

**UNIVERSITY OF GHANA**



**THE NEXUS BETWEEN BANK COMPETITION AND DYNAMIC COST  
PRODUCTIVITY – THE GHANAIAAN EXPERIENCE**

**BY**

**STEPHEN QUARSHIE**

**(INDEX NO.: 10456591)**

**THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN  
PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF A MASTER  
OF PHILOSOPHY IN FINANCE  
SEPTEMBER, 2024**



**DECLARATION**

I do hereby declare that this work is the result of my own research and has not been presented by anyone for any academic award in this or any other university. All references used in the work have been fully acknowledged.

I bear sole responsibility for any shortcomings.



19th September, 2024

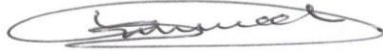
.....  
STEPHEN QUARSHIE (10456591)

DATE



**CERTIFICATION**

I hereby certify that this thesis was supervised in accordance with procedures laid down by the University



31<sup>st</sup> December, 2025

.....  
DR BENJAMIN AMOAH  
(SUPERVISOR)

.....  
DATE



29<sup>th</sup> December, 2025

.....  
DR KWAKU OHENE-ASARE  
(SUPERVISOR)

.....  
DATE



## ACKNOWLEDGEMENT

I would like to express my deepest gratitude to all those who have supported and guided me throughout the course of this research. Without their invaluable assistance, this study would not have been possible.

First and foremost, I am profoundly grateful to my supervisors Dr. Benjamin Amoah and Dr. Kwaku Ohene-Asare, for their continuous support, insightful feedback, and encouragement. Their expertise and dedication have been instrumental in shaping the direction of this research, and I am deeply appreciative of the time and effort they have invested in guiding me.

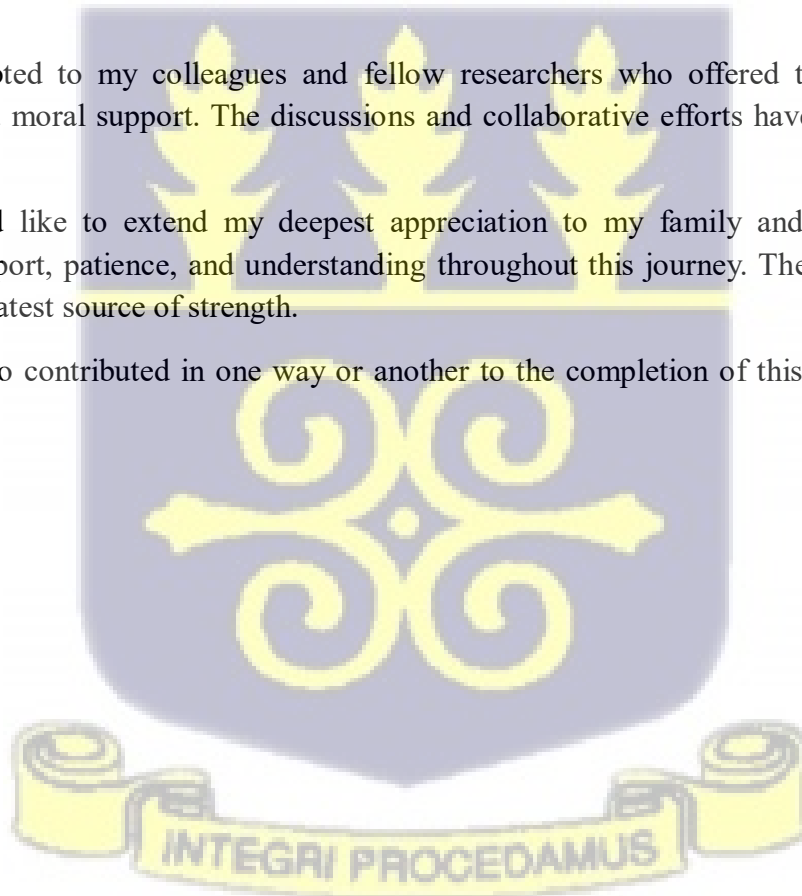
I would also like to thank the faculty and staff of University Of Ghana Business School for providing the academic environment and resources necessary for conducting this research.

My heartfelt thanks go to the bank officials and financial institutions who provided the data and information needed for this study. Their cooperation and openness were vital to the success of this research.

I am also indebted to my colleagues and fellow researchers who offered their perspectives, suggestions, and moral support. The discussions and collaborative efforts have greatly enriched my work.

Finally, I would like to extend my deepest appreciation to my family and friends for their unwavering support, patience, and understanding throughout this journey. Their encouragement has been my greatest source of strength.

To everyone who contributed in one way or another to the completion of this study, I offer my sincere thanks.



**TABLE OF CONTENTS**

DECLARATION .....	i
CERTIFICATION.....	ii
ACKNOWLEDGEMENT .....	iii
TABLE OF CONTENTS.....	iv
LIST OF TABLES .....	vii
LIST OF FIGURES.....	viii
LIST OF ABBREVIATIONS .....	ix
ABSTRACT.....	x
CHAPTER ONE .....	1
INTRODUCTION.....	1
1.1 Study Background.....	1
1.2 Problem Statement.....	4
1.3 Research Objectives.....	5
1.4 Research Questions.....	6
1.5 Study Contributions.....	6
1.6 Thesis Structure.....	7
CHAPTER TWO .....	8
LITERATURE REVIEW .....	8
2.1 Introduction.....	8
2.2 Theoretical Review.....	8
2.2.1 “Quiet Life” Hypothesis.....	8
2.2.2 “Structure-Conduct-Performance” Hypothesis.....	10
2.2.3 “Efficient – Structure” Hypothesis .....	11
2.2.4 “Banking Specificities” Hypothesis.....	12
2.2.5 Transaction Cost Theory .....	14
2.3 Empirical Review .....	16
2.3.1 Efficiency assessment in the banking industry .....	16
2.3.2 Cost productivity assessment of banks.....	20
2.3.3 Competition and cost efficiency in banking .....	22
2.4 Conceptual Framework.....	24
2.5 Conclusion .....	25

CHAPTER THREE METHODOLOGY .....	27
3.1 Introduction .....	27
3.2 Research Design .....	27
3.3 Population, Sampling and Source of data .....	28
3.4 Dynamic Productivity Model .....	28
3.4.1 The Malmquist Productivity Change Index (M) .....	28
3.4.2 The Cost Malmquist Productivity Index .....	35
3.4.3 Four and Eight factor Components of The Cost Malmquist Productivity Index .....	35
3.4.4 Numerical example .....	38
3.5 Test and Choice of Return To Scale (RTS) in DEA .....	40
3.6 Input and Output Specification .....	42
3.6.1 Input and input price .....	43
3.6.2 Output .....	45
3.7 Productivity Change Convergence .....	46
3.8 Second-Stage Regression Analysis .....	47
3.8.1 Econometric Tests .....	47
3.9 Data Analysis Instruments .....	54
3.10 Chapter Summary .....	55
CHAPTER FOUR .....	55
DATA ANALYSIS AND DISCUSSION .....	55
4.1 Introduction .....	55
4.2 Descriptive Statistics .....	56
4.3 Estimation of Bank Competition in Ghana .....	61
4.4 Evaluation of Cost Efficiency and Cost Productivity Change .....	64
4.5 Decomposition of Cost Productivity Change .....	66
4.6 Handling Potential Linear Programming Infeasibilities in Dynamic Cost Productivity Estimation ....	69
4.7 Exploring the Bi-directional Nexus Between Competition and Cost Productivity Change .....	71
5.4 Discussion of Findings .....	74
CHAPTER FIVE .....	81
SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS .....	81
5.1 Introduction .....	81
5.2 Summary of Findings .....	82
5.3 Conclusions of the Study .....	84

5.4 Recommendations .....	86
5.4.1 Recommendations for Practice .....	86
5.5 Limitations of the Study.....	91
5.6 Suggestions for Future Research .....	92
REFERENCES.....	95
APPENDIX.....	137



**LIST OF TABLES**

Table 4.1: Simar & Wilson CRS Test ..... 42  
Table 4.2: Descriptive Statistics of Key Variables (2000-2020).....57  
Table 4.3: Average Lerner Index per Bank (2000-2020).....61  
Table 4.4: Average Efficiency per Bank (2000-2020).....64  
Table 4.5: Decomposition of Cost Productivity Change per Bank (2000-2020) .....67  
Table 4.6: Bi-Directional Nexus Between Competition And Cost Productivity Change .....72



