INTERNATIONAL JOURNAL OF ECONOMICS AND FINANCE STUDIES
Vol: 14 **No:** 04 **Year:** 2022 **ISSN**: 1309-8055 (Online) (**pp.** 152-186) **Doi:** 10.34109/ijefs. 20220109
Received: 11.08.2022 | **Accepted:** 22.12.2022 | **Published Online:** 31.12.2022

-RESEARCH ARTICLE-

HOW EFFICIENT IS THE SOUTH AFRICAN BANKING SECTOR?

Chris van Heerden

School of Economics at the Potchefstroom Campus of
North-West University, South Africa
Email: Chris.vanheerden@nwu.ac.za
https://orcid.org/0000-0001-8074-0719

─Abstract─

Literature has failed to provide a sufficient long-term relative efficiency overview of the South African banking sector, which might aid bank management in establishing strategies to ensure profitability and long-term sustainability through improved resource management. This study utilized Coelli's (1998) multi-stage data envelopment analysis (DEA) technique to assess the technical and scale efficiency of 26 banks over 17 years (January 2004-December 2020). According to the findings, the top South African banks failed to meet expectations, as they could not consistently demonstrate comprehensive technical and scale efficiency. Moreover, the results show that banks have slowly recovered from the global financial crisis. The bank regulatory authority must also address the fact that several banks continue to demonstrate inefficient efficiency. Suppose future bank legislation aims to reduce risk sensitivity and the use of internal models in decision-making. In that case, it is suggested that the forthcoming Basel Accord include an additional prudential, all-inclusive tool derived from non-financial measure methodology to provide greater insight into resource management. By imposing a penalty on banks that demonstrate poor resource management, the government will encourage greater market disclosure and drive banks to operate more effectively, particularly during volatile times.

Keywords: DEA; banking stability; banking legislation; bank management; bank recovery; resource management; scale and technical efficiency; South African banking sector

JEL classification: C14, G21.

Citation (APA): Heerden, C. V. (2022). How Efficient is the South African Banking Sector?. *International Journal of Economics and Finance Studies, 14* (04), 152-186. doi:10.34111/ijefs. 20220109

1. INTRODUCTION

A well-functioning banking industry helps economic growth and development through the effective allocation of resources and diversification of risk, which can be called the lifeblood of most economies (Maredza et al., 2013). Compared to other industrial nations, South Africa's banking sector is properly regulated, well-developed, well-capitalized, and supported by a good legal framework. This industry could also mitigate some of the adverse consequences of the 2008-2009 financial crisis (Quiding, 2006; The Banking Association of South Africa, 2014; Oxford Business Group, 2014). With the South African banking sector's total assets-to-gross domestic product (GDP) ratio nearing 200% by 2020 [figures taken from SARB (2022a; 2022b)], it is crucial for the depositor, investor, and regulator that this sector is efficient and competitive (Yue, 1992). Specifically, the growth of financially reliant companies is necessary (Claessens et al., 2005) and to secure the long-term stability of banks (Chen, 2009).

Nonetheless, the South African banking system has become oligopolistic (Coppock et al., 2008), as the five largest bank-holding corporations control more than 90 percent of the sector's total assets (SARB, 2022c). In addition, the South African banking system has been vulnerable to several external variables, legislative changes, and political pressures during the past two decades, casting doubt on its ability to assure long-term efficiency. For instance, the significant volatility of currency rates between 2002 and 2004, the adoption of the Financial Sector Charter (2004), Basel I (2004), Basel II (2008), and Basel III (2013), the National Credit Act (2007), and the revision of the Bank Act (no. 3 of 2015) was noted (Cronje, 2007; BIS, 2011; KPMG, 2011). The implementation of the Financial Sector Regulation Bill of 2015 (SARB, 2016a); the implementation of the Twin Peaks system in 2016 (SARB, 2016b); political instability and downgrades (Fin24, 2017a; 2017b); and the negative effects of the COVID-19 virus (Deloitte, 2020) also impeded the ability of banks to maintain previous efficiency levels.

In addition, government efforts on banks to increase their exposure to microloans and the rise in the number of foreign banks exerted even more pressure on the historical performance of South African banks (Cronje, 2003). Claessens et al. (2001) confirm that the increased presence of foreign banks is associated with a decline in the profitability and margins of South African banks, thereby exposing them to a greater competitive threat and compelling them to enhance their innovative strategies and customer service. Yet, according to several studies, the latter already have concerns. In 2010, over 37% of the country's 33 million adults lacked financial services, and a significant portion of the country's informal companies could not utilize conventional banking services (African Development Bank, 2012). As a consequence, the very form of the banking license has been scrutinized as one of the primary causes of the failure to provide banking services to the poor (Paulson et al., 1998; Schombree, 2000; Maumbe, 2006).

Vol: 14 No: 04 Year: 2022 ISSN: 1309-8055 (Online) (pp. 152-186) Doi: 10.34109/ijefs. 20220109

Furthermore, it is suggested that internal inefficiencies caused by variables such as negligence, incompetence, fraud, and internal system breakdowns harmed the profitability of South African banks (Cronje, 2003). In addition, it is believed that other contributory factors can explain the prior low levels of profitability. These include (1) increasing staff costs (SARB, 2002); (2) the lack of financial services for all; (3) operating costs exceeding bank income; (4) expensive savings accounts; (5) customers not paying fair prices for financial services (Hawkins, 2004); and (6) the inability of banks to introduce new financial products (Akinboade et al., 2006). Nonetheless, there are indications that the South African banking sector is becoming more competitive as a result of (1) higher expenses resulting from financial and technological innovations; (2) an increase in the number of large international banks entering the market; and (3) stricter regulatory requirements (Kumbirai et al., 2010).

The South African banking sector's inability to address some of the inefficiencies listed above has been documented, see, for example, (O'Donnell & Van der Westhuizen, 2002; Cronje, 2003; Okeahalam, 2006; Van Heerden & Van der Westhuizen, 2008; Mlambo & Ncube, 2011; Van der Westhuizen & Lawrence, 2012; Van der Westhuizen & Battese, 2013; Van der Westhuizen, 2014). Previous South African studies either (1) measured only one aspect of performance by evaluating profitability (Ifeacho et al., 2014); (2) conducted a financial ratio analysis (Kumbirai et al., 2010), ignoring the fact that financial ratios are considered to be backwards-looking and unable to reflect the future consequences of managerial actions (Clark, 1997); or (3) only focused on small sample size. Only Cronje (2007) and Mlambo et al. (2011) attempted to examine a larger percentage of the relative efficiency of the South African banking sector. Still, they failed to provide useful insight due to a lack of data, a short period, or the absence of additional processing of the conclusions' implications. Hence, the literature has failed to give a good overview of relative efficiency that can aid bank management in establishing strategies to ensure profitability and long-term sustainability through improved resource management. Extreme events (market and regulatory shocks), discussed in the following section, might exacerbate the need for enhanced resource management. This innovative study will be the first to provide a broader perspective on the relative efficiency and stability of the South African banking system over the long term. It will also be the first to report on the rate of recovery (particularly after the financial crisis) relative to other banks and to provide recommendations to the Prudential Authority to improve the interdimensional operations of the South African banking sector from an input management standpoint. This 17-year study examines the technical and scale efficiency of 26 banks using an input-oriented (varying returns to scale) methodology (January 2004-December 2020). The interpretation of the efficiency scores[1] will be divided into a pre- (January 2004-December 2006), during (January 2007-December 2009), and post-

[1] The concept of efficiency in this study refers to banks' abilities to manage their resources. The level of efficiency (efficiency scores) is measured on a scale of 0 to 1, where a value of 1 indicates that the bank has superior resource management abilities, and a value closer to 0 indicates that the bank has poor resource management abilities.

Vol: 14 **No: 04 Year:** 2022 **ISSN**: 1309-8055 (Online) (**pp.** 152-186) **Doi:** 10.34109/ijefs. 20220109

financial crisis period (January 2010-Decmeber 2020), respectively. The input-orientated approach characterizes the banks' production technology for producing a given output mix with the minimum inputs (Coelli et al., 1998).

This study will be the first to comprehensively compare the efficiency levels of eleven locally-owned and five foreign-owned banks, one mutual bank, and nine foreign bank branches. However, the selection of banks is still constrained by data availability over the evaluation horizon. SARB (2022a) was consulted to collect the necessary inputs and outputs from monthly historical DI900 financial return statements converted to BA900 results. Yet, the speciality and size disparities between the evaluated institutions continue to be a worry since they will limit the generalizability of the efficiency estimates. A hierarchical agglomerative cluster algorithm (Keogh et al., 2005) to divide banks into three categories depending on their total assets (small, medium, and large) will provide a more robust efficiency comparison. With one exception, this study will also compare the relative efficiency of the top six bank holding companies, as these banks accounted for about 92% of the total banking assets in March 2021. Data sourced from (SARB, 2022a). This will provide a fresh perspective on the resource management abilities of Capitec Bank Holdings Limited and Investec Bank Limited from the standpoint of a medium-sized bank and as one of the top six South African banks. The revolutionary study by Farrell (1957) initially stated that efficiency might be measured by reducing current inputs proportionally to obtain predefined output levels. This can be empirically determined using a paradigm for non-parametric, non-stochastic mathematical programming (Charnes et al., 1978).

This framework, also known as the data envelopment analysis (DEA) model, was originally introduced by Charnes et al. (1978) from limited constant returns to scale (CRS) perspective[2]. However, it was Banker et al. (1984) who first developed the variable returns to scale (VRS)[3] model, based on the work of Shephard (1953; 1970), which accounts for possibilities such as capacity limitations on inputs. The DEA model has been lauded for its capacity to recognize interdimensional interactions (Cooper et al., 2007) and for its capacity to identify linkages that are unknown to other approaches (Kumar et al., 2014). Notwithstanding this, the literature has presented multiple DEA model alternatives, including various two-stage processes. However, no consensus has been established on model superiority, and no evidence has yet been produced to support the suggestion to adapt a different model to accomplish the feat as laid out in this work. Studies such as Zhu (2003) and Chen et al. (2004) argued that some modified two-stage processes might be biased, as some may conclude that two inefficient stages can lead to an overall efficient decision-making unit (DMU)[4] (with inputs from stage one and

[2] See Coelli et al. (1998) for a more detailed explanation.
[3] See Coelli et al. (1998) for a more detailed explanation.
[4] In the field of operational research decision-making units are the firms under evaluation. However, in this study it will be the banks under evaluation as summarised by Table 4.

outputs from stage two), which consequently, can distort the improvement to the DEA frontier. This study will utilize Coelli's (1998) multi-stage DEA version, as it solves two of the most significant limitations of the conventional two-stage linear programming (LP) procedure. First, the two-stage LP method maximizes the sum of slacks when it should have minimized it, and it selects the most distant efficient point when it should have identified the nearest one. Second, the two-step LP procedure is not unit-invariant (Lovell et al., 1995; Coelli, 1998). Zhu's DEA Frontier program was used to estimate the multi-stage DEA model. DEA Frontier is a DEA add-in for Microsoft Excel® (2016). This research begins with an overview of the South African banking industry (Section 2.1). The conceptual structure of the DEA model and the rationale for its application will be presented in Section 2.2. This will be followed by a discussion of the data and methodology in Part 3, while Section 4 will provide the results and practical implications. In Section 5, concluding observations and recommendations will be presented.

2. LITERATURE REVIEW

2.1 Overview of the South African Banking Sector

From 1999 to 2007, the number of registered banks in South Africa declined significantly from 42 to 19 due to various catastrophic events (see Table 1). Significant liquidity and market pressures led, for instance, to the dissolution of some banks, the withdrawal of registrations, and the curatorship of some institutions. Among these banks are Prima Bank Limited (1994), the African Bank Limited (1995), Community Bank (1996), NBS Bank Limited (1997), Islamic Bank Limited (1998), FBC Fidelity Bank Limited (1999), Regal Treasury Private Bank Limited (2001), Saambou Bank Limited (2002), BoE Bank Limited (2002), Mercantile Bank (2002/2003), and Peoples Bank Limited (2005). (SARB, 1994-2007).

