intermediation.

(Phochathan, et al.2009) [21] also applied the same method in measuring the efficiency of eight Thai major commercial banks. However, in their research, they measured the efficiency in two periods, before the economic crisis (1993-1996) and after the economic crisis (1997-2006). In addition, they also used Malmquist index of the Thai banking industry for the whole period of 1993-2006. Their research showed that the mean value of technical and scale efficiency scores before the economic crisis period are higher than those after the economic crisis period. In addition, the results also indicated that Thai commercial banks had a rising productivity level at a decreasing rate. Moreover, they also pointed out that the return on assets and non-performing loans have affected the productivity growth of the banking industry in Thailand.

(Mukherjee, et al. 2001) [20] investigated the productivity changes of 201 large commercial banks over the initial post deregulation period, from 1984 to 1990, by means of DEA. They measured productivity growth using the Malmquist indices, and estimated the contributions of technical change, technical efficiency change and scale change to calculate productivity growth. They found overall productivity growth at a rate of 4.5% per year on average, however, productivity dropped by 7.61% between 1984 and 1985 and 0.33% between 1988 and 1989. Applying a DEA and Malmquist Productivity Index, (Sufian, 2006) [24] investigated the efficiency and productivity of Malaysian banks for the period of 1998-2003. He found that Malaysian banks exhibited the highest mean overall efficiency score in 2000. It was found however, that Malaysian banks mean overall efficiency scores declined steadily in 2003, which could be attributed to the intensification of competition and sluggish loan growth.

(Yousif, 2007) [27] conducted a study aimed to measure and break down the technical efficiency of the banks in Palestine through the period from 2002 to 2005. In this research, he presented the mathematical background and characteristics of DEA model, and measured the efficiency of 16 banks out of the 21 banks working in Palestine. To measure technical efficiency, two basic models of the DEA were used under the assumptions of constant returns to scale and the variable returns to scale; the study found that, there were differences among banks in relation to their technical efficiency scores, and the average pure technical efficiency score was 96.3%. The main source of overall technical inefficiency was caused by the scale problem. The study compared the efficiency scores between local and foreign banks and found that local banks had a higher averaged score of technical efficiency than foreign banks, but the difference was statistically insignificant.

**3 Research Methodology**

This research employed secondary data. The data was collected from yearly financial statements of Zimbabwean commercial banks for the period under analysis (2003 to 2012). In this study annual data for loans, deposits and operating expenses were collected for the period 2003-2012 and were used as inputs in
Data Envelopment Analysis (DEA) in order to obtain the efficiency scores for the different banks. The intermediation approach was used in selecting bank inputs and outputs, deposits (Xij) and operating costs (X2j) were considered as inputs. Loans and advances (Y1j) were considered as outputs.

Sample Population
In order to provide a more precise and accurate estimation on the efficiency scores, this study limits the sample to 10 commercial banks that have at least 10 years of complete dataset. The sample consists of six private domestic-owned banks namely: Commercial Bank of Zimbabwe (CBZ), First Banking Corporation (FBC), NMBZ, MBCA, Metropolitan Bank and Kingdom bank; One state owned bank (ZB Bank formerly Zimbank), and three foreign-owned banks, namely: Barclays bank, Standard Chartered Bank and Stanbic bank.

Application of Data Envelopment Analysis (DEA) in measuring bank efficiency
DEA is a nonparametric method in operations research; it is used for the estimation of efficient frontiers and to measure the performance of DMUs such as banks. This methodology, first explained by Charnes et al. (1978) [12] defined efficiency as a weighted sum of outputs to a weighted sum of inputs. The main hypothesis behind this is that, inputs are considered similar and equal for all banks as they operate in the same market for money and services. Each bank is treated as a different bank in a different period which can increase the number of data points. Therefore, small sample sizes problem can be solved.

Among a number of DEA models, this study uses the two most frequently used models: the CCR model (Charnes, Cooper and Rhodes 1978) [12] and the BCC-(Banker, Charnes and Cooper 1984) [8]. The main difference between these two models is the treatment of returns to scale: while the latter allows for variable returns to scale, the former assumes that each DMU operates with constant returns to scale.