## LIST OF FIGURES

Figure 1: Level of Bank Competition .....	59
Figure 2: Conceptual framework .....	25



### LIST OF ABBREVIATIONS

ATM	Automated Teller Machine
CRS	Constant Returns to Scale
DEA	Data Envelopment Analysis
DMU	Decision-Making Unit
DRS	Decreasing Returns to Scale
GCB	Ghana Commercial Bank
GDP	Gross Domestic Product
IRS	Increasing Returns to Scale
KYC	Know Your Customer
NIRS	Non-Increasing Returns to Scale
RTS	Return to Scale
SCP	Structure-Conduct-Performance Hypothesis
SME	Small and Medium-Sized Enterprise
VRS	Variable Returns to Scale
WAMZ	West African Monetary Zone



## ABSTRACT

This study investigates the relationship between competition and cost productivity in the Ghanaian banking sector, with the aim of understanding how competitive dynamics influence bank efficiency and performance. The study is structured around five key objectives: estimating the level of competition among banks, evaluate cost efficiency and cost productivity changes, decompose cost productivity into its underlying drivers, address potential linear programming infeasibilities in productivity estimation, and explored the bi-directional nexus between competition and cost productivity. Using a combination of econometric analysis and Data Envelopment Analysis (DEA), the study examines data from Ghanaian banks over a specific period.

The findings reveal significant variability in competition levels, with some banks displaying substantial market power while others operate in highly competitive environments. On average, the banking sector remains moderately competitive, with concentration (HHI) stable between 0.20–0.30 and pricing power (Lerner Index) averaging 0.30–0.40. The study also finds considerable differences in efficiency levels, with larger banks benefiting more from scale efficiencies and technological advancements. Most banks operate close to the efficiency frontier, with technical efficiency around 0.96–1.02, though scale efficiency varies more widely (0.93–1.05). However, some banks face challenges due to inefficiencies in resource utilization. The regression analysis demonstrates a positive but modest correlation between competition, as measured by the Lerner Index, and cost productivity, suggesting that banks with greater market power tend to be more efficient. However, this relationship is complex and influenced by other factors such as technological adoption, management practices, and regulatory frameworks. The study concludes that while competition plays a significant role in shaping bank efficiency, it is not

the sole determinant. Strategic investments in technology, process optimization, and risk management are critical for enhancing productivity in the banking sector. The study offers several recommendations for both practitioners and policymakers, including the need to foster a balanced competitive environment, encourage technological adoption, and enhance regulatory oversight.



## CHAPTER ONE

### INTRODUCTION

#### 1.1 Background of the Study

Banks, globally, play critical roles in boosting economic growth and development by intermediating financial services between lenders and savers (Beck & Levine, 2004; Allen N. Berger, Molyneux, & Wilson, 2020; King & Levine, 1993; Levine, Loayza, & Beck, 2000; Levine & Zervos, 1998; Tadesse, 2002). For instance, the Ghanaian banking industry is seen as the engine of GDP growth in the country. For example from 1960 to 2021, the percentage of bank assets to GDP is estimated at 28.25% (GE, 2021). Given the importance of banks in the economy, it is crucial to assess how well they are doing in terms of their cost efficiencies and dynamic cost productivity from time to time.

To that effect several banking efficiency and productivity change studies have been conducted (Allen N Berger & Humphrey, 1997; Bhatia, Basu, Mitra, & Dash, 2018; Daraio, Kerstens, Nepomuceno, & Sickles, 2020; Fethi & Pasiouras, 2010; J. S. Liu, Lu, & Lu, 2016; Paradi & Zhu, 2013; L. Zhao, Zhu, & Zhang, 2021) and therefore received attention from researchers, policymakers, bank managers, and bank regulators. Such bank performance analyses have been undertaken using ratio analysis (Allen N Berger & Bouwman, 2013; Yeh, 1996; J. Zhao, Li, Yu, Chen, & Lee, 2022), Stochastic Frontier Analysis (SFA) (Badunenko, Kumbhakar, & Lozano-Vivas, 2021; Allen N Berger, Hasan, & Zhou, 2009; Delis, Iosifidi, & Tsionas, 2020; Glass, Kenjegalieva, & Weyman-Jones, 2020; Hassan & Aliyu, 2018; Kraft & Tirtiroğlu, 1998; Lensink & Meesters, 2014) and Data Envelopment Analysis (DEA) (Beck & Levine, 2004; Allen N Berger & Humphrey, 1997; Boubaker, Do, Hammami, & Ly, 2022; Daraio et al., 2020; Emrouznejad &

Yang, 2018; Fukuyama & Tan, 2022; Z. Li, Feng, & Tang, 2022; J. S. Liu, Lu, Lu, & Lin, 2013; Mahmoudabadi & Emrouznejad, 2019; Rostamzadeh, Akbarian, Banaitis, & Soltani, 2021). In the operational research literature, DEA and SFA are the most common and widely used analyses to appraise the efficiency and dynamic productivity of firms (Ahmad, Naveed, Ahmad, & Butt, 2020; Andor & Hesse, 2014; Jreisat, Rabbani, Omran, Al-Mohamad, & Bakry, 2022; Kutlu, Tran, & Tsionas, 2020; Omrani, Alizadeh, Emrouznejad, & Oveysi, 2022). The efficiency of any firm can loosely be defined as how well they can use their inputs to generate maximum outputs without creating waste relative to other firms (Farrell, 1957). Bank as a financial intermediary uses inputs such as labour, physical capital, and deposit to generate loans, interest income, and non-interest income (Fethi & Pasiouras, 2010; Shamshur & Weill, 2019; Thaker, Charles, Pant, & Gherman, 2022). To perform this role banks must perform well and contribute to the economic growth of the Ghanaian economy. The use of efficiency and productivity change has become the most preferred method in measuring the performance of banks.

There are a lot of studies on banking efficiency and productivity change that cut across many countries (e.g. European countries (B. Casu, A. Ferrari, C. Girardone, & J. O. Wilson, 2016; Fiordelisi & Molyneux, 2010; Galariotis, Kosmidou, Kousenidis, Lazaridou, & Papapanagiotou, 2021; H. Liu, Molyneux, & Wilson, 2013; Shamshur & Weill, 2019), China (Antunes, Hadi-Vencheh, Jamshidi, Tan, & Wanke, 2022; X. Chen & Wu, 2020; Dong, Firth, Hou, & Yang, 2016; Lee, Li, Yu, & Zhao, 2021; L. Zhao et al., 2021), India (Badunenko & Kumbhakar, 2017; Tzeremes, 2015), Pakistan (Nan Zhu, Shah, Kamal, & Yasmeen, 2021), United States of America (Assaf, Berger, Roman, & Tsionas, 2019; Z. Li et al., 2022), Brazil (Tecles & Tabak, 2010), and Sub-Saharan African countries (Lotto, 2019; Kwaku Ohene-Asare & Asmild, 2012; Wanke, Barros, & Emrouznejad, 2016). Efficiency and productivity are linked and are sometimes

mistakenly used interchangeably (Coelli, Rao, O'Donnell, & Battese, 2005; C. Yu, 2016) but there is a clear distinction in the efficiency and productivity literature. Efficiency is a component of productivity that assesses the performance of a bank at a particular time while productivity moves further to assess the performance of the bank over some time (Bhatia et al., 2018; Fethi & Pasiouras, 2010). It is necessary to assess both the efficiency and productivity change of banks to allow banks that are not doing well to learn from the efficient banks and also allow policymakers to come up with informed decisions to improve the banking industry.