Several smaller and medium-sized banks were denied access to lender-of-last-resort facilities, resulting in several deregistrations and mergers (Gilbert et al., 2009). Mboweni (2004) contends that the loss of numerous small and medium banks was not caused by the failure of other banks but rather by the consolidation of the banking industry. Already apparent in the early 1990s, when Volkskas Bank, Allied Bank, United Bank, and Sage Bank amalgamated in 1991 to form the Amalgamated Banks of South Africa Ltd (ABSA), this trend has continued (Akinboade et al., 2006). As a result of this trend of consolidation, the South African banking sector has become oligopolistic (Coppock et al., 2008), extremely concentrated, and dominated by six big South African bank holding firms. The top six bank holding corporations are (1) ABSA Group Ltd, (2) Standard Bank of South Africa Limited, (3) Nedbank Group Limited, (4) FirstRand Group Limited (which comprises First National Bank, Wesbank, and RMB), (5) Investec Bank Limited, and (6) Capitec Bank Holdings Limited.

Vol: 14 **No:** 04 **Year:** 2022 **ISSN**: 1309-8055 (Online) (**pp.** 152-186) **Doi:** 10.34109/ijefs. 20220109

Table 1. Banking Entities Registered in South Africa (1999-2020)

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Registered banks	42	42	41	30	22	20	19	19	19	19	18
Mutual banks	3	3	2	2	2	2	2	2	2	2	2
Cooperative banks	0	0	0	0	0	0	0	0	0	0	0
Local branches of foreign banks	12	15	15	14	15	15	15	14	14	14	13
Representative offices	57	61	56	52	44	43	47	43	46	43	42
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Registered banks	17	17	17	17	17	17	17	19	19	19	18
Mutual banks	2	2	3	3	3	3	3	3	4	4	4
Cooperative banks	0	2	2	2	2	2	2	3	4	4	5
Local branches of foreign banks	13	12	14	14	14	15	15	15	15	16	13
Representative offices	41	43	41	43	40	40	36	31	31	30	30

Source: Collected from the South African Reserve Bank's (SARB) bank supervision annual reports and the Prudential Authority annual report over several years (SARB, 1999-2018; SARB, 2019; SARB, 2018-2020; 2022d).

According to Table 2, the significantly high Gini concentration coefficient (Gini coefficient) and Herfindahl-Hirschman index (H-index) highlight the oligopolistic nature of this industry. From 2004 to 2020, the average Gini coefficient and H-index for the South African banking sector were 83.03 and 0.18, respectively. The degree of the oligopolistic nature is also supported by Figure 1, which depicts the variation in the number of banks from 1999 to 2020 on an annual basis. It is obvious from Figure 1 that the number of registered banks decreased by approximately 28.57 percent between 1999 and 2002 as a result of the previous catastrophic events, with the largest loss in registered banks (11 institutions) occurring between 2001 and 2002. Between 1999 and 2020, the number of representative offices fluctuated the most, followed by the number of registered banks and local branches of foreign banks, in that order. The number of mutual and cooperative banks displayed higher stability during this period (see Figure 1). From Table 1 and Figure 1, it is clear that the South African banking system is in a perpetual state of upheaval, with several events and sector consolidations claiming around 24 banks and 31 representative offices between 1999 and 2020.

According to Beck et al. (2006), this form of market concentration reduces the likelihood of experiencing a crisis. However, an intermediate concentration level may be desirable from a welfare standpoint (Calice, 2018). Yet, increased competition can lead to higher cost-effectiveness (Chen, 2009). Boyd et al. (2005) and Boyd et al. (2009) suggest that higher market concentration leads to more financial instability and riskier bank loan portfolios, particularly if banks become larger and more diversified under these market conditions. Moreover, larger banks may be more susceptible to internal inefficiency and operational risk (Beck et al., 2006; Cetorelli et al., 2007; Laeven et al, 2007).

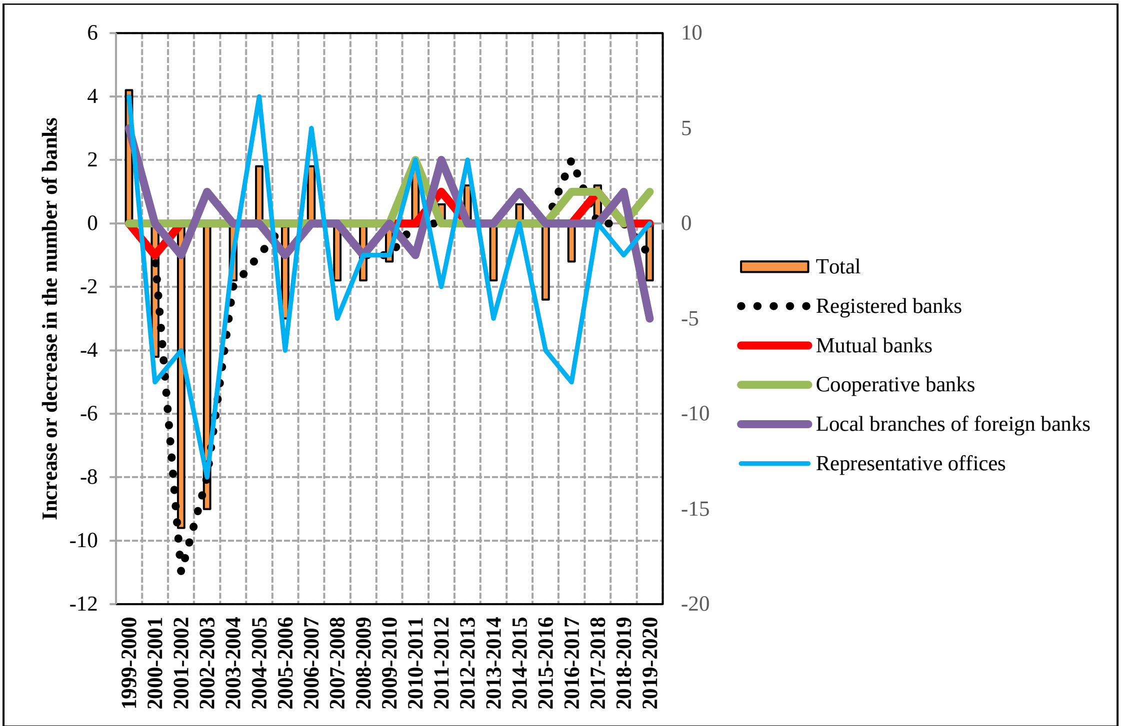

Figure 1. Year-on-Year Change in the Number of Banks in the South African Banking sector
Source: Data derived from Table 1.

Yet, the tremendous development in the banking indicators compared to the country's GDP, as presented in Table 2, highlights the significance of this industry. From 2004 to 2020, the total assets of the South African banking system increased significantly relative to GDP (152,62%). This is also visible for total deposits, current accounts, and other creditors relative to GDP (130,12%), for gross loans and advances relative to GDP (102,85%), and for insufficient advances relative to GDP (6,96%). (see Table 2). Moreover, on average (from 2004 to 2015), South African banks were better at managing their cost-income spread (55.58%) than international banks (59.72%). With a higher ROE ratio of 16.47% than the global average of 14.00%, a stronger level of profitability was also evident (see Table 2). Nonetheless, South African banks demonstrated a subpar ability to turn assets into income, as Table 2 displays a ROA ratio of 1.17 percent, which is lower than the global average of 1.34 percent. Nonetheless, South African banks are well-capitalized, with average Tier 1 capital adequacy and average total capital adequacy ratios of 11.59% and 14.72 %, respectively, from 2004 to 2020. These forecasts are far higher than the minimum norms of 6% and 10.50%, respectively (BIS, 2011), fostering market confidence.

Table 2. Selected Indicators for the South African Banking Sector: 2004-2020

Indicators under consideration	2004	2005	2006	2007	2008	2009	2010	2011	2012
Total deposits, current accounts and other creditors (R billions)	910	1102	1353	1658	2379	2366	2488	2717	2892
Total assets (R billions)	1498	1678	2075	2547	3177	2967	3126	3416	3653
Gross loans and advances (R billions)	1114	1354	1736	2124	2316	2257	2313	2522	2753
South African Gross Domestic Product (GDP in R billions)	2284	2397	2543	2673	2708	2681	2789	2862	2921
Cost-to-income ratio (%)	63.90	66.30	58.90	56.90	42.21	51.10	56.40	54.90	52.90
Bank's cost-to-income ratio (%) for the world	57.83	57.14	54.59	55.59	53.61	54.87	56.99	56.91	55.55
ROE ratio (%)	14.70	15.20	18.30	18.10	20.65	15.85	14.65	16.39	17.54
Bank's ROE ratio (%) for the world	15.66	16.75	18.20	18.52	15.01	11.17	12.58	12.80	12.98
ROA ratio (%)	1.20	1.20	1.40	1.40	1.15	0.94	0.97	1.15	1.26
Bank's ROA ratio (%) for the world	1.47	1.53	1.60	1.69	1.42	1.10	1.23	1.33	1.27
Tier 1 capital adequacy ratio (%)	9.30	8.90	9.00	9.50	10.22	10.97	11.80	12.20	12.60
Total capital adequacy ratio (%)	13.50	12.70	12.29	12.78	13.02	14.10	14.89	15.10	15.90
Liquidity coverage ratio (%)#	-	-	-	-	-	-	-	-	-
Liquid assets held to liquid asset requirement (%)	116.80	119.70	111.20	112.50	115.50	144.80	174.84	193.45	198.70
Leverage ratio (%)#	-	-	-	-	-	-	-	-	-
Impaired advances (credit risk) (R billions)	20.40	20.10	18.80	29.40	87.30	133.00	133.97	118	112
Gini concentration coefficient	83.10	83.10	83.10	83.40	84.04	83.65	82.57	82.57	82.49
Herfindahl–Hirschman index (H-index)	0.18	0.18	0.18	0.19	0.19	0.19	0.19	0.19	0.19
South African bank Z-score (not seasonally adjusted)**	12.38 {10.83} [27.70] (10.55) *9.75*	12.66 {10.64} [27.62] (6.66) *12.82*	12.48 {10.36} [27.72] (6.09) *18.12*	12.73 {11.31} [26.59] (6.42) *20.37*	11.71 {10.92} [22.96] (3.97) *18.41*	12.64 {10.94} [26.93] (5.24) *17.13*	13.42 {10.65} [28.96] (6.84) *19.17*	14.06 {10.96} [29.30] (7.33) *18.58*	15.20 {10.98} [29.38] (7.03) *19.44*

{} reports the world's bank Z-scores, which are discontinued.
[] reports the bank Z-scores of the United States of America (USA).
() reports the bank Z-scores of the United Kingdom (UK).
only reported after the implementation of Basel III.
… reports the bank Z-scores of China.
*** data are discontinued and only available until 2015.

Note: These numbers include local branches of foreign banks but exclude offshore branches and subsidiaries of South African banks, mutual banks and cooperative banks. The cost-to-income ratio for 2008 was only reported as unsmoothed. Regarding impaired advances, before 2006, it was reported as gross overdue (non-performing loans). Regarding the H-index, an H-index below 0.1 indicates no concentration in an industry, while an H-index between 0.1 and 0.18 indicates moderate concentration. However, an H-index above 0.18 indicates a high level of concentration (Mishi et al., 2016). The z-scores are discontinued from 2018.

Vol: 14 No: 04 Year: 2022 ISSN: 1309-8055 (Online) (pp. 152-) Doi: 10.34109/ijefs. 20220109

Source: Collected from the South African Reserve Bank's (SARB) bank supervision annual reports, financial stability review reports, and banking sector information reports over several years (SARB, 2004-2017; 2004-2020; 2004-2020; 2018-2020; 2020; 2022d). The annual, not seasonally adjusted bank Z-scores, bank's cost-to-income, ROE and ROA ratios for the world were obtained from the Federal Reserve Bank of St. Louis' (2021a; 2021b; 2021c; 2022d) website. The South African bank Z-score captures the probability of default in South Africa's banking sector, calculated as a weighted average of the Z-scores of South Africa's banks (the weights are based on the individual banks' total assets). South Africa's GDP at market price (annualized, seasonally adjusted) were sourced from SARB (2022b).