The CCR DEA MODEL
The algebraic model for the CCR (input based) ratio form is as follows:

\[
\max_{u,v} h_c(u, v) = \frac{\sum_{r=1}^{s} U_r Y_{rc}}{\sum_{i=1}^{m} V_i X_{ic}}
\]  

Subject to:

\[
\frac{\sum_{r=1}^{s} U_r Y_{rf}}{\sum_{i=1}^{m} V_i X_{ij}} \leq 1, j = 1, 2, \ldots, n
\]  

\[
u_r \geq 0, \quad r = 1, 2, \ldots, s
\]  

\[
v_i \geq 0, \quad i = 1, 2, \ldots, m
\]  

Where;

c = a specific bank to be evaluated, Yrf = the amount of output r from bank j, Xij = the amount of input i to bank j, Ur = weight chosen for output r , Vi = weight chosen for input i, n = number of banks, s = the number of outputs, m = the number of inputs.

The objective function defined by \( h_c \) aims to maximise the ratio of weighted outputs to weighted inputs of the bank under scrutiny. This is subject to the constraint that any other bank in the sample cannot exceed unit efficiency by using the same weights. It is important to note that these weights are assumed to be unknown, but obtained through optimisation.

Such optimisation is performed separately for each unit in order to compute the weights and the efficiency measure \( h_c \). The problem setting in (3.1) is a fractional program. This can be converted into linear program (LP) form by restricting the denominator of the objective function \( h_c \) to unity, and adding this as a constraint.
to the problem. The LP version of the fractional setting is shown in model (3.5):

$$\max_h \ h_c = \sum_{r=1}^{s} U_c Y_{rc}$$

(3.5)

Subject to:

$$\sum_{i=1}^{m} V_i X_{ic} = 1$$

(3.6)

$$\sum_{r=1}^{s} U_c Y_{rj} - \sum_{r=1}^{s} V_{ic} X_{ij} \leq 0, j = 1,2, \ldots, n$$

(3.7)

$$u_r \geq 0, \quad r = 1,2, \ldots, s$$

(3.8)

$$v_i \geq 0, \quad i = 1,2, \ldots, m$$

(3.9)

The maximising LP setting in (3.5) assumes constant returns to scale technologies. When the formulation constrains the weighted sum of the inputs to unity as in (3.5), and maximises the outputs, this becomes an input-based efficiency measurement. That means, given outputs, banks minimise the use of inputs.

One possible solution to the LP (the primal) in (3.5) is to formulate a dual companion. By denoting the input weights of bank $c$ by $\theta_c$ and the input and output weights of other banks in the sample by $\lambda_j$ the dual form of the maximising problem is formalised as follows:

**Dual**

$$\min_h \ h_c = \theta_c$$

(3.10)

Subject to:

$$\sum_{j=1}^{n} \lambda_j Y_{rj} - s_i^+ = y_{rc}$$

(3.11)

$$\sum_{j=1}^{n} \lambda_j X_{rj} - s_i^- = \theta_c x_{ic}$$

(3.12)

$$\lambda_j; s_i^-; s_i^+ \geq 0, \quad j = 1, \ldots, n$$

(3.13)

The bank $c$ is regarded as efficient if the $\theta_c$ is equal to one and the slacks ($s_i^-$ and $s_i^+$) are zero. That is, if and only if,

$$h_c^* = 1 \text{ with } s_i^- = s_i^+ = 0, \text{ for all } c \text{ and } j$$

The asterisk denotes optimal values of the variables in the dual. It is important to note that these conditions are also the conditions for Pareto efficiency. When the bank is fully efficient, it is impossible to improve its observed values of input or output without worsening other input or output values. The bank is regarded as inefficient if the $\theta_c$ is less than one and/or positive slack variables. For these inefficient banks, the optimal values of $\lambda_j$ construct a hypothetical bank, which is formed by the subset of the efficient banks.
It is important to note that the inclusion of $\sum_{j=1}^{n} \lambda_j = 1$ as an extra constraint to the model (3.10) considers the variable returns to scale (VRS) in the production (Banker, Charnes and Cooper 1984) [8] DEA efficiency scores are used as performance indicators to determine whether the banks are operating in a technically efficient way. Hence, it is also of considerable interest to explain DEA efficiency scores by investigating the determinants of technical efficiency. As defined in equations (3.1) to (3.11) the DEA score falls between the interval 0 and 1 (0<h*≤1), making the dependent variable a limited dependent variable.