Banks work in a competitive environment (Mester, 1996) and therefore it is meaningful to find how competition relates to bank efficiency and productivity change. Several studies have also looked at competition efficiency and productivity (Alhassan & Ohene-Asare, 2016a; Huang, Hu, & Chang, 2018; Marius Andrieş & Căpraru, 2012; Tan & Floros, 2018; Tan, Wanke, Antunes, & Emrouznejad, 2021; Weill, 2004). There is a body of literature that contends that competition fosters efficiency and productivity in the banking industry. A study conducted by (Zarutskie, 2013) in the United States of America (USA) shows that when there is intense competition, banks can specialize and modify their lending techniques and concentrate on specific loan types or borrower groups. This strategic approach could enable them to reduce loan processing and origination costs thereby improving the cost efficiency of the bank. Empirical studies from USA observed that heightened competition motivated banks to embrace advanced credit rating technology, facilitating the extension of new credit to both existing customers and individuals who were previously excluded from accessing credit (Dick & Lehnert, 2010). In a less competitive banking industry with only few firms dominating, managers of those few firms relax become and inefficient in their operation (Nguyen, Perera, & Skully, 2016)

Another line of research suggests that competition can result in inefficiency within the banking sector. Empirical evidence by (Weill, 2004) supports the negative relationship between competition and efficiency. Moreover, increased competition could lead banks to engage in excessive risk-taking while approving loans, subsequently elevating the likelihood of bank failure.

In this current study, banks are seen as firm playing an intermediary functioning within competitive markets and employing a multi-input-output technology (Kaparakis, Miller, & Noulas, 1994). Given the importance of the relationship between bank competition and productivity change to economic growth, it is imperative to investigate the impact of competition on productivity change and vice-versa in the Ghanaian banking industry.

## 1.2 Problem Statement

Of the various gaps identified in the banking efficiency and productivity literature, the following are worthy to note. First, there is no bank dynamic cost productivity study in Ghana. This is important because we need to capture an important form of efficiency called allocative efficiency and also the effect of input price changes which can only be ascertained if cost productivity change is estimated. By allocative efficiency we mean the ability of a bank to choose a more cost efficient input mix or by allocating funds towards a less expensive but sufficient input mix (Maniadakis & Thanassoulis, 2004). Existing Ghanaian banking efficiency literature only examined technical efficiency and productivity changes of banks without capturing price and allocative effect and hence cost changes (Ohene-Asare and Asmild, 2011; Bopkin, 2013; Alhassan and Ohene-Asare, 2016, Alhassan and Biekpe, 2016; Nartey et al, 2019).

Second, no bank dynamic productivity study has decomposed cost productivity change into eight components to determine all the potential drivers of cost productivity (Ohene-Asare and Baah,

2022). There is no application of the concept of cost innovators proposed by (Ohene-Asare and Baah, 2022) in the bank cost productivity change literature. Identifying these “movers and shakers” in the industry is important because arguably they are the one that determine the efficiency levels of other banks by shifting the cost frontier.

Third, there is no bank efficiency and productivity study that have investigated the interrelationship between competition and dynamic cost productivity. Only a handful of studies have empirically tested the relationship between competition and cost efficiency without considering cost factors (Alhassan & Ohene-Asare, 2016a; El Moussawi & Mansour, 2022; Fungáčová, Pessarossi, & Weill, 2013; Phan, Anwar, Alexander, & Phan, 2019)

Finally, there are a limited robust econometric techniques exploring the nexus between competition, financial crisis and bank dynamic cost productivity. Researchers that use Data Envelopment Analysis in the first stage of dynamic productivity estimation also use limited second stage robust techniques (R. Banker, Natarajan, & Zhang, 2019; R. D. Banker & Natarajan, 2008; Simar & Wilson, 2007; Léopold Simar & Paul W Wilson, 2011, 2015)

### **1.3 Research Objectives**

The objectives of this study are in three dimensions. First is to evaluate the measures of competition in the Ghanaian banking industry, second to find a way to estimate the cost productivity change and their components in the Ghanaian banking industry, and lastly to analyze the impact of competition on bank cost productivity change and their bi-directional effect. The specific objectives are to:

- i. Estimate the level of competition of banks in Ghana
- ii. Evaluate the cost efficiency and cost productivity change of banks in Ghana.

- iii. Decompose cost productivity change into multiple drivers
- iv. Handle potential linear programming infeasibilities in dynamic cost productivity estimation.
- v. Explore the bi-directional nexus between competition and cost productivity change.

#### 1.4 Research Questions

This study seeks to answer the following questions:

- i. What is the effective measure of competition in the Ghanaian banking industry?
- ii. What is the dynamic cost productivity of banks in Ghana?
- iii. To what extent do the 8 factors drive bank cost productivity change?
- iv. Do bank dynamic cost productivity significantly influence their competition in the banking industry
- v. To what extent does bank competition impact cost productivity change?

#### 1.5 Study Contributions

The study seek to ascertain the main drivers of bank cost productivity change and examine the relationship between competition and bank cost productivity change to guide policy recommendation for bank regulators, provide practical managerial policies on cost productivities and components for banks. The result for this study would contribute to policy, practice and academic research.

This study contributes to literature in five-fold. First, this study contributes to the bank efficiency and productivity studies by applying the Cost Malmquist Productivity change (CMPI) index in the banking industry for the first time. Second, the premier application of cost innovators concept in banking. Third, the novel application of nexus between bank competition and dynamic cost

productivity. Fourth, the study adds to the bank productivity literature by uniquely examining the potential reverse causality between bank competition and cost productivity change. Fifth, the study contributes to the bank efficiency and productivity studies by exploring different robust econometric methods.

## 1.6 Thesis Structure

The study is grouped into five chapters, each chapter has sections and possible subsections. The first chapter looks at research background, problem statement, research contributions, objectives and questions. The second chapter focuses on the existing theoretical and empirical literature related to efficiency and productivity studies connected to the research topic and the relationship between bank efficiency and competition. The third chapter discussed in detail the methodology of the study, the methodology includes research design, population, sampling and data sources, frontier productivity analysis and detailing the Cost Malmquist Productivity Index. The fourth chapter shows the results obtained from the data analysis which includes graphical illustrations and data presentations. The last chapter discusses, summarizes, concludes, makes recommendations and proposes directions for further research.



## CHAPTER TWO

### LITERATURE REVIEW

#### 2.1 Introduction

The important theories and empirical applications in the literature relating to competition, efficiency and productivity in the banking sector are discussed in this chapter. The chapter is divided into three primary sections: theoretical review, empirical review, and conceptual framework. The theoretical review discusses the theoretical basis for the study, while the empirical review details the current body of research on competition, efficiency, and productivity research related to the banking sector. The final part ties the theoretical and empirical reviews together to form the conceptual framework of the study, which serves as the study's engine.

#### 2.2 Theoretical Review

The theoretical foundations of this study are presented in this part. The theories are grouped into three categories: shareholders and management and firm performance.

##### 2.2.1 “Quiet Life” Hypothesis

The Quiet Life Hypothesis proposes that firms with significant market power may become complacent, prioritizing comfort and avoiding the pressure to improve efficiency or innovate (Hicks, 1935). In the banking sector, this hypothesis suggests that banks with greater pricing power are less inclined to minimize costs or enhance productivity, preferring a stable and less competitive operational environment.

One of the strengths of the Quiet Life Hypothesis is its intuitive explanation for observed inefficiencies among dominant banks. It highlights how reduced external pressure can diminish the incentives for operational improvement (Berger & Hannan, 1998). Recent empirical studies,

such as those by Amidu and Wolfe (2022), provide evidence that banks with stronger market power, particularly in emerging economies, often exhibit lower efficiency levels, supporting the core argument of the hypothesis.

However, the hypothesis has notable weaknesses. It generalizes firm behavior by assuming all dominant firms prefer complacency, whereas some banks actively pursue innovation and operational excellence even with significant market power (Djalilov & Piesse, 2021). It also underestimates the role of internal governance mechanisms and managerial incentives that can drive efficiency regardless of external competitive pressure.

The Quiet Life Hypothesis also faces limitations in empirical testing. Accurately measuring competition and market power remains challenging, especially in industries like banking where non-price competition and regulatory oversight are significant (Jiang et al., 2022). Furthermore, distinguishing between strategic business decisions and true inefficiency is complex, as banks may maintain higher costs to meet regulatory compliance or to invest in long-term capabilities rather than reflecting complacency.

Despite these weaknesses, the Quiet Life Hypothesis remains highly applicable in examining the Ghanaian banking sector. It provides a relevant theoretical lens for assessing whether banks with higher market power in Ghana tend to show signs of operational slack or cost inefficiency. Understanding this relationship is vital for policymakers aiming to foster competition while ensuring banking sector stability.