Table 2. Selected Indicators for the South African Banking Sector: 2004-2020 (Continues)

Indicators under consideration	2013	2014	2015	2016	2017	2018	2019	2020
Total deposits, current accounts and other creditors (R billions)	3097	3403	3777	3920	4061	4452	4716	5116
Total assets (R billions)	3842	4179	4830	4877	5157	5521	5885	6568
Gross loans and advances (R billions)	2967	3234	3601	3708	3800	4117	4283	4564
South African Gross Domestic Product (GDP in R billions)	3016	3064	3061	3087	3156	3161	3143	3010
Cost-to-income ratio (%)	53.65	54.39	55.39	55.05	56.66	57.23	58.80	58.73
Bank's cost-to-income ratio (%) for the world***	56.07	78.76	78.71	-	-	-	-	-
ROE ratio (%)	14.75	14.65	16.83	17.64	15.94	16.09	14.37	6.93
Bank's ROE ratio (%) for the world***	11.91	12.21	10.23	-	-	-	-	-
ROA ratio (%)	1.11	1.08	1.20	1.31	1.31	1.32	1.15	0.51
Bank's ROA ratio (%) for the world***	1.22	1.19	1.02	-	-	-	-	-
Tier 1 capital adequacy ratio (%)	12.42	11.92	11.44	12.85	13.50	13.20	13.62	13.57
Total capital adequacy ratio (%)	15.58	14.74	14.20	15.92	16.28	16.14	16.58	16.60
Liquidity coverage ratio (%)#	-	-	84.51	109.55	117.05	128.58	143.27	137.57
Liquid assets held to liquid asset requirement (%)	198.83	210.41	215.47	227.04	227.83	240.97	262.12	304.67
Leverage ratio (%)#	-	-	-	6.24	6.76	6.50	6.56	6.50
Impaired advances (credit risk) (R billions)	108	106	112	105.96	108.01	151.56	166.71	236.45
Gini concentration coefficient	83.09	82.73	82.53	82.68	82.91	83.40	83.21	83.00
Herfindahl–Hirschman index (H-index)	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
South African bank Z-score (not seasonally adjusted)	14.20 {10.87} [29.54] (7.74) *19.84*	14.11 {11.22} [29.70] (9.35) *20.51*	13.76 {10.76} [29.94] (12.77) *23.00*	14.91 {-} [29.58] (12.72) *21.19*	16.88 {-} [29.80] (9.96) *22.93*	-	-	-

Note: See footnotes on the previous page

In addition, since the implementation of Basel III, this sector has displayed an average leverage ratio of 6.51 percent (see Table 2), which is substantially above the permitted limit (Fischer, 2014). All of these estimations highlight the exceptional capital structure of this banking industry relative to worldwide norms. After the implementation of Basel III (see Table 2), the South African banking system is very liquid, with an average liquidity coverage ratio of 120.09 percent, which is considerably over the minimum standards (BIS, 2011). Since 2004, the ratio of liquid assets retained to liquid asset need has increased, averaging 186.75 percent between 2004 and 2020. (see Table 2).

In conclusion, the Z-score is a popular metric that can further validate this sector's level of stability and relevance. This metric is an indicator for determining the likelihood of bank failure. It is obvious from Table 2 that the South African banking industry had much higher Z-scores compared to global estimates, highlighting this sector's decreased default likelihood from 2004 to 2015. Nevertheless, the South African banking sector competes favorably with the three countries regarded to have the largest banking sectors [the United States (USA), the United Kingdom (UK), and China]. The South African banking sector exhibited a higher average Z-score than the United Kingdom and less than three times that of the United States and China. This is even though the average GDP of these three countries is 52, 9, and 25 times larger than South Africa's (from 2004 to 2020) [data sources from World Bank, 2022]. This suggests that even a modest economy can have a financial industry capable of establishing worldwide norms. Since 2009, the Global Competitiveness Report of the World Economic Forum has ranked the soundness of South African banks as one of the top ten worldwide (World Economic Forum, 2009-2016).

2.2 Measuring efficiency: The conceptual framework of the DEA model

Due to globalization, evolving technologies, legislative changes, increased competitive pressure from other foreign institutions and non-banking financial services providers, and shifting consumer preferences and needs, the modern banking industry has evolved significantly over the past decade (Vaithilingam et al., 2006; Greuning et al., 2009; Titko, Stankeviien, and Lce, 2014). So, the profitability and survival of competing financial organizations will depend on their management's ability to initiate and maintain more efficient processes. In the field of operational research, the non-parametric, non-stochastic, mathematical programming framework known as the DEA model (Charnes et al., 1978) and the stochastic frontier analysis (SFA) model (Aigner et al., 1977; Meeuss et al., 1977) are regarded as the two pioneering efficient measurement tools available to management (Sharma et al., 1997). The SFA creates a smooth parametric frontier that takes stochastic noise in the data into account, allowing for the testing of hypotheses on production systems and the degree of inefficiency (Hossain et al., 2012; Jacobs, 2001). Furthermore, the SFA model is less flexible because it requires an explicit parametric form for the underlying technology and an explicit distributional assumption for the inefficiency term (Sharma et al., 1999). In contrast, the estimators of the DEA model are consistent, unbiased, and converge more rapidly than estimators from other frontier methods (Grosskopf, 1996; Kittelsen, 1999). The popularity of the DEA model is driven by its adaptability, as it can simultaneously handle numerous non-commensurate inputs and outputs (Kirigia et al., 2001; Nunamaker, 1985). Moreover, it makes no assumptions about functional forms, making it less susceptible to misspecification (Herrero et al., 2002). The DEA model may also account for exogenous variables beyond the control of DMUs and provides insight into the input and output quantities that inefficient DMUs must attain to be considered efficient (Charnes et al., 1978; Nunamaker, 1985). As a result, the prominence of the DEA's application in finance can be justified by an array of literature, see, for example, (Van Heerden & Van der Westhuizen, 2008; Liu, Lu, Lu, & Lin, 2013; Van Heerden & Heymans, 2013; Van Heerden & Saayman, 2018; Van Heerden & Coetzee, 2019; Fourie, Van Heerden, & Du Plessis, 2022; Samad & Armstrong, 2022; Sokol & Frýd, 2022; Van Heerden & Van Heerden, 2022).

Measuring a company's efficiency is merely one component of its overall performance. It must be measured relative to an objective that can be quantified relative to the maximization of output, maximization of profits, or minimization of costs (also known as technical efficiency) (Mester, 2003). To assess efficiency using the DEA, a bank must be compared to a best practice DMU, which, based on the sample, is the most efficient bank (is on the efficient frontier and is closest to the least efficient bank) (Yeh, 1996; Avkiran, 1999). Hence, a measurement of overall economic efficiency can be obtained from technical and allocative efficiency. Total economic inefficiency occurs when a bank uses the incorrect combination of inputs to create outputs (allocative inefficiency) or wastes inputs (technical inefficiency), or both (Mester, 2003). Consider Figure 2 with two inputs (x_1,x_2) and a single output (y_1) in the production process under the assumption of constant returns to scale to explain this notion. Efficiency can be viewed in terms of the optimal combination of inputs for a particular output level (an input-orientation – applicable to this study) or the optimal output that might be produced given a set of inputs (an output-orientation). The SS curve in Figure 2 depicts banks that operate at maximum efficiency. Suppose a bank uses amounts of inputs as described by P to produce a unit of output. In that case, technical inefficiency can be represented by the distance QP, the amount by which all inputs might be proportionally reduced without reducing output. Clearly, QP/0P shows the proportion by which all inputs must be lowered to attain technical efficiency. Hence, technical efficiency can be assessed by 0Q/0P, where a value of one indicates complete technical efficiency, and a value of zero means total technical inefficiency. In addition, if the input price ratio is known, as noted in the isocost line AA', the allocative efficiency can be calculated (Coelli et al., 1998). However, allocative efficiency measurement is outside the scope of this study and is recommended for future research.

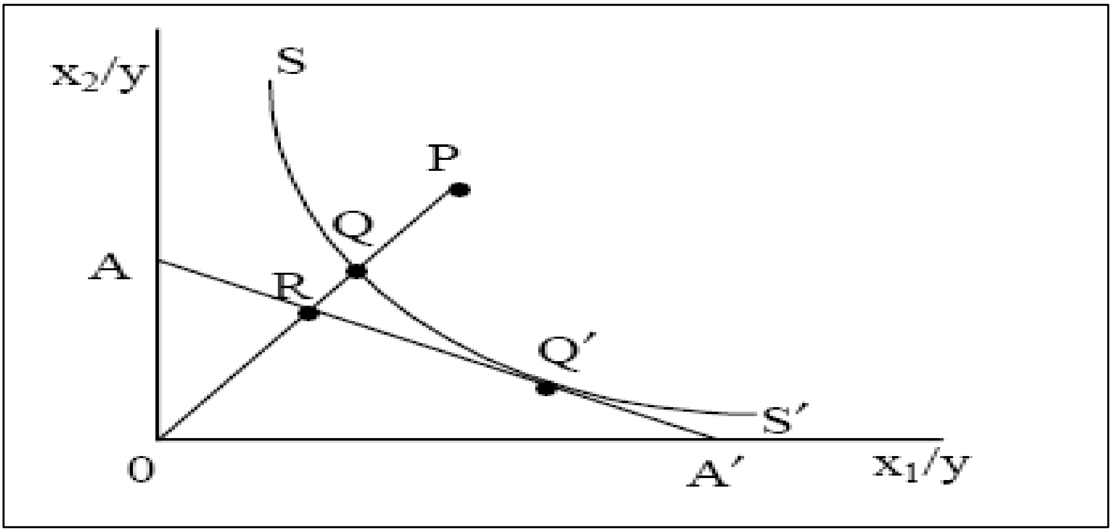

Figure 2. Illustration of an input-orientated scenario
Source: Farrell (1957); Coelli et al. (1998).

As used in the preceding scenario (see Figure 2), the CRS assumption is only applicable when all banks operate at optimal scale. Sadly, CRS requirements will not work under imperfect competition and financial constraints, as it will prevent banks from operating at optimal scales (Coelli et al.,1998). Scale efficiencies will therefore contradict the technical efficiency scores produced from this scenario. In Figure 3, the input-oriented technical inefficiency of P under CRS is represented by the distance $(PP)_c$.

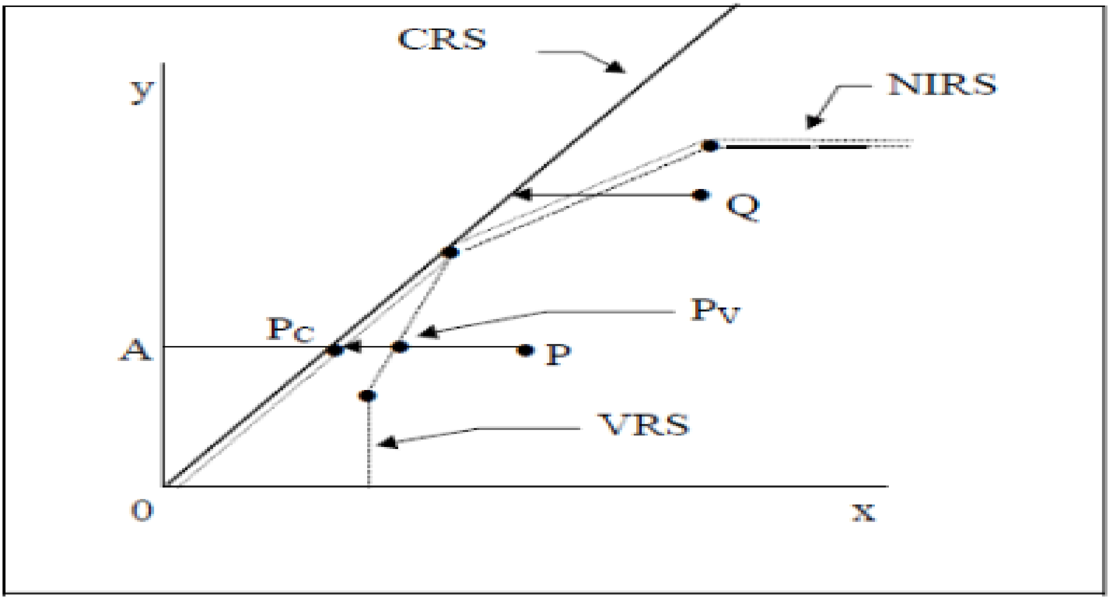

Figure 3. Concepts of efficiency and returns to scale
Source: Coelli et al. (1998).

VRS, the disproportional increase or decrease in outputs when inputs are increased, was developed by Banker et al. (1984) as a solution to this issue (Avkiran, 1999). Efficiency scores from the Virtual Reality System (VRS) show pure technological efficiency that measures without scale efficiency (Avkiran, 1999). In Figure 3, the input-oriented technical inefficiency of P under VRS is represented by the distance PP $_v$. The distance P $_c$ P $_v$ in Figure 3 illustrates a potential scale inefficiency measurement based on the gap between the VRS and CRS efficiency ratings.