The BCC DEA Model
The absence of constraints for the weights $\lambda_j$, other than the positivity conditions in the problem (3.11), implies constant returns to scale. For allowing variable returns to scale, it is necessary to add the convexity condition for the weights $\lambda_j$, i.e. to include in the model (3.11) the constraint:

$$\sum_{j=1}^{n} \lambda_j = 1$$  \hspace{1cm} (3.14)

The resulting DEA model that exhibits variable returns to scale is called the BCC-model, after Banker, Charnes and Cooper (1984) [8]. The input-oriented BCC-model for the DMU0 can be written formally as:

$$\min_{\lambda} z_0 = \theta_0$$  \hspace{1cm} (3.15)

Subject to:

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{ro}, \hspace{0.5cm} r = 1,2,\ldots,s$$  \hspace{1cm} (3.16)

$$\theta_0 x_{i0} - \sum_{j=1}^{n} \lambda_j x_{ij} \geq 0, \hspace{0.5cm} i = 1,2,\ldots,m$$  \hspace{1cm} (3.17)

$$\sum_{j=1}^{n} \lambda_j = 1$$  \hspace{1cm} (3.18)

$$\lambda_j \geq 0, \hspace{1cm} j = 1,2,\ldots,n$$  \hspace{1cm} (3.19)

The BCC-efficiency scores are obtained by running the above model for each DMU (with similar interpretation of its values as in the CCR-model). These scores are also called “pure technical efficiency scores”, since they are obtained from the model that allows variable returns to scale and hence eliminates the “scale part” of the efficiency from the analysis. Generally, the CCR-efficiency score for each DMU will not exceed the BCC-efficiency score, which is intuitively clear since the BCC-model analyses each DMU “locally” (i.e. compared to the subset of DMUs that operate in the same region of returns to scale) rather than “globally”.

Malmquist TFP Index
When one has panel data, one may use DEA-like linear programs and a (input or output based) Malmquist TFP index to measure productivity change into technical change and technical efficiency change. When selecting variables for the model, the intermediation approach was chosen because the objective is to test the efficiency change of the ‘intermediation’ process of the banks raäther than the production process. Following (Färe and Grosskopf 1992) [16] the output oriented Malmquist productivity change index will be adopted for this study. Output orientation refers to the emphasis on the equi-proportionate increase of outputs, within the context of a given level of input.
Fare, et al. 1994) specify an output based Malmquist productivity change index as:

\[
m_0(y_{t+1}, x_{t+1}, y_t, x_t) = \left[ \frac{d_0^t(x_{t+1}, y_{t+1})}{d_0^t(x_t, y_t)} \times \frac{d_0^{t+1}(x_{t+1}, y_{t+1})}{d_0^{t+1}(x_t, y_t)} \right]
\]  

(3.20)

This represents the productivity of the production point \((x_{t+1}, y_{t+1})\) relative to the production point \((x_t, y_t)\).

A value greater than one indicates positive TFP growth from period \(t\) to period \(t+1\). This index is in fact, the geometric mean of two output based Malmquist TFP indices. One index uses period \(t\) technology and the other period \(t+1\) technology. To calculate equation (3.21) we must calculate the four component distance functions, which will provide four LP problems.

The CRS output oriented LP used to calculate \([d_0^t(x_t, y_t)]^{-1}\) is similar to the input oriented DEA model except that the VRS restriction has been removed and time subscripts have been included. That is,

**First LP**

\[
[d_0^t(x_t, y_t)]^{-1} = \max_{\Phi, \lambda} \Phi
\]

Subject to:

\[
-\Phi y_{i,t} + Y_t \lambda \geq 0
\]

\[\lambda \geq 0\]  

(3.22)

(3.23)

The remaining three LP problems are simple variants of this:

**Second LP**

\[
[d_0^{t+1}(x_{t+1}, y_{t+1})]^{-1} = \max_{\Phi, \lambda} \Phi
\]

Subject to:

\[
-\Phi y_{i,t+1} + Y_{t+1} \lambda \geq 0
\]

\[\lambda \geq 0\]  

(3.25)

(3.26)