### 2.2.2 “Structure-Conduct-Performance” Hypothesis

The Structure-Conduct-Performance (SCP) Hypothesis suggests that the structure of a market influences firm behavior (conduct), which in turn determines the level of market performance (Bain, 1956). In the banking sector, the hypothesis argues that a more concentrated market structure leads to less competitive behavior among banks, resulting in higher profits but potentially lower efficiency and innovation.

A major strength of the SCP Hypothesis is its straightforward, logical chain linking market concentration, firm behavior, and performance outcomes. It provides a clear framework for analyzing how structural factors such as the number of competitors, entry barriers, and market share distribution affect competition and firm outcomes. Recent studies, such as Adusei and Ntim (2022), have shown that in many African banking sectors, higher market concentration is associated with reduced competition and inefficiencies, lending empirical support to the SCP framework.

However, the SCP Hypothesis has notable weaknesses. It assumes a unidirectional causality—from structure to conduct to performance—without considering the possibility that efficient firms might naturally gain greater market share, thus altering the market structure (a point central to the Efficient-Structure Hypothesis). Moreover, it does not adequately account for the dynamic nature of competitive behavior, especially in rapidly changing environments where innovation and technological disruption can alter conduct independently of structural changes (Berger, 2021).

In terms of limitations, empirical tests of the SCP Hypothesis often suffer from measurement challenges. Market concentration ratios such as the Herfindahl-Hirschman Index (HHI) may not fully capture competitive intensity, particularly in industries like banking where product differentiation and non-price competition are prevalent (Boateng & Asamoah, 2023). Additionally,

regulatory interventions can sometimes distort the natural link between market structure and conduct, complicating empirical validation.

Despite these weaknesses and limitations, the SCP Hypothesis remains highly applicable to analyzing competition and efficiency in the Ghanaian banking sector. It provides a valuable framework for assessing whether the observed market concentration among Ghanaian banks has led to anti-competitive behavior and how this, in turn, affects operational efficiency and cost productivity. Understanding these linkages can guide policymakers in promoting regulatory frameworks that foster healthier competition without undermining sector stability.

### **2.2.3 “Efficient – Structure” Hypothesis**

The Efficient Structure Hypothesis posits that firms achieve larger market shares and greater profitability not because of anti-competitive practices or market dominance, but because they are inherently more efficient (Demsetz, 1973). In the context of banking, it suggests that more efficient banks can lower their costs and offer better services, thereby naturally acquiring larger market shares without necessarily reducing competition.

A significant strength of the Efficient Structure Hypothesis is that it challenges the assumption made by the Structure-Conduct-Performance Hypothesis that concentration leads to inefficiency. Instead, it argues that concentration may be the result of superior managerial capabilities, better technology adoption, or more effective cost management. Empirical support for this view has been found in studies such as those by Alhassan and Nketiah-Amponsah (2022), who show that in several African banking markets, larger and more profitable banks often exhibit higher operational efficiency.

However, the Efficient Structure Hypothesis has its weaknesses. One key issue is that it can be difficult to disentangle efficiency-driven market concentration from concentration caused by anti-competitive behavior (Ghosh, 2022). In some cases, banks may simultaneously benefit from both efficiency advantages and market power, making it challenging to attribute their market position solely to superior performance. Additionally, the hypothesis tends to understate the role of regulatory frameworks and institutional quality, which can significantly influence banking competition and operational outcomes, particularly in emerging economies.

In terms of limitations, the measurement of efficiency itself presents challenges. Most studies rely on models such as Data Envelopment Analysis (DEA) or Stochastic Frontier Analysis (SFA), both of which depend heavily on the choice of input and output variables and can produce varying results depending on the assumptions made (Ayadi et al., 2021). Furthermore, efficiency may vary significantly across different types of banks (e.g., multinational vs. local banks), which the hypothesis does not fully capture.

Nonetheless, the Efficient Structure Hypothesis remains highly applicable for interpreting the competitive behavior of banks in Ghana. It offers a useful theoretical lens to assess whether banks with larger market shares have achieved their position through genuine efficiency gains rather than exploiting market power. In this study, the hypothesis helps frame the analysis of whether observed cost productivity improvements among Ghanaian banks are efficiency-driven or simply a consequence of market structure advantages.

#### **2.2.4 “Banking Specificities” Hypothesis**

The Banking Specificities Hypothesis argues that the unique characteristics of banks—such as their heavy regulation, risk-taking behavior, capital structure dependence, and the critical role they play in financial intermediation—necessitate specialized models when analyzing competition,

efficiency, and productivity (Freixas & Rochet, 2008). Unlike firms in traditional industries, banks face systemic risks and moral hazard problems that require different theoretical considerations when assessing their performance and market behavior.

A major strength of the Banking Specificities Hypothesis is its realism in acknowledging that banking markets are fundamentally different from other sectors. It highlights the importance of regulatory constraints, deposit insurance, liquidity management, and interconnectedness, factors that significantly shape how banks compete and operate (Schaeck & Cihak, 2022). By incorporating these unique elements, the hypothesis provides a more accurate framework for analyzing the effects of competition on efficiency and stability in banking systems.

However, a notable weakness is that the Banking Specificities Hypothesis can sometimes overemphasize regulatory and systemic aspects at the expense of standard market mechanisms. It may underplay the influence of traditional factors such as innovation, cost control, and customer service improvements that are equally important in competitive dynamics (Le, 2021). This overemphasis on regulation might lead to models that insufficiently capture the competitive behavior of modern banks, particularly those operating in relatively liberalized environments.

In terms of limitations, empirical applications of the Banking Specificities Hypothesis often face challenges in isolating banking-specific factors from broader economic or institutional influences. For instance, it is difficult to fully separate the impact of capital requirements, monetary policy shifts, and macroprudential regulation on bank behavior from the effects of competition itself (Moyo & Ngwenya, 2021). Moreover, the hypothesis does not always adequately address how technological disruptions, such as fintech innovations, are transforming banking competition and efficiency today.

Despite these weaknesses and limitations, the Banking Specificities Hypothesis remains highly applicable to the Ghanaian banking sector. Given the extensive regulatory reforms, recapitalization requirements, and financial stability measures undertaken in Ghana in recent years, the hypothesis provides an important lens for understanding how regulatory frameworks and risk considerations mediate the relationship between competition and cost productivity. Its emphasis on systemic stability aligns well with the realities of the Ghanaian banking environment, where safeguarding financial sector health remains a policy priority.

### **2.2.5 Transaction Cost Theory**

Transaction Cost Theory, initially proposed by Coase (1937) and further expanded by Williamson (1975), posits that firms seek to minimize the costs associated with economic exchanges, such as negotiating, monitoring, and enforcing contracts. In the context of banking, the theory suggests that institutions structure their operations, including their competitive behavior and efficiency strategies, in ways that reduce transaction costs linked to credit allocation, payment services, risk management, and regulatory compliance.

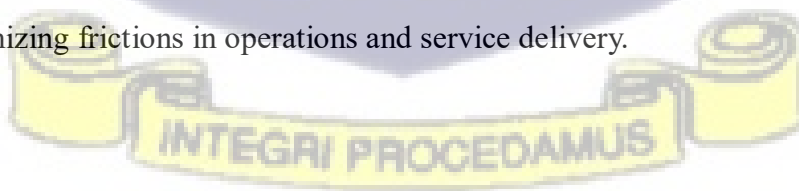
A major strength of Transaction Cost Theory is its explanatory power in understanding organizational decisions beyond traditional profit-maximization motives. It offers valuable insights into why banks may internalize certain activities (e.g., offering bundled services) or why they prefer vertical integration in specific areas to minimize transaction uncertainties and costs (Tian & Yu, 2021). In banking, where information asymmetry and contractual incompleteness are pervasive, the theory helps explain strategic behaviors that impact operational efficiency and cost structures.

Nonetheless, Transaction Cost Theory also has notable weaknesses. Its traditional models often assume rational actors with clear information about transaction costs, an assumption that does not

always hold in complex financial systems. Banks operate in environments of uncertainty, regulatory complexity, and rapidly changing customer preferences, where predicting transaction costs is difficult (Mazzuca & Tamburino, 2022). Moreover, the theory tends to focus more on static organizational forms and may not fully account for the dynamic adjustments banks make over time in response to competition and technological change.