However, this metric of scale efficiency does not specify whether the bank is seeing increasing or declining returns to scale. To assess the economies of scale, a second model must be calculated from the perspective of non-increasing return to scale (NIRS). Comparing the technical efficiency scores of the NIRS and VRS perspectives makes it possible to establish whether a bank is experiencing declining or increasing returns to scale. If these models produce identical efficiency scores (as in the case of point Q in Figure 3), it indicates that the bank is experiencing diminishing returns to scale. In contrast, rising returns to scale exist if the efficiency scores of the VRS perspective and the NIRS model are unequal (as in the case of point P in Figure 3). (Coelli et al., 1998).

3. METHODOLOGY AND DATA

The DEA model's popularity can be explained by its modeling flexibility, its ability to handle non-commensurable multiple inputs and outputs simultaneously, its capacity to address both qualitative and quantitative data, and its ability to accommodate various non-discretionary and discretionary inputs (Nunamaker, 1985; Golany & Storbeck, 1999; Kirigia et al., 2001). The DEA model calculates relative or comparative efficiency in inputs and outputs of a DMU or bank by comparing non-best practices to best practices to evaluate the degree of inefficiencies (Avkiran, 1999; Jaforullah et al., 1999). Compared to sample averages or parametric populations, this approach has the capacity and advantage of focusing on each bank separately. It may also adapt to external variables outside the control of DMUs and support many inputs and outputs without requiring homogenous measurement units.

This model does not require functional form assumptions between inputs and outputs and may focus on observable best-practice frontiers rather than their central tendency features. In addition, it reveals the input and output quantities that inefficient banks must accomplish to function on the efficient frontier. It generates a single efficiency estimate for each bank based on input-output connections (Charnes et al., 1978; Nunamaker, 1985). Although the DEA model does not address the problem of output assessment, it attempts to combine multiple inputs and outputs in a single, non-arbitrary, non-subjective manner based on the criterion of Pareto efficiency without requiring specification of any priori weights (Nunamaker, 1985). (Cooper et al., 2007). As a result, the literature emphasizes the attractiveness of these features by highlighting the selection of the DEA model in bank efficiency studies, such as Avkiran (1999); Jaforullah et al.

Vol: 14 **No: 0**4 **Year:** 2022 **ISSN**: 1309-8055 (Online) (**pp.** 152-) **Doi:** 10.34109/ijefs. 20220109

(1999); Soteriou et al. (2000); Cronje (2003); Okeahalam (2006); Van Heerden et al. (2008); Mlambo et al. (2011); Van Heerden et al. (2013); Van der Westhuizen (2019).

Table 3. The Input and Output Variables for Measuring Relative Efficiency

INPUT VARIABLES	Item #	Citations	Source of data
Total deposits	1	Adopted from Van Heerden & Heymans (2013); Van Heerden & Coetzee (2019).	South African Reserve Bank's website (SARB, 2022a).
Total Equity	96		
Central bank and money	103		
South African group financing	111		
OUTPUT VARIABLES	**Item #**		
Other liabilities	80		
Deposits, loans and advances	110		
Investments and bills	195		

Note: The item numbers are indicated as reported in the historical DI900 converted financial return statements.
Source: Compiled by Author.

Due to banks' multi-product nature, there is currently no consensus regarding the optimal combination of inputs and outputs (Girardone et al., 2004). Sealey and Lindley's (1977) intermediation method, which considers financial institutions as intermediaries between the supply and demand for funds, is most applicable to this study (Molyneux et al., 1996; Mester, 1996). This study used the methodology of Kaparakis et al. (1994) and Favero et al. (2000) when determining inputs and outputs 1995. Due to the restricted data available for some banks, only four inputs and three outputs were chosen from the monthly historical DI900 financial return statements translated to BA900 returns (see Table 3). The input and output choices were based on the research conducted by Van Heerden et al. (2013) and Van Heerden et al. (2005). The information was gathered from the website of the South African Reserve Bank (SARB, 2022a) and spanned January 2004 to December 2020. The output variable for deposits, loans, and advances does not include South African group funding when the latter is utilized as an input variable. Based on the availability of data, only eleven locally controlled banks, five foreign-controlled banks, one mutual bank, and nine branches of foreign banks (see Table 4) will be evaluated during the pre-crisis, crisis, and post-crisis periods (January 2004-December 2006, January 2007-December 2009, and January 2010-December 2020, respectively).

Yet, the size and niche disparities between the evaluated banks will restrict the generalizability of the results and must be considered a weakness of this study. The 26 estimated banks will be separated into three categories depending on their total assets to present a more viable efficiency comparison. Using an agglomerative single linkage method (Kaufman et al., 2009), a hierarchical cluster analysis could classify banks as small, medium, or large.

Table 4. Summary of Banks under Evaluation

NAME OF BANK	TYPE	CLASSIFICATION
Absa Group Limited	Locally Controlled	Large-sized
African Bank Limited	Locally Controlled	Medium-sized
Albaraka Bank Limited	Foreign Controlled	Small-sized
Bank of China Limited Johannesburg branch	Branch of foreign bank	Small-sized
Bank of Taiwan South Africa branch	Branch of foreign bank	Small-sized
Bidvest Bank Limited	Locally Controlled	Small-sized
Capitec Bank Holdings Limited	Locally Controlled	Medium-sized
China Construction Bank Corporation - Johannesburg branch	Branch of foreign bank	Small-sized
Deutsche Bank AG	Branch of foreign bank	Medium-sized
Firstrand Group Limited	Locally Controlled	Large-sized
GBS Mutual Bank	Mutual	Small-sized
Grindrod Bank Limited	Locally Controlled	Small-sized
Habib Overseas Bank Limited	Foreign Controlled	Small-sized
HBZ Bank Limited	Foreign Controlled	Small-sized
Investec Bank Limited	Locally Controlled	Medium-sized
JPMorgan Chase Bank	Branch of foreign bank	Medium-sized
Mercantile Bank Limited	Foreign Controlled	Small-sized
Nedbank Group Limited	Locally Controlled	Large-sized
Sasfin Bank Limited	Locally Controlled	Small-sized
Société Générale Johannesburg branch	Branch of foreign bank	Small-sized
Standard Chartered Bank	Branch of foreign bank	Small-sized
State Bank of India	Branch of foreign bank	Small-sized
The Hong Kong and Shanghai Banking Corporation Limited Johannesburg branch	Branch of foreign bank	Medium-sized
The South African Bank of Athens Limited	Foreign Controlled	Small-sized
The Standard Bank of South Africa Limited	Locally Controlled	Large-sized
UBank Limited	Locally Controlled	Small-sized

Note: The cluster analysis results are available on request.
Source: Compiled by Author.

According to the results, the top four banks must be assigned to the first cluster (large-sized). In contrast, African Bank Limited, Capitec Bank Holdings Limited, Deutche Bank AG, Investec Bank Limited, JP Morgan Chase Bank, and the Johannesburg branch of Hong-Kong and Shanghai Banking Corporation Limited must be assigned to the second cluster (medium-sized) (medium-sized). The remaining evaluable banks will be assigned to the final (small) cluster (see Table 4). Nonetheless, an extra relative efficiency comparison will also be performed on the top six dominating bank holding firms, including the medium-sized banks Capitec Bank Holdings Limited and Investec Bank Limited and the four large-sized banks shown in Table 4.

Each cluster of banks will be analyzed separately pre-, during-, and post-financial crisis using the multi-stage DEA model (Coelli, 1998), which will be estimated using the DEAFrontier program, a Zhu-developed DEA add-on for Microsoft Excel® (2016). Consider K as the number of inputs and M as the number of outputs for each of the N banks in this model, where the vectors represent the inputs and outputs for the ith bank x_i and y_i, respectively. Y represents the MN output matrix, whereas X represents the KN input matrix. The constant returns to scale, input-oriented, multi-stage DEA model can thus be shown by the following stages (see Equations 1 through 4), with slight modifications when a variable returns to scale approach is utilized (Coelli, 1998):

Firstly, conduct a radial LP process with the following form:

$$\begin{aligned} \min_{\theta,\lambda} \quad & \theta \\ \text{s.t.} \quad & -y_i + Y\lambda \geq 0, \\ & \theta x_i - X\lambda \geq 0, \\ & \lambda \geq 0, \end{aligned} \tag{1}$$

Where θ is a scalar and λ denotes a $N \times 1$ vector of constants. This process is continued N times, generating a θ for each bank. Secondly, this process is followed by a second stage LP process in which the sum of any remaining slacks is maximized, illustrated as follows (Coelli, 1998):

$$\begin{aligned} \max_{\lambda, OS, IS} \quad & (M1'OS + K1'IS) \\ \text{s.t.} \quad & -y_i + Y\lambda - OS = 0, \\ & cx_i - X\lambda - IS = 0, \\ & \lambda \geq 0, OS \geq 0, IS \geq 0, \end{aligned} \tag{2}$$

where cx_i denotes the input vector of the ith bank, which has been multiplied by θ (being contracted) from step 1; OS denotes the $M \times 1$ vector of output slacks; IS denotes the $K \times 1$ vectors of input slacks; and $K1$ and $M1$are $K \times 1$ and $M \times 1$ vectors of ones, respectively. This process is continued N times, where, after all, the banks with

Vol: 14 **No:** 04 **Year:** 2022 **ISSN**: 1309-8055 (Online) (**pp.** 152-) **Doi:** 10.34109/ijefs. 20220109

no slacks and those with a technical efficiency score of $\theta = 1$ are identified and classed as 'efficient banks'. This process is also duplicated for all banks with non-zero slack variables and is then classed as the 'banks with slacks' set. The 'banks with slacks' set are then used to estimate a sequence of radial movements, based on projected points calculated in step 1, to obtain the projected point on the efficient frontier, whereas the 'efficient banks' will only be used as a reference in the LP estimations from this stage on (Coelli, 1998).

Lastly, execute a series of K LPs to identify only those input dimensions of the ith bank in the 'banks with slacks' set that consists of slacks. This step will fail, however, if any of the input values are 0. In this procedure, each LP will only permit contractions in one of the inputs, hence determining the presence of potential slacks within these inputs. The LP for the jth input of the ith bank can be depicted in the following manner (Coelli, 1998):

$$\begin{aligned}
&\min_{\theta,\lambda} \quad \theta \\
&\text{s.t.} \quad -y_i + Y_e\lambda \geq 0, \\
&\qquad \theta c x_i^j - X_e^j\lambda \geq 0, \\
&\qquad c x_i^{\neq j} - X_e^{\neq j}\lambda \geq 0, \\
&\qquad \lambda \geq 0,
\end{aligned} \tag{3}$$

where cx_i^j denotes the jth input of the ith bank, which is multiplied by θ (being contracted) that is obtained from step 1; X_e^j denotes the $1 \times N_e$ vector of the jth inputs of all the efficient banks; $cx_i^{\neq j}$ denotes the $(K-1) \times 1$ vector of inputs of the ith bank, which excludes the jth input that is then contracted by being multiplied by θ, as obtained in Equation 1; $X_e^{\neq j}$ denotes the $(K-1) \times N_e$ matrix of inputs of all the efficient banks, also excluding the jth input; N_e denotes the number of efficient banks as already identified in step 2; Y_e denotes the matrix of outputs of the efficient banks, and λ has a dimension of $N_e \times 1$ (Coelli, 1998).

Fourthly, estimate an LP for the ith bank in the 'banks with slacks' set, which seeks a radial reduction in all inputs already identified during step 3 as having potential slacks. This estimation can be illustrated as follows (Coelli, 1998):

$$\begin{aligned}
&\min_{\theta,\lambda} \quad \theta \\
&\text{s.t.} \quad -y_i + Y_e\lambda \geq 0,
\end{aligned}$$

Vol: 14 **No:** 04 **Year:** 2022 **ISSN**: 1309-8055 (Online) (**pp.** 152-) **Doi:** 10.34109/ijefs. 20220109

$$\theta c x_i^s - X_e^s \lambda \geq 0,$$

$$c x_i^{ns} - X_e^{ns} \lambda \geq 0,$$

$$\lambda \geq 0, \quad (4)$$

where s denotes the subset of inputs with potential slacks, and ns denotes the remainder of the inputs used. Note that the radial reduction in this step begins by applying the estimated projected point (y_i,cx_i) from step 1. Fifthly, it is conceivable for some input slacks to persist after the prior step's radial reduction. To resolve this issue, steps 3 and 4 must be repeated with the projected point, determined in step 4, until no input slacks remain (Coelli, 1998). Do a radial expansion in the dimensions of the output slacks until no output slacks remain.