**Third LP**

\[
[d_0^t(x_t, y_t)]^{-1} = \max_{\Phi, \lambda} \Phi
\]

Subject to:

\[
-\Phi y_{i,t} + Y_t \lambda \geq 0
\]

\[x_{i,t+1} + X_t \lambda \geq 0
\]

\[\lambda \geq 0\]  

(3.29)

(3.30)

**Fourth LP**

\[
[d_0^{t+1}(x_t, y_t)]^{-1} = \max_{\Phi, \lambda} \Phi
\]

Subject to:

\[
-\Phi y_{i,t} + Y_{t+1} \lambda \geq 0
\]

\[x_{i,t+1} - X_t \lambda \geq 0
\]  

(3.33)
\[ \lambda \geq 0 \]  

(3.34)

In the third LP and fourth LP, where production points are compared to technologies from different time periods, the parameter \( \Phi \) need to be \( \leq 1 \). If technological progress has occurred, then a value of \( \Phi < 1 \) is possible. The \( \Phi \) and \( \lambda \)s are likely to take different values in the above four LPs. The above four LPs must be calculated for each DMU in the sample. As you add extra time periods, you must calculate an extra three LPs for each firm to construct a chained index. If you have \( T \) time periods, you must calculate \((3T-2)\) LPs. Results on each and every firm for each and every adjacent pair of time periods can be tabulated and summary measures across time can be presented.

**Malmquist TFP index and Scale Efficiency**

The above approach can be extended by decomposing the (CRS) technical efficiency change into scale efficiency and pure (VRS) technical efficiency components. This involves calculating two additional LPs (when comparing two production points). These would involve repeating first and second LPs with convexity restriction \((N\lambda = 1)\) added to each. One can use the CRS and VRS values to calculate the scale efficiency effect residually.

### 4 Data analysis and interpretation

DEAP2.1 statistical software was used to determine efficiency scores and productivity change indices.

**Technical Efficiency (TE) Results (Assuming Constant Returns to Scale)**

Table 1 below presents the CRS technical efficiency scores for 10 commercial banks used in this study. The simple DEA model is based on the constant returns to scale assumption (CRS), implying that the size of the bank is not relevant in assessing efficiency. CRS scores are composed of non-additive combination of pure technical efficiencies. A ratio of the overall CRS technical efficiency scores to VRS technical efficiency scores provides scale efficiency scores. A fully technical efficient bank needs to achieve a score of 1 (100%). A score less than 1 reflect that a bank is wasting resources, hence technically inefficient.

<table>
<thead>
<tr>
<th>Bank</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barclays</td>
<td>0.14</td>
<td>1</td>
<td>0.95</td>
<td>0.77</td>
<td>0.54</td>
<td>0.34</td>
<td>0.2</td>
<td>0.26</td>
<td>0.24</td>
<td>0.48</td>
<td>0.492</td>
</tr>
<tr>
<td>CBZ</td>
<td>0.78</td>
<td>0.9</td>
<td>0.88</td>
<td>0.6</td>
<td>0.53</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.869</td>
</tr>
<tr>
<td>FBC</td>
<td>0.46</td>
<td>0.73</td>
<td>1</td>
<td>0.84</td>
<td>0.6</td>
<td>0.87</td>
<td>0.24</td>
<td>0.65</td>
<td>0.66</td>
<td>0.9</td>
<td>0.695</td>
</tr>
<tr>
<td>Kingdom</td>
<td>0.95</td>
<td>0.94</td>
<td>0.42</td>
<td>0.8</td>
<td>0.93</td>
<td>0.71</td>
<td>1</td>
<td>0.75</td>
<td>0.93</td>
<td>1</td>
<td>0.843</td>
</tr>
<tr>
<td>MBCA</td>
<td>0.86</td>
<td>0.72</td>
<td>1</td>
<td>0.83</td>
<td>0.57</td>
<td>0.43</td>
<td>0.78</td>
<td>0.74</td>
<td>0.56</td>
<td>0.779</td>
<td>0.7269</td>
</tr>
<tr>
<td>Metbank</td>
<td>0.9</td>
<td>1</td>
<td>0.55</td>
<td>0.75</td>
<td>1</td>
<td>0.68</td>
<td>0.61</td>
<td>0.8</td>
<td>0.67</td>
<td>0.838</td>
<td>0.7798</td>
</tr>
<tr>
<td>NMBZ</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.78</td>
<td>0.55</td>
<td>0.44</td>
<td>1</td>
<td>0.83</td>
<td>0.927</td>
<td>0.8527</td>
</tr>
<tr>
<td>Stanbic</td>
<td>1</td>
<td>0.22</td>
<td>1</td>
<td>1</td>
<td>0.19</td>
<td>0.33</td>
<td>0.88</td>
<td>1</td>
<td>0.88</td>
<td>0.989</td>
<td>0.7489</td>
</tr>
<tr>
<td>Stanchart</td>
<td>0.91</td>
<td>0.36</td>
<td>0.62</td>
<td>0.62</td>
<td>0.6</td>
<td>0.51</td>
<td>0.26</td>
<td>0.55</td>
<td>0.46</td>
<td>0.79</td>
<td>0.568</td>
</tr>
<tr>
<td>ZB Bank</td>
<td>0.54</td>
<td>0.5</td>
<td>0.64</td>
<td>0.47</td>
<td>0.52</td>
<td>0.28</td>
<td>0.35</td>
<td>0.7</td>
<td>0.58</td>
<td>0.618</td>
<td>0.5198</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>0.754</td>
<td>0.747</td>
<td>0.808</td>
<td>0.796</td>
<td>0.633</td>
<td>0.523</td>
<td>0.576</td>
<td>0.745</td>
<td>0.681</td>
<td>0.8321</td>
<td>0.70951</td>
</tr>
</tbody>
</table>