The theory faces additional limitations in empirical application. Measuring transaction costs directly is inherently challenging because many of these costs—such as opportunity costs, negotiation efforts, or compliance burdens—are not easily observable (Nugroho et al., 2022). Consequently, studies often rely on proxies or case-specific analyses, which may limit generalizability. Furthermore, the rise of digital banking platforms has altered traditional transaction cost structures in ways that classic formulations of the theory did not originally anticipate.

Despite these limitations, Transaction Cost Theory remains highly applicable to this study. It provides a solid framework for interpreting how competition among banks influences internal organizational decisions aimed at minimizing costs and improving productivity. Particularly in Ghana, where banks navigate complex regulatory landscapes and competitive pressures, Transaction Cost Theory helps explain variations in cost productivity strategies and organizational structuring. It supports the idea that enhancing efficiency is not merely about pricing or scale, but also about minimizing frictions in operations and service delivery.



## 2.3 Empirical Review

### 2.3.1 Efficiency assessment in the banking industry

Efficiency assessment is a critical aspect of evaluating the performance and competitiveness of any industry, and the banking sector is no exception. In the context of the banking industry, efficiency refers to the ability of financial institutions to optimize resources, streamline operations, and deliver quality services while minimizing costs (Alhassan & Ohene-Asare, 2016b; Asmild, Kronborg, Mahbub, & Matthews, 2019; Chiu & Chen, 2009; Fethi & Pasiouras, 2010; Girardone, Molyneux, & Gardener, 2004; Shawtari, Ariff, & Abdul Razak, 2015; Ning Zhu, Hougaard, Yu, & Wang, 2020). Several key factors contribute to the efficiency assessment in the banking sector: Cost-to-Income Ratio (CIR), Technology Integration, Risk Management Practices, Branch Network Optimization, Customer Experience, Employee Productivity, Liquidity Management and Benchmarking (Alhassan & Tetteh, 2017; Fethi & Pasiouras, 2010; Fujii, Managi, Matousek, & Rughoo, 2018; Kolia & Papadopoulos, 2022; Wanke et al., 2016).

The cost-to-income ratio (CIR) is a fundamental metric used to evaluate the efficiency of a bank. It is calculated by dividing the operating expenses by the total income generated by the bank. A lower CIR indicates that a bank is more efficient in managing its operational costs relative to its revenue (Antwi, 2019; Chortareas, Girardone, & Ventouri, 2012; Svensson, 2022; Tresch, 2015). The adoption and integration of advanced technologies play a crucial role in improving efficiency in the banking industry. Automation of routine tasks, implementation of artificial intelligence, and the use of advanced analytics contribute to faster and more accurate decision-making processes, reducing operational costs and improving overall efficiency (B. Casu, A. Ferrari, C. Girardone, & J. O. S. Wilson, 2016; Tziogkidis, Philippas, & Tsionas, 2020; M.-M. Yu, See, & Hsiao, 2021). Efficient banks have robust risk management practices in place. This involves assessing and

mitigating various risks, including credit, market, and operational risks. Effective risk management ensures that the bank operates within acceptable risk parameters, avoiding unnecessary losses and disruptions.

With the rise of digital banking, the physical branch network's efficiency is now a focal point (Nartey, Osei, & Sarpong-Kumankoma, 2019; Shi, Zhou, Xiao, Chen, & Zuo, 2014; Tan, 2014). Banks need to optimize their branch networks based on customer preferences and technology trends. Investing in digital channels and self-service options can reduce the reliance on traditional brick-and-mortar branches, resulting in cost savings (Edelstein & Paradi, 2013; Eskelinen & Kuosmanen, 2013; Ioannou & Mavri, 2007; LaPlante & Paradi, 2015). Efficient banks prioritize a seamless and positive customer experience. Streamlining processes, reducing wait times, and offering user-friendly digital interfaces contribute to overall efficiency by attracting and retaining customers. Satisfied customers are more likely to remain loyal and recommend the bank to others (Colonia-Willner, 2004; Walker & Francis, 2003; Yoon, 2010).

Efficient banks are adept at navigating the complex landscape of regulatory requirements. Staying compliant with financial regulations is not only a legal necessity but also contributes to the overall stability and trustworthiness of the bank. Adhering to regulations without unnecessary bureaucracy is a hallmark of efficiency (Honig, 2001). Employee efficiency is a key determinant of overall efficiency in the banking industry. Adequate training, effective communication, and a supportive work environment contribute to employee productivity (Chang, Hu, Chou, & Sun, 2012). Banks that invest in their workforce and foster a culture of continuous improvement tend to be more efficient in the long run (Fidrmuc, Fungáčová, & Weill, 2015; Millán, Congregado, Román, van Praag, & van Stel, 2014). Efficient management of liquidity is crucial for a bank's stability and overall efficiency. Striking the right balance between short-term assets and liabilities ensures that

the bank can meet its financial obligations without incurring unnecessary costs(Becchetti & Sierra, 2003; Allen N Berger & Bouwman, 2009; Martín-Oliver, Ruano, & Salas-Fumás, 2013; Tziogkidis et al., 2020). Comparing key performance indicators (KPIs) with industry benchmarks allows banks to assess their efficiency relative to their peers. Benchmarking helps identify areas for improvement and implement best practices adopted by top-performing banks(An, Pang, Chen, & Liang, 2015; Antwi, 2019; Han, Ding, Nie, & Hao, 2020; Hassan & Aliyu, 2018; Wu, Liang, & Yang, 2009).

The assessment of competition within the Ghanaian banking sector is a fundamental aspect of understanding the industry's efficiency. Existing studies by Alhassan and Ohene-Asare (2016b);El Moussawi and Mansour (2022); Fungáčová and Weill (2013); Phan et al. (2019) have examined the relationship between competition and cost efficiency. However, the existing literature lacks a consensus on the most effective measure of competition. This study will explore the methodologies employed in measuring competition, highlighting their strengths and weaknesses.

Previous studies in Ghana, such as those conducted by Alhassan and Ohene-Asare (2016b); Alhassan and Biekpe (2016b); K. Ohene-Asare and Asmild (2011); Nartey et al. (2019) have predominantly focused on technical efficiency and overall productivity changes in the banking sector. However, these studies have overlooked the importance of capturing cost changes, specifically the allocative effect and the impact of input price changes on cost efficiency. The gap in the literature becomes evident as these studies did not delve into the bank's ability to choose a cost-efficient input mix or allocate funds towards a less expensive but sufficient input mix, known as allocative efficiency. The absence of a dynamic cost productivity study in Ghana has hindered the understanding of how banks adapt to input price changes and their ability to achieve allocative efficiency, which is why this study will address these shortfall of the existing papers.

Another critical gap identified is the lack of studies that decompose cost productivity change into its eight components. The concept of identifying "movers and shakers" in the industry, as proposed by D. K. Ohene-Asare and Baah (2023), has not been applied to the bank cost productivity change literature, this study will apply the 8 factor decomposition in the Ghanaian banking industry. Understanding these components is crucial for determining the potential drivers of cost productivity and how they contribute to the overall efficiency of the banking sector.

The existing literature has also overlooked the interrelationship between competition and dynamic cost productivity. While some studies have explored the relationship between competition and cost efficiency, the consideration of cost factors in this relationship has been limited. Alhassan and Ohene-Asare (2016b); El Moussawi and Mansour (2022); Fungáčová and Weill (2013); Phan et al. (2019) have empirically tested the relationship between competition and cost efficiency but have not comprehensively investigated the impact of competition on dynamic cost productivity and vice versa. Furthermore, the literature reveals a shortage of robust econometric techniques exploring the nexus between competition, financial crises, and bank dynamic cost productivity. Limited second-stage robust techniques have been applied in studies that use Data Envelopment Analysis for dynamic productivity estimation. This study will address all the loopholes identified in these study.

Considering the identified gaps, the proposed research aims to address these shortcomings by undertaking a comprehensive evaluation of competition, cost efficiency, and dynamic cost productivity in the Ghanaian banking industry. The study's objectives, which include measuring competition, estimating cost productivity change and its components, and analyzing the bi-directional effect between competition and cost productivity change, are designed to contribute significantly to the existing body of knowledge in banking efficiency and productivity in Ghana.

The research will employ advanced econometric techniques to provide a more nuanced understanding of the relationships and factors influencing the efficiency dynamics in the banking sector.