This can be performed by taking the predicted points of the ith bank from step 5 and repeating steps 3 to 5. The final projected point from this phase, independent of the selected units of measurement, will lie on the efficient surface. The slacks can then be computed by subtracting the final predicted point from the projected point from step 1. In addition, the ith bank's peers can be identified using the vector of the final projected position (Coelli, 1998). The next section describes the outcomes of implementing the multi-stage DEA model.

4. RESULTS AND PRACTICAL IMPLICATIONS

Table 5 reveals that, regarding technical and scale efficiency, large banks demonstrated stronger stability than medium and small banks, particularly during the financial crisis. Yet, there is potential for improvement as the leading South African banks were uneven in their capacity to handle resources/inputs over the study period (see Figure 4 and Table 5). Research implies that management is obsessed with increasing market share, optimizing costs and profits, and ensuring survival (Berger et al., 2013; Du Toit et al., 2018), which could jeopardize good resource management.

Nonetheless, the leading South African banks demonstrated an overall inclination to operate on a too-small scale (increasing returns to scale). This accords with the conclusions of Wheelock et al. (2012) and Hughes et al. (2013). According to Sapci's et al. (2017) research, returns to scale may incentivize banks to expand. Banks tend to exploit increasing returns to scale until they become excessively huge (Sapci et al., 2017). Yet, these results highlight the need for caution on the part of the Prudential Authority, as reducing the size of banks may lead to an increase in bank costs (Wheelock et al., 2012; Kovner et al., 2014).

Vol: 14 **No: 0**4 **Year:** 2022 **ISSN**: 1309-8055 (Online) (**pp.** 152-) **Doi:** 10.34109/ijefs. 20220109

Table 5. Summary of Results: Technical and Scale Efficiency Scores and Return To Scale Estimates

BANKS UNDER EVALUATION	PRE-CRISIS PERIOD					DURING CRISIS PERIOD					POST-CRISIS PERIOD				
	Efficiency scores		Return to scale			Efficiency scores		Return to scale			Efficiency scores		Return to scale		
	Technical	Scale	IRS	DRS	CRS	Technical	Scale	IRS	DRS	CRS	Technical	Scale	IRS	DRS	CRS
TOP SIX BANKS															
ABSA Group Limited	0,92	1,00	35	1	0	0,92	1,00	27	9	0	0,86	0,99	73	59	0
FirstRand Group Limited	0,87	1,00	36	0	0	0,90	1,00	27	9	0	0,88	1,00	100	29	3
Nedbank Limited	0,79	1,00	36	0	0	0,77	1,00	34	2	0	0,83	1,00	91	41	0
The Standard Bank of South Africa Limited	0,98	1,00	25	1	10	0,97	1,00	16	11	9	0,93	0,99	30	92	10
Capitec Bank Holdings Limited	0,83	0,81	30	3	3	0,77	0,95	0	35	1	0,74	0,98	2	130	0
Investec Bank Limited	0,86	0,99	35	0	1	0,86	1,00	35	0	1	0,83	1,00	125	4	3
Overall average	***0,88***	***0,97***	***33***	***1***	***2***	***0,86***	***0,99***	***23***	***11***	***2***	***0,85***	***0,99***	***70***	***59***	***3***
TOP FOUR BANKS (large-sized banks)															
ABSA Group Limited	0,97	0,95	35	0	1	0,92	0,99	27	9	0	0,86	0,99	73	59	0
FirstRand Group Limited	0,94	0,93	36	0	0	0,91	0,99	27	9	0	0,88	0,99	101	28	3
Nedbank Limited	0,86	0,91	36	0	0	0,79	0,98	36	0	0	0,84	0,99	91	41	0
The Standard Bank of South Africa Limited	0,99	0,99	25	1	10	0,97	1,00	16	11	9	0,93	0,99	30	92	10
Overall average	***0,94***	***0,95***	***33***	***0***	***3***	***0,90***	***0,99***	***27***	***7***	***2***	***0,88***	***0,99***	***74***	***55***	***3***
MEDIUM-SIZED BANKS															
African Bank Limited	0,92	0,99	27	6	3	0,54	0,99	11	25	0	0,83	0,90	4	125	3
Capitec Bank Holdings Limited	0,73	0,33	36	0	0	0,42	0,81	36	0	0	0,44	0,87	16	116	0
Deutsche Bank AG	0,94	0,61	36	0	0	0,72	0,87	36	0	0	0,74	0,72	125	6	1
Investec Bank Limited	0,74	0,59	0	36	0	0,90	0,51	0	36	0	0,92	0,48	0	132	0
JP Morgan Chase Bank	0,96	0,87	30	0	6	0,90	0,90	26	0	10	0,77	0,89	100	25	7
The Hong Kong and Shanghai banking corporation Limited - Johannesburg branch	0,86	0,61	36	0	0	0,49	0,94	36	0	0	0,37	0,92	59	73	0
Overall average	***0,86***	***0,67***	***28***	***7***	***2***	***0,66***	***0,84***	***24***	***10***	***2***	***0,68***	***0,80***	***51***	***80***	***2***
SMALL-SIZED BANKS															
Albaraka Bank Limited	0.78	0.92	36	0	0	0.60	0.88	36	0	0	0.54	0.99	132	0	0
Bank of China Limited Johannesburg branch	0.85	0.60	36	0	0	0.82	0.86	35	0	1	0.91	0.97	25	87	20
Bank of Taiwan South Africa branch	0.73	0.81	36	0	0	0.86	0.70	35	0	1	0.77	0.73	129	0	3
Bidvest Bank Limited	0.74	0.96	11	25	0	0.56	0.94	24	11	1	0.50	0.90	39	93	0
China Construction Bank Corporation - Johannesburg branch	0.80	0.76	36	0	0	0.75	0.86	35	1	0	0.90	0.96	34	77	21
GBS Mutual Bank	0.79	0.69	36	0	0	0.73	0.70	36	0	0	0.66	0.84	132	0	0
Gindrod Bank Limited	0.81	0.55	36	0	0	0.64	0.68	36	0	0	0.51	0.98	110	22	0
Habib Overseas Bank Limited	0.82	0.60	36	0	0	0.71	0.57	36	0	0	0.55	0.77	132	0	0

Vol: 14 **No: 0**4 **Year:** 2022 **ISSN**: 1309-8055 (Online) (**pp.** 152-) **Doi:** 10.34109/ijefs. 20220109

Table 5. Continued

HBZ Bank Limited	0.67	0.69	36	0	0	0.53	0.82	36	0	0	0.54	0.86	132	0	0
Mercantile Bank Limited	0.69	0.91	35	1	0	0.59	0.93	35	1	0	0.57	0.95	69	61	2
Sasfin Bank Limited	0.82	0.56	36	0	0	0.68	0.64	36	0	0	0.73	0.90	110	19	3
Societe Generale Johannesburg branch	0.86	0.88	32	0	4	0.84	0.80	28	4	4	0.79	0.84	113	2	17
Standard Chartered Bank	0.77	0.95	32	2	2	0.68	0.98	7	29	0	0.76	0.97	11	113	8
State Bank of India	0.88	0.71	34	0	2	0.81	0.68	36	0	0	0.62	0.87	111	20	1
The South African Bank of Athens Limited	0.73	0.90	36	0	0	0.72	0.89	36	0	0	0.65	0.97	132	0	0
Ubank Limited	0.35	0.73	36	0	0	0.44	0.81	36	0	0	0.74	0.99	111	16	5
Overall average	***0.76***	***0.76***	***34***	***2***	***1***	***0.68***	***0.80***	***33***	***3***	***0***	***0.67***	***0.91***	***95***	***32***	***5***

Note 1: IRS denotes increasing returns to scale; DRS denotes decreasing returns to scale; and CRS means constant returns to scale.
Note 2: More detailed results are available on request.
Source: Compiled by Author.

Vol: 14 **No:** 04 **Year:** 2022 **ISSN**: 1309-8055 (Online) (**pp.** 152-) **Doi:** 10.34109/ijefs. 20220109

In contrast, Berger et al. (1998) contend that banks in highly concentrated markets will engage in collusion and have little motivation to compete and reduce costs. The implication is that if the market concentration is limited, bank expenses are likely to decrease (Berger ett al., 1998). Yet, as shown in Table 2, the rising cost-to-income ratio from 2012 to 2020 contradicts this notion. Despite this, data suggests stricter cost management has been applied since 2018, with operating expenses remaining consistent. On the other hand, IT expenses continue to rise as banks boost their digitalization efforts (PwC, 2018).

Two of the top four South African banks, ABSA Group Limited and Standard Bank of South Africa Limited, saw the biggest decline in technical efficiency between September 2008 and January 2010, followed by FirstRand Group Limited and Nedbank Group Ltd, respectively. This contradicts Erasmus et al.'s (2014) conclusion that the financial crisis had little effect on the efficiency of the majority of South African banks. In contrast, despite its poor performance (lowest technical efficiency till September 2010), Nedbank Group Limited demonstrated a greater recovery than the other banks (especially from September 2010 to October 2010). In contrast, the other banks were more passive in the three years (September 2008 to September 2011) that followed the bankruptcy of Lehman Brothers (see Figure 4 and Table 5). Nedbank Group Limited's substantial recovery may have contributed to the Banker magazine's November 2011 selection of Nedbank Group Limited as South Africa's bank of the year (Nedbank, 2011).

Capitec Bank Holdings Limited, one of the smaller top six South African banks, exhibited the lowest overall average technical efficiency from September 2008 to September 2011 but reached full technical efficiency faster than the other banks (in March 2011), followed by Investec Bank Limited in June 2011. Capitec Bank Holdings Limited was also one of just two banks (with Nedbank Group Limited as the top performer) that improved their technical efficiency in the three years following the fall of Lehman Brothers (September 2008 to September 2011).

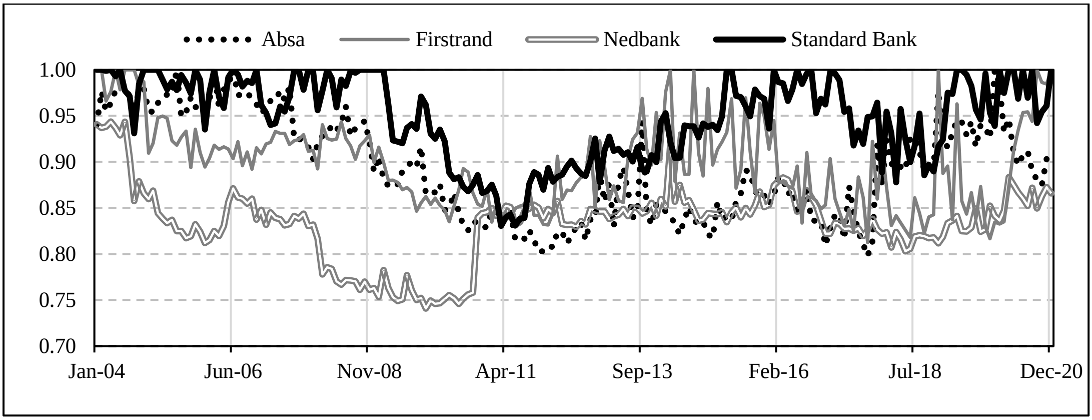

Figure 4: Technical efficiency of the large-sized (top four) banks
Source: Compiled by Author.

Vol: 14 **No: 0**4 **Year:** 2022 **ISSN**: 1309-8055 (Online) (**pp.** 152-) **Doi:** 10.34109/ijefs. 20220109

Compared to Capitec Bank Holdings Limited and Investec Bank Limited, the remaining top six banks demonstrated slower trends in obtaining complete technical efficiency, albeit averaging a greater degree of technical efficiency from October 2011 onwards (except for Nedbank Group Limited, which exhibited a lower technical efficiency estimate compared to Investec Bank Limited). Nonetheless, among the top six South African banks, Capitec Bank Holdings Limited showed greater inconsistency in technical efficiency from September 2008 to September 2011 and continued this behavior for the remainder of the evaluation period, highlighting the urgent need for Capitec Bank Holdings Limited to improve its resource management. Table 5 reveals that Capitec Bank Holdings Limited had a larger propensity to operate at a size that was too large, exhibiting falling returns to scale for 35 and 130 months, respectively, throughout the crisis and post-crisis periods. The variance in efficiency and delayed recovery trend of the top six South African banks justifies Basel III's implementation of additional capital for domestic systemically significant banks. Basel III mandates that systemically significant banks have greater loss-absorbing ability than the minimum capital requirements, as big banks can have systemic effects on the country that the financial sector cannot afford (BIS, 2011).