The results presented in table 1 above reveal that the banks used in this study achieved a mean technical efficiency of 70.95% between 2003 and 2012 under the CRS assumption. The results imply that the banks on average are wasting 29.05% of the inputs used generate output. The banks are able to produce the current output using only 70.95% of their current inputs. Furthermore the summary of bank means reflects that CBZ is the most technical efficient bank given the CRS assumption. CBZ has an average technical efficiency score of 86.9%. The score shows that the bank on average utilises 86.9% of its inputs to produce output. Table 1 also shows that CBZ achieved full efficiency for five years during the period under consideration.
In contrast, Barclays is the least technical efficient bank on average with a score of 49.2%. The score implies that the bank wastes 50.8% of its inputs used to generate output on average.

Figure 1: CRS TE Results

Figure 1 shows the yearly means of the CRS technical efficiency scores. The graph shows that the banks achieved their highest CRS technical efficiency average in 2005 with a mean of 81%. The lowest CRS technical efficiency average was recorded in 2008 (51.6%), implying that the banks wasted 48.4% of their inputs on average which could be attributed to the economic recession and the resultant hyperinflation experienced in Zimbabwe in that year.

Variable Returns to Scale (VRS) TE Results

The CRS model asserts that the size of a bank is irrelevant when assessing efficiency. However, it is likely that the size of the bank will influence the ability of a bank to provide services more efficiently. A VRS frontier allows the best practice level of outputs to inputs to vary with size. The VRS efficiency scores are better than the CRS efficiency scores because in the VRS model banks are benchmarked with banks of the similar size. The VRS is less restrictive and shows better performances of the sector as compared to the CRS model. An efficiency score equal to 1 indicates that a bank is fully efficient, which means a bank is minimising the inputs at a given output level. Table 2 below represents the VRS technical efficiency results for 10 commercial banks used in this study.