### **2.3.2 Cost Productivity Assessment of Banks**

Cost productivity assessment is a crucial aspect of evaluating the performance and efficiency of banks. It involves examining how well a bank utilizes its resources to generate value and deliver financial services. The key components and considerations in assessing cost productivity in the banking sector: Cost-to-Income Ratio (CIR), Operational Efficiency, Technology Investments, Scale and Scope Economies, Employee Productivity, Outsourcing Strategies, Cost Control Measures, Product and Service Mix, Risk Management Practices and Benchmarking. Cost productivity assessment in the banking industry involves a comprehensive analysis of various factors, including financial metrics, operational efficiency, technology adoption, and risk management practices. Banks that consistently focus on optimizing costs while maintaining service quality are better positioned to navigate the dynamic and competitive financial landscape (Al-Khasawneh, Essaddam, & Hussain, 2020; Boucinha, Ribeiro, & Weyman-Jones, 2013; Hajdari, Qerimi, & Qerimi, 2023; Roghanian, Rasli, & Gheysari, 2012).

A notable gap in the literature pertains to the absence of dynamic cost productivity studies in the Ghanaian context. Previous efficiency assessments by Alhassan and Ohene-Asare (2016b); El Moussawi and Mansour (2022); Fungáčová and Weill (2013); Phan et al. (2019) primarily focused on technical efficiency without incorporating the critical dimensions of allocative efficiency and the impact of input price changes. This study will empirically review and should explore how dynamic cost productivity studies contribute to a more comprehensive understanding of banking efficiency.

An innovative aspect of the current research lies in the decomposition of cost productivity change into eight components. This novel approach, as proposed by D. K. Ohene-Asare and Baah (2023), introduces a more granular analysis of the factors driving cost productivity. This study will investigate whether similar decomposition techniques can be employed in the banking contexts and their efficacy in identifying specific drivers of cost productivity change.

Previous works by Alhassan and Ohene-Asare (2016b); El Moussawi and Mansour (2022); Fungáčová and Weill (2013); Phan et al. (2019) have tested the relationship between competition and cost efficiency, but the consideration of cost factors remains limited. Exploring how competition influences cost productivity change and vice versa is crucial to understanding the holistic dynamics of banking efficiency. The study will examine the limited existing studies that have investigated the interrelationship between competition and dynamic cost productivity in the banking sector.

Understanding the methodological robustness of these techniques is essential for validating the findings and ensuring the reliability of cost productivity assessments. The study will critically assess the econometric techniques employed in cost productivity assessments, particularly focusing on studies that utilize Data Envelopment Analysis in the first stage and the robustness of second-stage techniques which the existing studies did not consider (R. Banker et al., 2019; R. D. Banker & Natarajan, 2008; Simar & Wilson, 2007; Léopold Simar & Paul W. Wilson, 2011; L. Simar & P. W. Wilson, 2015). The current study aims to contribute to a more nuanced understanding of the cost dynamics within the Ghanaian banking industry and provide valuable insights for future research and policymaking.

### 2.3.3 Competition and cost efficiency in banking

Competition and cost efficiency are interconnected aspects that significantly impact the performance and sustainability of banks. The banking industry, characterized by intense competition, regulatory pressures, and evolving customer expectations, requires institutions to continuously enhance their cost efficiency to stay competitive (Alhassan & Biekpe, 2016a; El Moussawi & Mansour, 2022). The efficiency and competitiveness of banks are crucial factors for financial stability and economic growth. This current study aims to explore existing literature on the interplay between competition and cost efficiency in the banking sector, with a focus on the identified research problem, objectives, and questions related to the Ghanaian banking industry. The relationship between competition and cost efficiency in banking is complex and multifaceted. Successful banks are those that can navigate the competitive landscape, optimize costs, and continuously adapt to changing market dynamics. Striking the right balance between efficiency, customer satisfaction, and innovation is essential for long-term success in the competitive banking industry.

Numerous studies have attempted to measure competition in the banking sector, but the literature lacks consensus on the most effective approach. Previous research by Alhassan and Ohene-Asare (2016b); El Moussawi and Mansour (2022); Fungáčová and Weill (2013); Phan et al. (2019) has examined the relationship between competition and cost efficiency, but there is a need to critically assess the methodologies employed for measuring competition. This study will highlight the strengths and limitations of different competition metrics applied in the context of the Ghanaian banking industry.

The identified research problem underscores the absence of dynamic cost efficiency studies in the Ghanaian banking literature. Previous efficiency assessments by Alhassan and Ohene-Asare

(2016b); Nartey et al. (2019); K. Ohene-Asare and Asmild (2011) primarily focused on technical efficiency, neglecting the dynamic aspects of cost efficiency and productivity changes. The current study will explore how incorporating dynamic elements enhances our understanding of the relationship between competition and cost efficiency.

The current research introduces a novel approach by decomposing cost productivity change into eight components. The empirical review should investigate whether similar decomposition techniques have been applied in previous studies and the insights gained from such analyses. Understanding the specific drivers of cost efficiency can provide valuable information for policymakers and practitioners in the banking sector.

Prior studies have empirically tested the relationship between competition and cost efficiency, but the current study will delve into the nuances of this relationship, examining the extent to which competition influences cost efficiency and identifying potential nonlinearities or thresholds is crucial for comprehensively understanding the dynamics at play.

The research questions highlight the need to explore the bidirectional relationship between competition and cost efficiency. The empirical review should critically analyze existing studies that have investigated how cost efficiency impacts competition in the banking industry. Insights into these interdependencies can provide a more holistic understanding of the competitive dynamics in the Ghanaian banking sector.

This study of competition and cost efficiency in banking would provide a comprehensive synthesis of existing literature, emphasizing methodologies, gaps, and key empirical findings. By addressing these aspects, the current study will contribute to a nuanced understanding of the complex

relationship between competition and cost efficiency in the Ghanaian banking industry, offering insights for both academia and industry stakeholders.

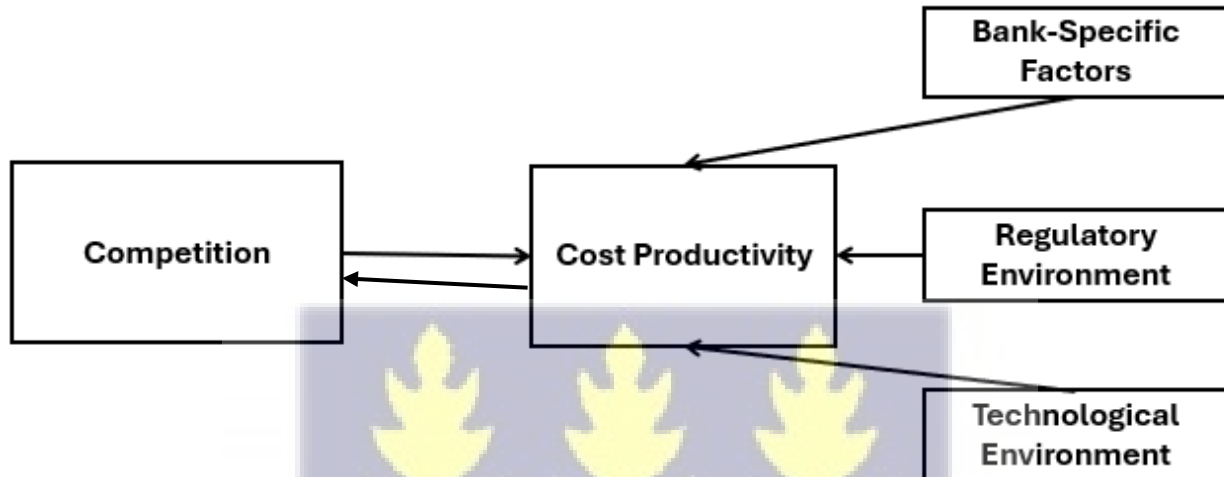
## 2.4 Conceptual Framework

The conceptual framework for this study illustrates the relationship between competition (Lerner Index) and cost productivity (efficiency) in the Ghanaian banking sector. It also highlights key moderating factors that may influence this relationship, including bank-specific factors, regulatory environment, and technological environment. As shown in the framework, competition is the independent variable, directly influencing cost productivity. The expectation is that as competition levels change, banks may adjust their operational strategies, which in turn affects their efficiency. A higher Lerner Index, which indicates lower competition and greater market power, may lead to improved cost productivity if banks use their market advantage to optimize operations. However, in cases where competition fosters innovation and efficiency, banks with lower market power may also improve their cost productivity.