Yet, the instability in efficiency can also be linked to South Africa's unstable economy, random political events, and legislative changes. Moody's, for example, lowered South Africa to Baa1 in 2011, while S&P reduced it to junk status in 2017. In addition, financial sector reform was present in 2011, and South African banks began implementing Basel III in 2013 and Twin Peaks in April 2018. In 2015, three ministers of finance were appointed in less than a week, culminating in political instability. In addition, former president Zuma conducted a massive cabinet upheaval in 2017 that cast more doubt on the legitimacy of the South African government. These events exerted tremendous pressure on the South African market, with a number of them also resulting in significant capital outflows.

Standard Bank of South Africa Limited, as one of the top six South African banks, displayed the best overall average technical efficiency and was one of the institutions with the highest scale efficiency during the three evaluation years despite the presence of efficiency instability (see Table 5). This bank was also more consistent than the top six South African banks in being entirely scale-efficient (constant returns to scale). ABSA Group Limited demonstrated the second-best capacity to manage its resources more efficiently across the three time periods evaluated (overall average), trailed by FirstRand Group Limited, Investec Bank Limited, Nedbank Group, and Capitec Bank Holdings Limited, in that order (see Table 5). In addition to the impact of the financial crisis, it is interesting to note that ABSA Group Limited exhibited a downward trend in technical efficiency following the Barclays takeover in 2005, which continued until 2012, and then exhibited a flattening trend until 2018 when Barclays reduced its exposure in ABSA to 14.90%. (see Figure 4).

Vol: 14 **No:** 04 **Year:** 2022 **ISSN**: 1309-8055 (Online) (**pp.** 152-) **Doi:** 10.34109/ijefs. 20220109

From the standpoint of medium-sized banks, JP Morgan Chase Bank had the highest overall technical efficiency, despite exhibiting the third-highest level of instability across the evaluation period (terms of technical efficiency). JP Morgan Chase Bank was also more consistent in being entirely scale efficient (constant returns to scale) over all three test periods. However, African Bank Limited demonstrated the highest overall average scale efficiency throughout all three evaluation periods (see Table 5). Nonetheless, regarding technical efficiency, African Bank Limited continued to perform poorly even after the crisis. Even while technological efficiency has improved since 2010, it was due to irresponsible lending, where unsecured loans were the primary source of income. In August 2014, African Bank Limited failed and was placed under curatorship, which may explain why technical efficiency levels were more consistent throughout that time (see Figure 5). The restructuring of African Bank Limited can account for the rapid decline in technical efficiency in 2016.

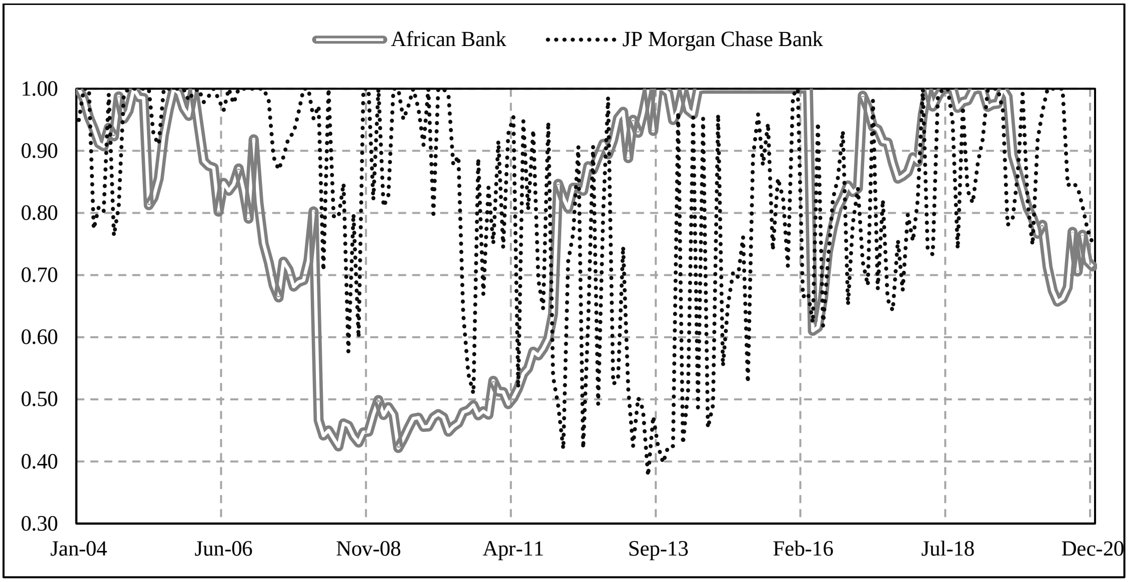

Figure 5: Technical efficiency of African Bank Limited relative to the best-performing medium-sized bank, JP Morgan Chase Bank
Source: Compiled by Author.

In addition, Hong Kong and Shanghai Banking Company Limited demonstrated the lowest and most unstable technical efficiency among medium-sized banks (see Table 5). Despite this, Investec Bank Limited showed the highest average technical efficiency for the subsequent three years (September 2008 to September 2011) following the demise of Lehman Brothers, followed by JP Morgan Chase Bank and Deutsche Bank AG, respectively. Between September 2008 and September 2011 (in October 2008), JP Morgan Chase Bank attained complete technical efficiency the quickest, followed by Deutsche Bank AG in March 2011 and Investec Bank Limited in June 2011. In addition, the average technical efficiency of the medium-sized banks was significantly lower than

Vol: 14 **No: 0**4 **Year:** 2022 **ISSN**: 1309-8055 (Online) (**pp.** 152-) **Doi:** 10.34109/ijefs. 20220109

that of the top four (17%) and six (13%) South African banks. The average scale efficiency of the medium-sized banks was significantly lower than that of the top four (21%) and top six (22%) South African banks (see Table 5). In general, medium-sized banks exhibited a greater tendency to operate at a scale that was too small (growing returns to scale).

In contrast, a greater tendency to operate at a scale that is too large emerged post-crisis (see Table 5). However, it was noteworthy that Capitec Bank Holdings Limited and Investec Bank Limited performed even worse as medium-sized banks than as two of the six largest South African banks. This may suggest that future research should not classify these banks as medium-sized because their technological efficiency was comparable to that of larger banks.

From the standpoint of a small bank, the Bank of China Limited Johannesburg branch demonstrated the highest overall average technical efficiency over all three evaluation periods (see Table 5). UBank Limited, on the other hand, showed the lowest overall average technical efficiency. In contrast, the Bank of China Limited Johannesburg branch demonstrated the greatest level of improvement in technical efficiency over the next three years (September 2008 to September 2011) following the collapse of Lehman Brothers, followed by China Construction Bank Corporation Johannesburg branch and The SA bank of Athens Limited, respectively. On the downside, the Societe Generale Johannesburg branch was one of ten banks that demonstrated a decline in technical efficiency over the next three years (September 2008 to September 2011) following the collapse of Lehman Brothers, with the latter exhibiting the third-worst performance during this time frame. Although the Societe Generale Johannesburg branch showed the quickest recovery, reaching full technical efficiency the most immediately (September 2008, October 2008, and again in February 2009) in the three years following the collapse of Lehman Brothers (September 2008 to September 2011), it exhibited the fifth lowest technical efficiency (among the 16 small banks) in September 2011.

Regarding overall technical efficiency, UBank Limited demonstrated the highest amount of instability, while GBS Mutual Bank exhibited the lowest instability. The Bank of China, Limited Johannesburg branch reached full technical efficiency second-fastest (in October 2009 and again in March 2010), followed by the China Construction Bank Corporation Johannesburg branch in March 2010. In addition, Standard Chartered Bank demonstrated the highest overall average scale efficiency over the three time periods evaluated, while Habib Overseas Bank Ltd demonstrated the lowest overall average scale efficiency. Throughout all three evaluation periods, it is noteworthy that most tiny banks tended to operate at a scale that was too small (growing returns to scale). In the post-financial crisis period, this trait was also more significant for large banks than for medium-sized banks. Compared to other small banks, the Societe Generale Johannesburg branch was the most consistent in scale efficiency (constant returns to scale) across all three evaluation periods. Even though small-sized banks demonstrated the lowest overall technical efficiency across all three evaluation periods, they outperformed medium-sized banks in terms of overall scale efficiency (see Table 5).

In conclusion, all evaluated banks, including the smaller ones, displayed inconsistency in technical and scale efficiency during the three evaluation periods. During the financial crisis, medium-sized banks demonstrated the biggest decline in average technical efficiency. However, large, medium, and small banks failed to fully recover after the crisis (to approach pre-crisis average levels), with the top four, top six, and small banks exhibiting an even lower intermediate level of technical efficiency throughout the post-crisis period (see Table 5). This demonstrates the effects of a stressed domestic economy in a low-growth environment and the limits resulting from the slow pace of structural reforms, including macroeconomic and global economic issues (PwC, 2019). In 2021, dismal economic growth forecasts and a significant fiscal deficit are anticipated to harm the performance of banks. Still, the South African banking system is healthy, and a steady recovery is expected after 2022. (S&P Global, 2021).

5. CONCLUSION

As anticipated, the large South African banks demonstrated more consistency and higher technical and scale efficiency levels, particularly during the crisis. Unfortunately, the top South African banks were not entirely technically efficient and could not maintain scale efficiency during the three time periods evaluated. Moreover, the results demonstrated that banks were slow to recover from the financial crisis. Overall, the inconsistency in the capacity to manage resources must be addressed, particularly following the crisis time. Also, most banks operated at a scale that was too modest (raising returns to scale), which may push them to grow too large, increasing future bank costs.

If reducing risk sensitivity and utilizing internal models in decision-making are core objectives of the forthcoming Basel IV, these results urge the Prudential Authority to change Basel III and future Accord criteria. It is suggested that the Prudential Authority should consider establishing an extra, all-inclusive, prudential tool derived from non-financial measure methodology that will provide greater insight into the management of resources. As one of the six largest banks in South Africa, Capitec Bank Holdings Ltd may increase its technical and scale efficiencies by 22% and 9%, respectively (on average over the three periods under evaluation). The implication is that an additional punishment must be applied for bad resource management. This will incentivize banks to run more effectively from a micro-management standpoint and encourage increased market disclosure, as the latter is anticipated to be a requirement of future Accords.

Based on the results, it was clear that Capitec Bank Holdings Limited and Investec Bank Limited worked more efficiently as two of the top six banks in South Africa; future research should not consider these banks to be medium- or small-sized. Due to the ongoing evolution of the banking industry, a regular efficiency review will be required to determine the impact of newly registered banks (Tyme Bank Limited and Discovery Bank Limited at the time of this study). Data restrictions continue to be a key barrier to assessing bank efficiency. Future research must investigate the applicability of adopting a non-financial measure methodology to identify troubled banks as a tipping point. Because non-financial indicators might represent the future repercussions of managerial actions, models like the DEA have the potential to serve as an early warning signal to identify failing banks. This would promote more stability in the banking industry because the South African Reserve Bank could handle such concerns in advance. This theory can be tested on defunct banks (such as Saambou, Islamic Bank Limited, Regal Treasury Private Bank Limited, and VBS Mutual Bank) to uncover common elements that can be watched to detect warning signals of problems.

REFERENCES

African Development Bank. (2012). Country outlook, South Africa. Retrieved from http://www.afdb.org/en/countries/southern-africa/south-africa/

Aigner, D., Lovell, C.K., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics, 6*(1), 21-37. Doi: https://doi.org/10.1016/0304-4076(77)90052-5

Akinboade, O.A., & Makina, D. (2006). Financial sector development in South Africa, 1997-2002. *Studies in Economics and Econometrics, 30*(1), 101-127. doi: https://doi.org/10.1080/10800379.2006.12106402

Avkiran, N.K. (1999). An application reference for data envelopment analysis in branch banking: helping the novice researcher. *International Journal of Marketing, 17*(5), 206-220. doi.org/10.1108/02652329910292675.