<table>
<thead>
<tr>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barclays</td>
<td>0.34</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.13</td>
<td>0.25</td>
<td>0.3</td>
<td>0.34</td>
<td>0.46</td>
</tr>
<tr>
<td>CBZ</td>
<td>0.84</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.7</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>FBC</td>
<td>0.51</td>
<td>0.98</td>
<td>1</td>
<td>0.91</td>
<td>0.63</td>
<td>1</td>
<td>0.28</td>
<td>0.68</td>
<td>0.76</td>
<td>1</td>
</tr>
<tr>
<td>Kingdom</td>
<td>1</td>
<td>1</td>
<td>0.5</td>
<td>0.81</td>
<td>1</td>
<td>1</td>
<td>0.75</td>
<td>1</td>
<td>0.72</td>
<td>1</td>
</tr>
<tr>
<td>MBCA</td>
<td>0.92</td>
<td>0.73</td>
<td>1</td>
<td>0.9</td>
<td>0.84</td>
<td>1</td>
<td>0.81</td>
<td>1</td>
<td>0.93</td>
<td>1</td>
</tr>
<tr>
<td>Metbank</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.17</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>NMBZ</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.79</td>
<td>0.08</td>
<td>0.66</td>
<td>1</td>
<td>0.95</td>
<td>1</td>
</tr>
<tr>
<td>Stanbic</td>
<td>1</td>
<td>0.22</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.88</td>
<td>1</td>
<td>0.9</td>
<td>1</td>
</tr>
<tr>
<td>Stanchart</td>
<td>1</td>
<td>0.45</td>
<td>0.94</td>
<td>0.83</td>
<td>1</td>
<td>0.26</td>
<td>0.28</td>
<td>0.57</td>
<td>0.53</td>
<td>0.65</td>
</tr>
<tr>
<td>ZB Bank</td>
<td>0.59</td>
<td>0.57</td>
<td>0.83</td>
<td>0.48</td>
<td>0.8</td>
<td>0.67</td>
<td>0.42</td>
<td>0.7</td>
<td>0.64</td>
<td>1</td>
</tr>
<tr>
<td>Mean</td>
<td>0.82</td>
<td>0.795</td>
<td>0.927</td>
<td>0.893</td>
<td>0.906</td>
<td>0.601</td>
<td>0.658</td>
<td>0.8</td>
<td>0.805</td>
<td>0.815</td>
</tr>
</tbody>
</table>

As shown by table 2 above, the commercial banks are 80% technically efficient on average. The results also suggest that the banks are wasting 20% of their inputs on average. The most technically efficient bank is
CBZ (95%) and the least efficient bank is Barclays bank (58%). This implies that, on average, CBZ utilises 95% of its inputs to generate outputs and Barclays wastes 42% of its inputs used to generate output. CBZ achieved full efficiency (a score of 1) for 8 years during the period under consideration while Barclays only achieved full efficiency for 4 years.

Figure 2 above shows the VRS technical efficiency results for 10 commercial banks used in this study. The results show that the commercial banks were most efficient in 2005 (93%) and were least efficient in 2008 (60%) which can be attributed to the effects of hyperinflation. In 2005, seven banks achieved full efficiency and only three banks were found to be inefficient. On the other hand in 2008 only 4 banks were fully efficient (recorded a score of one); hence the mean efficiency was the lowest in that year.

**Scale efficiency Results**

A bank operating at optimum scale needs to achieve a scale efficiency score of 1 (one). An efficiency score which is less than one show that a bank is operating at a scale too large or too small. If a bank is operating in a region of decreasing returns to scale (DRS), this implies that it is operating on a scale that is too large. If a bank is operating in a region of increasing returns to scale (IRS), this implies that the bank is operating at a scale that is too small. Table 3 below presents the scale efficiency results for each of the 10 commercial banks used in this study.

According to table 3 above, the average scale efficiency score for commercial banks in Zimbabwe is 0.84 which translates to 84%. This implies that the actual scale of production for Zimbabwean commercial banks diverged from the most productive scale size by 16%. The least scale efficient bank is Barclays (71%)
meaning that its scale of operation diverges from the optimum scale of operations by 29%. Table 3 also confirms that NMBZ has the highest scale efficiency (94%).

![Scale Efficiency](image)

Figure 3: Scale Efficiency Results

Figure 3 above shows the scale efficiency for the 10 commercial banks used in this study. The graph reflects that the commercial banks were most efficient in 2010 where the mean scale efficiency score is 93% implying that the actual scale of production for Zimbabwean commercial banks in 2010 only diverged from the most productive scale by 7%. The least scale efficiency average was recorded in 2007 where the banks achieved a mean scale efficiency score of 73.7% which could be attributed to the effects of hyperinflation during that period.