Additionally, three key factors—bank-specific factors, regulatory environment, and technological environment—are considered as moderating influences on the relationship between competition and cost productivity. Bank-specific factors (such as size, capital structure, and management efficiency) may determine how well a bank leverages its competitive position to achieve cost productivity. The regulatory environment affects bank operations by enforcing compliance with financial policies, capital requirements, and competitive fairness. Lastly, the technological environment plays a significant role in enhancing efficiency, as digital banking, automation, and financial innovations can improve operational processes and cost management. This framework provides a structured approach to analyzing the interaction between competition and cost productivity while accounting for external influences that shape banking efficiency. The

subsequent analysis will empirically test these relationships using panel data econometric models to determine the extent to which these factors contribute to bank performance in Ghana.

**Figure 2: Conceptual Framework**



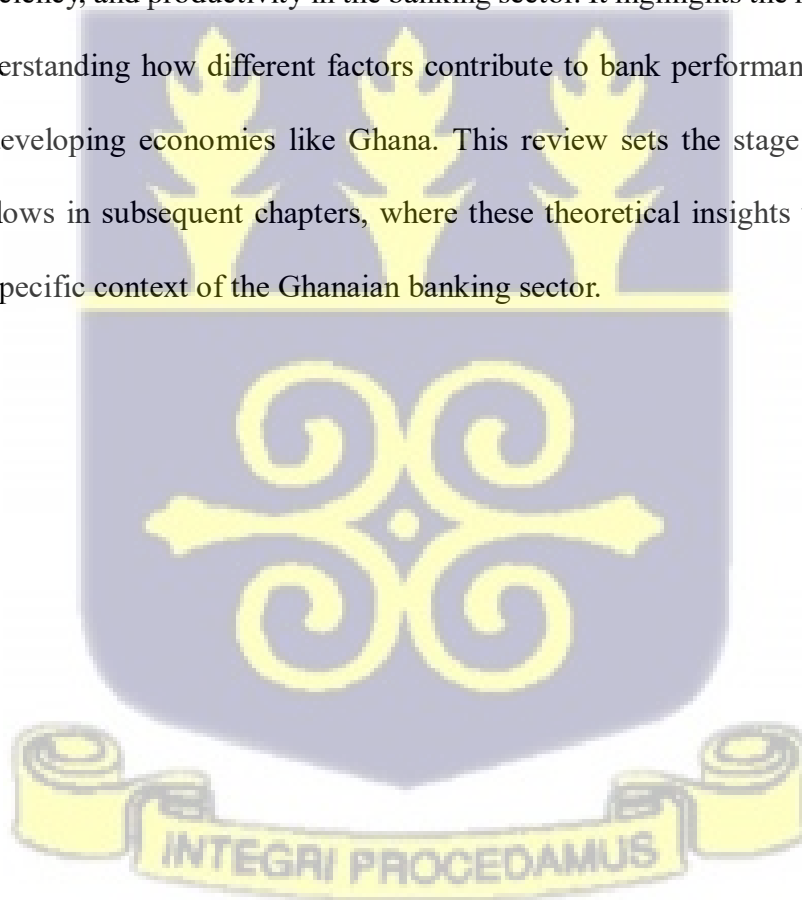
Source: Author's Construct

## 2.5 Conclusion

Chapter Two provided a comprehensive review of the literature related to the core concepts and theoretical frameworks underpinning this study on the relationship between competition and cost productivity in the Ghanaian banking sector. The chapter began by defining key concepts such as competition, cost efficiency, and productivity, offering a clear understanding of the factors that influence bank performance. It then explored various theoretical perspectives, including the Structure-Conduct-Performance (SCP) hypothesis, the Efficient Structure Hypothesis, and the Resource-Based View, which collectively provide a foundation for analyzing how market dynamics shape operational efficiency in banks.

The empirical review highlighted the findings of previous studies on banking competition and productivity, with a focus on emerging markets similar to Ghana. The review revealed that while competition can drive efficiency by incentivizing banks to optimize their operations, it can also lead to market concentration, which may reduce the overall competitiveness of the sector. Additionally, the literature pointed out the critical role of technological adoption and scale economies in enhancing productivity, particularly in sectors where rapid innovation is a key driver of growth.

In conclusion, the literature reviewed in this chapter underscores the complex interplay between competition, efficiency, and productivity in the banking sector. It highlights the need for a nuanced approach to understanding how different factors contribute to bank performance, particularly in the context of developing economies like Ghana. This review sets the stage for the empirical analysis that follows in subsequent chapters, where these theoretical insights will be tested and explored in the specific context of the Ghanaian banking sector.



## CHAPTER THREE

### METHODOLOGY

#### 3.1 Introduction

This chapter expatiates on the statistical procedures and techniques used to arrive at the objectives set out in this study. This study highlights the proxies used to estimate bank competition. This chapter presents the research design, population, sampling, data sources, and analytical techniques used for the analysis of variables in the study.

#### 3.2 Research Design

Research design is the systematic roadmap of how the study is conducted from the collection of data stage based on the research problem to the interpretation and dissemination of the data to achieve the research objectives. The research design creates a scientific framework of enquiries into the research questions to arrive at the research objectives (Creswell, 2014). The philosophy that is guiding this research is the post-positivism philosophical worldview, it holds both deterministic and reductionist philosophy; for every cause, there is an effect and complex ideas can be broken to simple parts to enhance deeper understanding (Creswell, 2014). This study adopts a casual quantitative panel research design to the relationship between competition and cost productivity in the Ghanaian banking sector. The design is appropriate as the study seeks to establish cause-and-effects relationship between the key variables while controlling for bank—specific, regulatory, and technological factors. This study shows how different variables affects bank performance and how performance is broken into smaller elements. The post-positivity philosophy is adopted because the knowledge of competition and bank cost productivity must requires objectivity from the researcher. A deductive approach is used in line with this philosophy to test the hypothesis of specific data. The study uses a non-experimental quantitative research

approach to achieve the research objectives. This research collects data from a secondary source and uses mathematical and statistical techniques to analyze and interpret the results. The quantitative research uses an unbalanced panel data methodology to allow for multiple observation of the same unit and cater for banks that were non-existing at a certain period.

### **3.3 Population, Sampling and Source of data**

The study uses all universal banks operating in Ghana from a period of 2000 to 2020 as the population of this study. The period selection was driven by data availability, regulatory consistency, and the need to capture major banking reforms and structural changes in Ghana. The sample therefore consist of an unbalanced panel of 23 banks in Ghana on average of which 11 are domestic banks and 12 foreign banks. This sample period was used for all the banks due to unavailability of data. The reason why all banks is part of the study is to generate results that will be relevant and also explain competition and cost productivity of banking industry in Ghana. The data used for this study was taken from annual reports of the respective banks and cross-validated figures from Bank of Ghana.

### **3.4 Dynamic Productivity Model**

#### **3.4.1 The Malmquist Productivity Change Index (M)**

Effectiveness, Profitability, quality, customer satisfaction, efficiency and productivity are all different ways of measuring performance. DEA was first introduced by Charnes, Cooper, and Rhodes (1978) as a tool for gauging the effectiveness and productivity of decision-making units (Emrouznejad & Yang, 2018). Over the years, DEA method have become a popular approach used to assess the efficiency and productivity of a firm (Bod'a & Piklová, 2018; Dutta & Saha, 2021; Emrouznejad & Yang, 2018; Fethi & Pasiouras, 2010; Hammami, Ngo, Tripe, & Vo, 2022; Nan Zhu et al., 2021) and majority of empirical studies demonstrate that using this approach to estimate

the efficient frontier can produce reliable outcomes (Seiford & Thrall, 1990). In a banking performance survey, 74 percent of the studies used frontier analysis (FA) to evaluate the performance of the banking industry, and data envelopment analysis (DEA) was the method most frequently used (Ahmad et al., 2020). DEA is a non-parametric mathematical technique used to produce a convex set of production possibilities, the set of these best-practice observations is connected by piecewise linear combinations to form the DEA frontier to assess the performance of each decision making units (Allen N Berger & Humphrey, 1997). Using multiple inputs and outputs as comparison points, the DEA technique evaluates the relative performance of businesses (Alhassan & Ohene-Asare, 2016a). Data Envelopment Analysis approach has become an acceptable and reliable means of assessing the efficiency and productivity of banks since it can make use of multiple inputs and multiple outputs.