Banker, R.D., Charnes, A.W., & Cooper, W.W. (1984). Some models for estimating technical and scale efficiency in data envelopment analysis. *Management Sciences, 30*(9), 1078-1092. doi: https://doi.org/10.1287/mnsc.30.9.1078

Beck, T., Demirgüç-Kunt, A., & Levine, R. (2006). Bank concentration, competition, and crises: first results. *Journal of Banking and Finance, 30*(5), 1581-1603. doi: https://doi.org/10.1016/j.jbankfin.2005.05.010

Berger, A., & Hannan, T. (1998). The efficiency cost of market power in the banking industry: a test of the quiet life and related hypotheses. *Review of Economics and Statistics, 80*(3), 454-465. doi: https://doi.org/10.1162/003465398557555

BIS (Bank for International Settlements). (2011). Basel III: A global regulatory framework for more resilient banks and banking systems. Retrieved from http://www.bis.org/publ/bcbs189.pdf

Boyd, J.H., & De Nicoló, M.G. (2005). The theory of bank risk taking and competition revisited. *The Journal of Finance, 60*(3), 1329-1343. doi: https://doi.org/10.1111/j.1540-6261.2005.00763.x

Boyd, J.H., De Nicoló, M.G., & Jalal, A.M. (2009). Bank competition, risk and asset allocations. *IMF Working Paper No. 09/143*, 36. doi: https://doi.org/10.5089/9781451872903.001

Calice, P., & Leonida, L. (2018). Concentration in the banking sector and financial stability, 2-39. Retrieved from http://hdl.handle.net/10986/30583

Cetorelli, N., Hirtle, B., Morgan, D., Peristiani, S., & Santos, J. (2007). Trends in financial market concentration and their implications for market stability. *Economic Policy Review, Federal Reserve Bank of New York, 13*(1), 19. Retrieved from https://www.newyorkfed.org/medialibrary/media/research/epr/07v13n1/0703hirt.html

Charnes, A.W., Cooper, W.W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research, 2*(6), 429-444. doi: https://doi.org/10.1016/0377-2217(78)90138-8

Chen, C. (2009). Bank efficiency in Sub-Saharan African middle income countries. *IMF Working Paper, 13*(1), 19. doi: https://doi.org/10.5089/9781451871616.001

Chen, Y., & Zhu, J. (2004). Measuring information technology's indirect impact on firm performance. *Information Technology And Management, 5*(1-2), 9-22. doi: https://doi.org/10.1023/B:ITEM.0000008075.43543.97

Claessens, S., Demirgüç-Kunt, A., & Huizinga, H. (2001). How does foreign entry affect domestic banking markets? *Journal of Banking and Finance, 25*(5), 891-911. doi: https://doi.org/10.1016/S0378-4266(00)00102-3

Claessens, S., & Laeven, L. (2005). Financial dependence, banking sector competition, and economic growth. *Journal of the European Economic Association, 3*(1), 179-207. doi: https://doi.org/10.1162/1542476053295322

Clark, P. (1997). The balanced scorecard. *Accountancy Ireland, 29*(6), 25-26.

Coelli, T. (1998). A multi-stage methodology for the solution of orientated DEA models. *Operations Research Letters, 23*(3), 143-150. doi: https://doi.org/10.1016/S0167-6377(98)00036-4

Coelli, T., Rao, D.S.P., & Battese, G. (1998). *An introduction to efficiency and productivity analysis*. Boston: Kluwer Academic Publishers. Retrieved from https://books.google.co.in/books?hl

Cooper, W.W., Seiford, L.M., & Tone, K. (2007). *Data envelopment analysis: a comprehensive text with models, applications, references and DEA-solver software*, 2nd ed. New York, NY: Springer, 318. doi: https://doi.org/10.1007/b109347

Coppock, M., Forte, D., Ncube, B., Ooka, E., Richards, K., & Vyas, A. (2008). Basic information about South Africa. Retrieved from http://fic.wharton.upenn.edu/fic/africa/South%20Africa%20Final.pdf

Cronje, J.J.L. (2003). The efficiency of South African banks: a non-parametric approach. *Southern African Business Review, 7*(1), 32-40. Retrieved from https://journals.co.za/doi/pdf/10.10520/EJC90720

Cronje, J.J.L. (2007). Assessing the relative efficiency management of South African banks. *Management Dynamics: Journal of the Southern African Institute for Management Scientists, 16*(4), 11-23. Retrieved from https://journals.co.za/doi/epdf/10.10520/EJC69730

Deloitte. (2020). Deloitte insights: COVID-19 potential implications for the banking and capital markets sector. Retrieved from file:///C:/Users/12692174/Downloads/za-covid-19-banking%20(1).pdf

Du Toit, E., & Cuba, Y.Z. (2018). Cost and profit efficiency of listed South African banks pre and post the financial crisis. *Research in International Business and Finance*, *45*, 435-445. doi: https://doi.org/10.1016/j.ribaf.2017.07.175

Erasmus, C., & Makina, D. (2014). An empirical study of bank efficiency in South Africa using standard and alternative approaches to Data Envelopment Analysis (DEA). *Journal of Economics and Behavioural Studies*, *6*(4), 310-317. doi: https://doi.org/10.22610/jebs.v6i4.494

Farrell, M.J., (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society. Series A (General)*, *120*(3), 253–290. doi: https://doi.org/10.2307/2343100

Favero, C.A., & Papi, L. (1995). Technical efficiency and scale efficiency in the Italian banking sector: a non-parametric approach. *Applied Economics*, *27*(4), 385-395. doi: https://doi.org/10.1080/00036849500000123

Federal Reserve Bank of St. Louis. (2021a). Bank's Cost to Income Ratio for World. Retrieved from https://fred.stlouisfed.org/series/DDEI071WA156NWDB

Federal Reserve Bank of St. Louis. (2021b). Bank's Return on Equity for World. Retrieved from https://fred.stlouisfed.org/series/DDEI061WA156NWDB

Federal Reserve Bank of St. Louis. (2021c). Bank's Return on Assets for World. Retrieved from https://fred.stlouisfed.org/series/DDEI051WA156NWDB

Federal Reserve Bank of St. Louis. (2021d). Bank Z-score. Retrieved from https://fred.stlouisfed.org/tags/series?t=world+bank%3Bz-score

Fin24. (2017a). SA banks becoming battleground in Zuma war – analysts. Retrieved from https://www.fin24.com/Economy/sa-banks-becoming-battleground-in-war-around-zuma-20170127

Fin24. (2017b). Banking index bleeds over 11% in a week. Retrieved from https://www.fin24.com/Markets/Equities/banking-index-bleeds-over-11-in-a-week-20170406

Fischer, D. (2014). What the new leverage ratio means to banks and their customers. *Journal of Corporate Accounting and Finance*, *26*(1), 39-44. doi: https://doi.org/10.1002/jcaf.22003

Fourie, A., Van Heerden, C., & Du Plessis, E. (2022). Improving destination competitiveness in South Africa: a DEA approach. *Tourism Economics*, *28*(4), 1080-1100. doi: https://doi.org/10.1177/13548166211009987

Gilbert, E., Calitz, E., & Du Plessis, S. (2009). Prudential regulation, its international background and the performance of the banks a critical review of the South African environment since 1970. *South African Journal of Economic History*, *24*(2), 43-81. doi: https://doi.org/10.1080/10113430909511219

Girardone, C., Molyneux, P., & Gardener, EPM (2004). Analyzing the determinants of bank efficiency: the case of Italian banks. *Applied Economics*, *36*(3), 215-227.

Retrieved from https://www.tandfonline.com/doi/abs/10.1080/00036840420001753334?journalCode=raec20

Golany, B., & Storbeck, J. (1999). A data envelopment analysis of the operational efficiency of bank branches. *Interfaces*, *29*(3), 14-26. doi: https://doi.org/10.1287/inte.29.3.14

Greuning, H., & Bratanovic, S.B. (2009). Analyzing banking risk: a framework for assessing corporate governance and risk management. *Washington: IBRD/World Bank*. Retrieved from http://dspace.khazar.org/jspui/bitstream/20.500.12323/2787/1/Analyzing%20Banking%20Risk.pdf

Grosskopf, S. (1996). Statistical inference and non-parametric efficiency: a selective survey. *Journal of Productivity Analysis*, *7*(2), 161-176. doi: https://doi.org/10.1007/BF00157039

Hawkins, P. (2004). South Africa's financial sector ten years on: performance since democracy. *Development South Africa*, *21*(1), 179-204. doi: https://doi.org/10.1080/0376835042000181471

Hossain, M.K., Kamil, A.A., Baten, M.A., & Mustafa, A. (2012). Stochastic frontier approach and data envelopment analysis to total factor productivity and efficiency measurement of Bangladeshi rice, *PLoS ONE 7(10): e46081*. doi: https://doi.org/10.1371/journal.pone.0046081

Hughes, J. P., & Mester, L. J. (2013). Who said large banks don't experience scale economies? Evidence from a risk-return-driven cost function. *Journal of Financial Intermediation*, *22*, 559-585. doi: https://doi.org/10.1016/j.jfi.2013.06.004

Jacobs, R. (2001). Alternative methods to examine hospital efficiency: data envelopment analysis and stochastic frontier analysis. *Health Care Management Science*, *4*(2), 103-115. doi: https://doi.org/10.1023/A:1011453526849

Ifeacho, C., & Ngalawa, H. (2014). Performance of the South African banking sector since 1994. *The Journal of Applied Business Research*, *30*(4), 1183-1195. doi: https://doi.org/10.19030/jabr.v30i4.8663

Jaforullah, M., & Whiteman, J. (1999). Scale efficiency in the New Zealand dairy industry: a non-parametric approach. *The Australian Journal of Agricultural and Resource Economics*, *43*(4), 523-541. doi: https://doi.org/10.1111/1467-8489.00093

Kaparakis, E.I., Miller, S.M., & Noulas, A.G. (1994). Short-run cost inefficiency of commercial banks: a flexible stochastic frontier approach. *Journal of Money, Credit and Banking*, *26*(4), 875-893. doi: https://doi.org/10.2307/2077953

Kaufman, L., & Rousseeuw, P.J. (2009). *Finding groups in data: an introduction to cluster analysis*. Hoboken: Wiley. Retrieved from https://books.google.co.in/books?hl

Keogh, E., & Lin, J. (2005). Clustering of time-series subsequences is meaningless: implications for previous and future research. *Knowledge and Information Systems*, *8*(2), 154-177. doi: https://doi.org/10.1007/s10115-004-0172-7

Kirigia, J.M., Sambo, L.G., & Scheel, H. (2001). Technical efficiency of public clinics in KwaZulu-Natal province of South Africa. *East-African Medical Journal*, *78*(3), 1-13. doi: https://doi.org/10.4314/eamj.v78i3.9070

Kittelsen, S.A. (1999). Monte carlo simulations of DEA efficiency measures and hypothesis tests (No. 1999, 09). Memorandum, Department of Economics, University of Oslo. Retrieved from https://www.econstor.eu/bitstream/10419/63113/1/323421636.pdf

Kovner, A., Vickery, J., & Zhou, L. (2014). Do big banks have lower operating costs? *Economic Policy Review*, *20*(2), 1-27. Retrieved from https://ssrn.com/abstract=2419659

KPMG. (2011). Basel III: issues and implications. Retrieved from http://www.kpmg.com/global/en/issuesandinsights/articlespublications/documents/basell-iii-issues-implications.pdf

Kumar, N., & Singh, A. (2014). Efficiency analysis of banks using DEA: a review. *International Journal of Advance Research and Innovation*, *1*, 120-126. Retrieved from https://www.researchgate.net/profile/NandKumar/publication/261297255

Kumbirai, M., & Webb, R. (2010). A financial ratio analysis of commercial bank performance in South Africa. *African Review of Economics and Finance*, *2*(1), 30-53. Retrieved from https://www.ajol.info/index.php/aref/article/view/86945

Laeven, L., & Levine, R. (2007). Is there a diversification discount in financial conglomerates? *Journal of Financial Economics*, *85*(2), 331-367. doi: https://doi.org/10.1016/j.jfineco.2005.06.001

Liu, J.S., Lu, L.Y, Lu, W.M., & Lin, B.J.Y. (2013). A survey of DEA applications. Omega, 41(5), 893-902. doi: https://doi.org/10.1016/j.omega.2012.11.004

Lovell, C.A., & Pastor, J.T. (1995). Units invariant and translation invariant DEA models. *Operations Research Letters*, *18*(3), 147-151. doi: https://doi.org/10.1016/0167-6377(95)00044-5

Maredza, A., & Ikhide, S. (2013). Measuring the impact of the global financial crisis on efficiency and productivity of the banking system in South Africa. *Mediterranean Journal of Social Sciences*, *4*(6), 553-568. doi: https://doi.org/10.5901/mjss.2013.v4n6p553

Maumbe, B.M. (2006). Digital financial service delivery to poor communities in South Africa: a preliminary assessment. *International Review of Business Research Papers*, *2*(2), 72-79. Retrieved from https://www.researchgate.net/profile/Blessing-Maumbe-2/publication/228894589

Mboweni, T.T. (2004). The South African banking sector - an overview of the past 10 years. Retrieved from https://www.bis.org/review/r041231f.pdf

Meeusen, W., & Van Den Broeck, J. (1977). Efficiency estimation from Cobb-Douglas production functions with composed error. *International Economic Review, 18*(2), 435-444. doi: https://doi.org/10.2307/2525757

Mester, L.J. (1996). A study of bank efficiency taking into account risk-preferences. *Journal of Banking and Finance, 20*(6), 1025-1045. doi: https://doi.org/10.1016/0378-4266(95)00047-X

Mester, L.J. (2003). Applying efficiency measurement techniques to central banks. *FRB of Philadelphia Working Paper No. 03-13*, 40. Retrieved from https://core.ac.uk/download/pdf/6887928.pdf

Mishi, S., Sibanda, K., & Tsegaye, A. (2016). Industry concentration and risk-taking: evidence from the South African banking sector. *African Review of Economics and Finance, 8*(2), 113-136. Retrieved from https://journals.co.za/doi/abs/10.10520/EJC198163

Mlambo, K., & Ncube, M. (2011). Competition and efficiency in the banking sector in South Africa. *African Development Review, 23*(1), 4-15. doi: https://doi.org/10.1111/j.1467-8268.2010.00268.x

Molyneux, P., Altunbas, Y., & Gardener, E.P.M. (1996). *Efficiency in European banking*. New York, NY: Wiley.