**Improvements in inputs and outputs**

Table 4 below shows the required improvements in variables for each bank in 2012 in order for the inefficient banks to reach the efficiency frontier. The original value of each variable represents the actual value of the variable (data entered to the model), radial and slack movements represent the potential improvement needed for the variable in order to reach the efficiency frontier, and projected value represents the target value for each variable (output or input), the difference between the original value and the projected value is the improvement needed for each variable.
According to table 4 above, only Kingdom and CBZ were fully efficient in 2012, hence the projected values were the same as original values for both banks. As for the remaining banks, there is need for improvements in inputs for the banks to reach the efficiency frontier. For example, in the case of ZB bank, it was necessary for the bank to reduce its operating costs by $29,521,000 and the bank should have targeted $133,975,000 in deposits to be technically efficient.

### Total Factor Productivity Results

The Malmquist TFP index calculates the change in productivity between two points by estimating the ratio of the distances of each point relative to a common technology. An index which is greater (less) than one also reflects an efficiency increase (decrease) or technical progress (regress). Similarly, the overall efficiency change is the product of pure technical efficiency and scale efficiency changes. The advantage of the Malmquist index is that it allows the researcher to distinguish between shifts in the production frontier (technological change, TECHCH) and movements of firms towards the frontier technical efficiency change.
EFFCH). Table 5 below presents the efficiency change, technical change, pure technical change, scale efficiency change and the total factor productivity change for 10 commercial banks used in this study.

Table 5: Malmquist Index Summary of Banks Means

<table>
<thead>
<tr>
<th>Bank</th>
<th>Effch</th>
<th>Techch</th>
<th>Pech</th>
<th>Sech</th>
<th>Tfpch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barclays</td>
<td>1.148</td>
<td>0.962</td>
<td>1.138</td>
<td>1.009</td>
<td>1.105</td>
</tr>
<tr>
<td>CBZ</td>
<td>1.028</td>
<td>0.954</td>
<td>1.017</td>
<td>1.011</td>
<td>0.98</td>
</tr>
<tr>
<td>FBC</td>
<td>1.077</td>
<td>1.016</td>
<td>1.08</td>
<td>0.997</td>
<td>1.095</td>
</tr>
<tr>
<td>Kingdom</td>
<td>1.006</td>
<td>0.915</td>
<td>1.001</td>
<td>1.005</td>
<td>0.921</td>
</tr>
<tr>
<td>MBCA</td>
<td>0.989</td>
<td>1.03</td>
<td>1.01</td>
<td>0.979</td>
<td>1.019</td>
</tr>
<tr>
<td>Methbank</td>
<td>0.993</td>
<td>1.069</td>
<td>1</td>
<td>0.993</td>
<td>1.061</td>
</tr>
<tr>
<td>NMBZ</td>
<td>0.992</td>
<td>1.022</td>
<td>1</td>
<td>0.992</td>
<td>1.013</td>
</tr>
<tr>
<td>Stanbic</td>
<td>0.999</td>
<td>1.007</td>
<td>1</td>
<td>0.999</td>
<td>1.005</td>
</tr>
<tr>
<td>Stanchart</td>
<td>0.985</td>
<td>1.003</td>
<td>0.976</td>
<td>1.009</td>
<td>0.988</td>
</tr>
<tr>
<td>ZB Bank</td>
<td>1.015</td>
<td>1.038</td>
<td>1.023</td>
<td>0.993</td>
<td>1.054</td>
</tr>
<tr>
<td>Average</td>
<td>1.0232</td>
<td>1.0016</td>
<td>1.0245</td>
<td>0.9987</td>
<td>1.0241</td>
</tr>
</tbody>
</table>

Table 5 shows that the mean Total Factor Productivity (TFP) increase for Zimbabwean commercial banks from 2003 to 2012 is 2.41%. This figure consists of an efficiency gain of a 2.32%, a technological gain of 0.16%, a scale efficiency decrease of 0.13% and pure efficiency gain of 2.45%.

![Figure 4: Bank Total Factor Productivity Changes](image)

Figure 4 above show that Barclays recorded the highest average positive increase in total factor productivity of 10.5%. The 10.5% productivity gain for Barclays consists of an efficiency gain of 14.8% and technological regress of 3.8%. Kingdom bank recorded the lowest average total factor productivity change with an average decline of 7.9% in total factor productivity. This 7.9% decline consists of an efficiency gain of 0.6% and technological regress of 8.5%. The results also show that 7 out of 10 banks used in this study exhibited overall gain in productivity and three banks exhibited an overall loss in productivity.
Table 6: Malmquist Index of Annual Means