Nedbank. (2011). Nedbank Group named South African Bank of the Year for 2011. Retrieved from https://www.nedbank.co.za

Nedbank. (2021). Group overview. Retrieved from https://www.nedbank.co.za/content

Nunamaker, T.R. (1985). Using data envelopment analysis to measure the efficiency of non-profit: a critical evaluation. *Managerial and Decision Economics, 6*(1), 50-58. doi: https://doi.org/10.1002/mde.4090060109

O'Donnell, C.J., & Van der Westhuizen, G. (2002). Regional comparisons of banking performance in South Africa. *South African Journal of Economics, 70*(3), 224-240. doi: https://doi.org/10.1111/j.1813-6982.2002.tb01301.x

Okeahalam, C. (2002). Structure and conduct in the commercial banking sector of South Africa, 4-20. Retrieved from http://www.tips.org.za/files/499.pdf

Okeahalam, C.C. (2006). Production efficiency in the South African banking sector: a stochastic analysis. *International Review of Applied Economics, 20*(1), 103-123. doi: https://doi.org/10.1080/02692170500362819

Oxford Business Group. (2014). The report: South Africa 2014. Retrieved from https://www.oxfordbusinessgroup.com/south-africa-2014

Paulson, J., & McAndrews, J. (1998). Financial services for the urban poor: South Africa's E Plan. doi: https://doi.org/10.1596/1813-9450-2016

PwC. (2019). Still a balancing act. Retrieved from https://www.pwc.co.za/en/assets/pdf/major-banks-analysis-nov-2019.pdf

Quiding, C. (2006). *The cost-benefit of regulation in South African banking*. MBA thesis, University of Pretoria. Retrieved from http://upetd.up.ac.za/thesis/available/etd-03312010-145049/unrestricted/dissertation.pdf

Samad, A., & Armstrong, V.S. (2022). Bootstrap-DEA management efficiency and early prediction of bank failure: evidence from 2008-2009 US bank failures. *Central Bank Review, 22*(3), 119-127. doi: https://doi.org/10.1016/j.cbrev.2022.08.002

Sapci, A., & Miles, B. (2017). Bank size, returns to scale and cost efficiency. Retrieved from https://core.ac.uk/download/pdf/229475488.pdf

S&P Global. (2021). South African banking sector 2021 outlook: Still beset by pandemic woes. Retrieved from https://www.spglobal.com/_assets/documents/ratings/research/100048924.pdf

Sealey, C.W., & Lindley, J.T. (1977). Inputs, outputs and a theory of production and cost as depositary financial institutions. *Journal of Finance, 32*(4), 1251-1266. doi: https://doi.org/10.1111/j.1540-6261.1977.tb03324.x

Schoombee, A. (2000). Banking for the poor: the successes and failures of South African banks, Poverty, Prosperity and Progress. Victoria University of Wellington, Wellington, New Zealand, November, 17-19.

Sharma, K.R., Leung, P., & Zaleski, H.M. (1997). Productive efficiency of the swine industry in Hawaii: Stochastic frontier vs. data envelopment analysis. *Journal of Productivity Analysis, 8*(4), 447-459. Retrieved from https://link.springer.com/article/10.1023/A:1007744327504

Sharma, K.R., Leung, P., & Zaleski, H.M. (1999). Technical, allocative and economic efficiencies in swine production in Hawaii: A comparison of parametric and non-parametric approaches. *Agricultural Economics, 20*(1), 23-35. doi: https://doi.org/10.1016/S0169-5150(98)00072-3

Shephard, R.W. (1953). *Cost and Production Functions*. Princeton, NJ.: Princeton University Press.

Shephard, R.W. (1970). *Cost and Production Functions*, 4th ed. Princeton, NJ.: Princeton University Press.

Sokol, O., & Frýd, L. (2022). DEA efficiency in agriculture: Measurement unit issues. *Socio-Economic Planning Sciences*, (Des), 101497. doi: https://doi.org/10.1016/j.seps.2022.101497

Soteriou, A.C., & Stavrinides, Y. (2000). An internal customer service quality data envelopment analysis model for bank branches. *The International Journal of Bank Marketing, 18*(5), 246-252. doi: https://doi.org/10.1108/02652320010356799

South African Reserve Bank (SARB). (1994-2007). Bank supervision annual reports. Retrieved from https://www.resbank.co.za/Publications/Reports/Pages/BankSupervisionAnnualReports.aspx

South African Reserve Bank (SARB). (1999-2018). Bank supervision department annual reports. Retrieved from https://www.resbank.co.za/Publications/Reports/Pages/BankSupervisionAnnualReports.aspx

South African Reserve Bank (SARB). (2004-2017). Bank supervision department annual reports. Retrieved from https://www.resbank.co.za

South African Reserve Bank (SARB). (2004-2020). Selected South African banking sector trends. Retrieved from https://www.resbank.co.za

South African Reserve Bank (SARB). (2004-2020). Financial stability review. Retrieved from https://www.resbank.co.za/Publications/Reviews/Pages/FinancialStabilityReview.aspx

South African Reserve Bank (SARB). (2002). Bank supervision department: annual report 2002. Retrieved from https://www.resbank.co.za

South African Reserve Bank (SARB). (2012). Bank supervision department: annual report 2012. Retrieved from: https://www.resbank.co.za/Publications/Reports/Pages

South African Reserve Bank (SARB). (2016a). Financial stability review. Retrieved from http://www.rba.gov.au/publications/fsr/2016/oct/pdf/financial-stability-review-2016-10.pdf

South African Reserve Bank (SARB). (2016b). Bank supervision department: annual report 2016. Retrieved from: https://www.resbank.co.za/Publications/Reports/Pages

South African Reserve Bank (SARB). (2019). Bank supervision department: annual report 2019. Retrieved from https://www.resbank.co.za/Publications/Reports

South African Reserve Bank (SARB). (2018-2020). Selected South African banking sector trends. Retrieved from https://www.resbank.co.za/PrudentialAuthority/Statistics

South African Reserve Bank (SARB). (2020). Financial stability review. Retrieved from https://www.resbank.co.za/Lists/News%20and%20Publications/Attachments/9956

South African Reserve Bank (SARB). (2022a). Banks historical DI900 converted to BA900. Retrieved from https://www.resbank.co.za/RegulationAndSupervision/BankSupervision

South African Reserve Bank (SARB). (2022b). Economic and financial statistics for South Africa. Retrieved from https://www.resbank.co.za/en/home/what-we-do/statistics/releases

South African Reserve Bank (SARB). (2022c). Prudential authority annual report. Retrieved from https://www.resbank.co.za/en/home/publications/publication-detail-pages

South African Reserve Bank (SARB). (2022d). Financial stability review. Retrieved from https://www.resbank.co.za/content/dam/sarb/publications/reviews/finstab-review/2021

The Banking Association of South Africa. (2014). South African banking sector overview. Retrieved from http://www.banking.org.za/docs/default-source/publication/banking

Titko, J., Stankevičienė, J., & Lāce, N. (2014). Measuring bank efficiency: DEA application. *Technological and Economic Development of Economy, 20*(4), 739-757. doi: https://doi.org/10.3846/20294913.2014.984255

Vaithilingam, S., Nair, M., & Samudram, M. (2006). Key drivers for soundness of the banking sector: lessons for developing countries. *Journal of Global Business and Technology, 2*(1), 1-11. Retrieved from https://gbata.org/wp-content/uploads/2013/02/JGBAT_Vol2-1-p1.pdf

Van der Westhuizen, G. (2014). Bank efficiency and financial ratios: rating the performance of the four largest South African banks. *Journal of Applied Business Research, 30*(1), 93-104. doi: https://doi.org/10.19030/jabr.v30i1.8286

Van der Westhuizen, G., & Battese, G.E. (2013). Technical efficiency of South African banks in generating interest and noninterest income: a stochastic frontier analysis. *Studia Universitatis Babes-Bolyai, 58*(3), 20-42. Retrieved from https://www.ceeol.com/search/article-detail?id=225544

Van der Westhuizen, G., & Lawrence, D. (2012). The total factor productivity of the four largest banks in South Africa: preliminary evidence from index numbers methodology. *Studia Universitatis Babes-Bolyai, 57*(3), 45-59. Retrieved from https://www.ceeol.com/search/article-detail?id=80767

Van Heerden, C. & Coetzee, J. (2019). Re-examining the ability to explain future South African banking share returns: a data envelopment analysis approach. *South African Journal of Economics and Management Sciences, 22*(1), 1-18. doi: https://doi.org/10.4102/sajems.v22i1.2852

Van Heerden, C., & Heymans, A. (2013). A fundamental evaluation of the top five South African banks after the financial crisis. *Journal of Economic and Financial Sciences, 6*(3), 731-762. doi: https://doi.org/10.4102/jef.v6i3.256

Van Heerden, C., & Saayman, M. (2018). Sustainability of a national arts festival: an application of a data envelopment analysis approach. *Tourism Economics, 24*(5), 576-592. doi: https://doi.org/10.1177/1354816618762186

Van Heerden, C., & Van der Westhuizen, G. (2008). The cost of banking services and the technical efficiency of a South African bank. *The Journal for Transdisciplinary Research in Southern Africa, 4*(2), 401-417. doi: https://doi.org/10.4102/td.v4i2.160

Van Heerden, C., & Van Heerden, W. (2022). Evaluating the usefulness of the DEA model to identify ratios that can explain South African stock market returns. *International Journal of Economics and Finance Studies, 14*(3), 168-210. doi: https://doi.org/10.34111/ijefs.20220069

Wheelock, D., & Wilson, P. (2012). Do large banks have lower costs? New estimates of returns to scale for US banks. *Journal of Money, Credit and Banking, 44*(1), 171-199. doi: https://doi.org/10.1111/j.1538-4616.2011.00472.x

World Bank. (2022). GDP (current US$). Retrieved from https://data.worldbank.org/indicator/NY.GDP.MKTP.CD

World Economic Forum, (2009-2016). The global competitiveness report. Retrieved from http://www.weforum.org/reports

Yeh, Q.J. (1996). The application of data envelopment analysis in conjunction with financial ratios for bank performance evaluation. *Journal of the Operational Research Society*, *47*(8), 980-988. doi: https://doi.org/10.1057/jors.1996.125

Yue, P. (1992). Data envelopment analysis and commercial bank performance: A primer with applications to Missouri banks. *IC² Institute Articles*, 31-45. Retrieved from https://repositories.lib.utexas.edu/handle/2152/46390

Zhu, J. (2003*). Quantitative models for performance evaluation and benchmarking: data envelopment analysis with spreadsheets*, 327. Boston: Kluwer Academic Publishers. https://doi.org/10.1007/978-0-387-85982-8

Zhu, J. (2016). DEAFrontier. Retrieved from http://www.deafrontier.net/deasupport