<table>
<thead>
<tr>
<th>Year</th>
<th>effch</th>
<th>techch</th>
<th>pech</th>
<th>sech</th>
<th>tfpch</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>0.676</td>
<td>1.696</td>
<td>0.922</td>
<td>0.733</td>
<td>1.146</td>
</tr>
<tr>
<td>2005</td>
<td>0.951</td>
<td>0.507</td>
<td>0.963</td>
<td>0.987</td>
<td>0.482</td>
</tr>
<tr>
<td>2006</td>
<td>1.479</td>
<td>0.906</td>
<td>1.143</td>
<td>1.294</td>
<td>1.34</td>
</tr>
<tr>
<td>2007</td>
<td>1.004</td>
<td>0.847</td>
<td>1.309</td>
<td>0.767</td>
<td>0.85</td>
</tr>
<tr>
<td>2008</td>
<td>0.473</td>
<td>1.083</td>
<td>0.431</td>
<td>1.097</td>
<td>0.512</td>
</tr>
<tr>
<td>2009</td>
<td>1.624</td>
<td>1.361</td>
<td>1.357</td>
<td>1.197</td>
<td>2.211</td>
</tr>
<tr>
<td>2010</td>
<td>0.87</td>
<td>1.928</td>
<td>0.927</td>
<td>0.938</td>
<td>1.677</td>
</tr>
<tr>
<td>2011</td>
<td>1.512</td>
<td>0.652</td>
<td>1.428</td>
<td>1.058</td>
<td>0.986</td>
</tr>
<tr>
<td>2012</td>
<td>1.264</td>
<td>0.822</td>
<td>1.199</td>
<td>1.055</td>
<td>1.039</td>
</tr>
<tr>
<td>Average</td>
<td>1.094778</td>
<td>1.089111</td>
<td>1.075444</td>
<td>1.014</td>
<td>1.138111</td>
</tr>
</tbody>
</table>

As shown by table 6 above, the mean total factor productivity increase for Zimbabwean commercial banks was 13.8% from 2003 to 2012. This figure is composed of an efficiency gain of 9.48% and a technological gain of 8.91%; it can also be noted that the average total factor productivity increase was highest in 2009 (121.1%) and was lowest in 2005 (-52%). An increase in TFP can be noted in 2004, 2006, 2009, and 2010. A decrease in TFP is evident in 2005, 2007, 2008, and 2011.

Figure 5: Annual TFP Change

Figure 5 shows that the total factor productivity index peaked in 2009 where it reached a value of 121.1% which can be attributed to the dollarization of the economy. This is in sharp contrast with the 2005 index (-52%) which was the lowest in this study period. The total factor productivity index has since declined from 2009; end up at 22.2% in 2012.

5 Conclusions

The research measured the technical efficiency of the commercial banks in Zimbabwe and found out the score for each bank relative to other banks. It was found that there are differences among banks in their technical efficiency scores. The research determined that the average technical efficiency scores under the Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS) assumptions for the commercial
banking sector as a whole to be 70.95% and 81.5% respectively, which answered the first research question, and fulfilled the first objective which is “Determining the efficiency of commercial banks in Zimbabwe using DEA”.

It was also shown that the commercial banks in Zimbabwe operate at an inappropriate scale efficiency (84.39%), which answered the second research question and fulfilled the second research objective which is “establishing the scale economies of commercial banks in Zimbabwe using DEA”. The results also showed that the commercial banks were most efficient in 2010 where the mean scale efficiency score was 93% and the least scale efficiency average was recorded in 2007 where the banks achieved a mean scale efficiency score of 73.7%.

As a result of the findings, improvements in variables (outputs and inputs) were suggested for inefficient banks in order to reach the efficiency frontier. These improvements answered the third research question and fulfilled the third research objective which is “Determining the improvements in inputs and outputs for inefficient banks to reach the efficiency frontier.” This research also showed that the mean total factor productivity increase for Zimbabwean commercial banks was 13.8% between 2003 and 2012, which answered the fourth research question, and fulfilled the fourth objective which is determining total factor productivity change and efficiency change using Malmquist DEA methods. The results also showed that the total factor productivity index peaked in 2009 where it reached a value of 121.1% and reached the lowest point in 2005 where it went down to (-52%).

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