DEA was chosen as the methodology for the current study due to its many benefits. Benchmarking results give DEA a distinct advantage over other efficiency approaches (Rostamzadeh et al., 2021) therefore it is important to enumerate these advantages. The advantages of DEA can be discussed under five points, which are: Firstly, DEA is able to take into account a variety of inputs and outputs when analyzing the efficiency of organizations (Alhassan & Ohene-Asare, 2016a; R. D. Banker & Park, 2021; Charnes, Cooper, & Rhodes, 1978; Y. Chen, Du, Sherman, & Zhu, 2010; Contreras, 2020; Cook, Tone, & Zhu, 2014; Färe, Lovell, & Zieschang, 1983; Sueyoshi & Sekitani, 2009). The use of multiple inputs and outputs was demonstrated by (Phan et al., 2019) where he used total deposits, total physical capital and labor as inputs and total loans and other earning assets as outputs to examine the relationships between competition, efficiency and stability in the banking systems of four East Asian countries (China, Hong Kong, Malaysia and Vietnam). Organizations in the real world generate a variety of outputs, which may include goods, services, or results, by

utilizing a variety of resources or inputs, including labor, capital, materials, energy, and technology. Instead of aggregating the inputs and output or use single input or output which in reality may not be the case, DEA has the ability to determine the efficiency of the banks by incorporating all the separate inputs and outputs to determine efficiency and productivity change.

Secondly, DEA estimation methodology is also able to disintegrate efficiency of banks into various sources (R. D. Banker, Charnes, & Cooper, 1984; Drake & Hall, 2003; Färe, Grosskopf, & Lovell, 1985; Fukuyama, Matousek, & Tzeremes, 2020; Yang, 2014). This helps to identify any weak points within a bank so that the proper amount of effort can be put into enhancing performance (Yang, 2014). For example, (Fukuyama & Tan, 2022) broke down the total bank efficiency level into five distinct efficiency components ; innovation inefficiency, profitability inefficiency, primary business stability inefficiency, strategic management stability inefficiency and corporate social responsibility inefficiency using DEA. Another example is a paper by (Tan & Floros, 2018) used DEA to separate technical efficiency into scale efficiency and pure technical efficiency to tests the interrelationships among risk, competition, and efficiency in the Chinese Banking industry. Using DEA methodology makes room to go deeper to assess the eight factor decomposition of bank dynamic cost productivity in Ghana.

Thirdly, unlike methods like Stochastic Frontier Analysis (SFA) and Ordinary Least Squares (OLS), DEA doesn't force any form of restrictive function for the production model and not all of the production process must be known (R. D. Banker & Park, 2021; Cooper, Seiford, & Tone, 2006; Fethi & Pasiouras, 2010; Guan, Yam, Mok, & Ma, 2006; Olesen & Ruggiero, 2022). There is no need to assume or specify the production form before analysis, this helps to avoid the errors related to specification.

Last but not the least, DEA is independent of units (Antunes et al., 2022; Cook, Du, & Zhu, 2017; Lovell & Pastor, 1995; Tone & Tsutsui, 2010) The efficiency scores are unaffected by the units used to measure the inputs and outputs. This is evident in the case of measuring Labour in man-hours, production space in square meters and customer deposits in currency units despite the difference in units, efficiency scores can be computed using DEA. DEA lowers the possibility of measurement errors or biases linked to particular units by not relying on them. More accurate and trustworthy efficiency assessments may result from this.

Lastly, DEA can identify peers or reference sets that contain any inefficient DMU, it is essential for strategic management policy-making (Aggelopoulos & Georgopoulos, 2017; Amirteimoori, Sahoo, & Mehdizadeh, 2023; Fukuyama, Tsionas, & Tan, 2023; Omrani, Oveysi, Emrouznejad, & Teplova, 2023). When DEA identifies the peers that are not performing well, it gives the bank management to improve upon areas that are lacking and it is also relevant to the central bank in order to maintain financial stability in the economy.

First established by (Charnes et al., 1978), Data Envelopment Analysis (DEA) operates under the premise of Constant Return to Scale (CRS) and it was then expanded upon by (R. D. Banker et al., 1984) to incorporate Variable Return to Scale assumption (VRS) assumption (Cook & Seiford, 2009; Zarrin & Brunner, 2023). These two assumptions resulted in the two most frequently used DEA models in the efficiency and productivity studies literature namely ; the CCR model named after (Charnes et al., 1978) and the BCC model named after (R. D. Banker et al., 1984). When the returns to scale is constant, the unit is considered to be operating at an ideal scale, as this is when the average total cost reaches its lowest point (Blavet, Ouellette, & Vigeant, 2023; Y. Li, 2020; Kwaku Ohene-Asare, Asare, & Turkson, 2019). This indicates that the company is operating at the best scale for its particular operations and goals and is neither too small nor too large. The return

to scale assumption in assessing economic and environmental efficiency is not a black-and-white one, according to theory and literature (Manello, 2017). This shows that even in theory the choice of the return to scale efficiency and productivity change is debatable. There are situations in which using variable returns to scale (VRS) makes sense rather than assuming CRS (R. D. Banker et al., 1984). In the real world assuming constant return will mostly not work, this is due to imperfect market competition, financial constraint, regulations by government (Coelli et al., 2005; Martínez-Campillo & Fernández-Santos, 2020). It is possible to distinguish the two assumptions conceptually and by computation (Manello, 2017), hence the need to test for the return to scale.

Numerous methodological extensions and applications of DEA have been developed since the publication of the seminal paper (Cooper, Thompson, & Thrall, 1996). An example of DEA extensions was the Malmquist Productivity Change Index (M), developed by (Färe, Grosskopf, Lindgren, & Roos, 1992). The Malmquist productivity change index is a metric derived from the Data Envelopment Analysis (DEA) methodology. This index makes it possible to measure changes in productivity by comparing efficiency over a specified time period (Kuljanin, Kalić, Caggiani, & Ottomanelli, 2019). The Malmquist productivity index was first introduced by Caves, Christensen, and Diewert (1982) but not in the context of DEA (Caves, Christensen, & Diewert, 1982). The Malmquist productivity change index by Färe, Grosskopf, Lindgren, and Roos (1992) was based upon the concepts of Malmquist (1953), Caves, Christensen, and Diewert (1982) and Charnes et al (1978). MPI has been used extensively to track changes in DMU's productivity over time (Aparicio, Ortiz, Pastor, & Zabala-Iturriagoitia, 2020; X. Chen, Grifell-Tatjé, & Fu, 2023). There are multiple examples in literature on the use of Malmquist productivity change index. For example, (Arocena, Saal, Urakami, & Zschille, 2020) assessed the productivity change of companies in Japanese water supply sector from 2003 to 2009, (Tavana, Khalili-Damghani, Santos

Arteaga, & Hashemi, 2020) measured the productivity change of several Iranian oil refineries from 2015 to 2016, (Mavi & Mavi, 2019) assessed the trends of improvement or declination over time for energy and environmental efficiency OECD countries from 2012 to 2015 using DEA-based Malmquist productivity index, (Ashiagbor, Dziwornu, Gbade, Offei-Kwafo, & Liticia, 2023) measured the efficiency and productivity changes in the life insurance industry in Ghana from 2015 to 2020, (Jahan, 2019) evaluated the productivity performance of 29 listed commercial banks in Bangladesh by employing Malmquist productivity index of total factor productivity (TFP) from 2011 to 2015, (Nan Zhu et al., 2021) measured the operational efficiency scores and productivity growth change Pakistan's banking sector using DEA and Malmquist productivity index (MPI) together from 2006 to 2017.

Malmquist Productivity Change Index (M) can be decomposed into two factors, three factors and four factors to understand the drivers of the productivity. Färe et al. (1990, 1992, 1994a) brought the two factors productivity index's breakdown into the non-parametric frontier production function, drawing inspiration from Nishimizu and Page (1982), who were the first to do so (Førsund, 2016). The MPI was divided into two elements by multiplication by FGLR (1992) and FGNZ (1994). The frontier shift (technological change index) was the first component; it showed changes in product innovation or industrial processes in addition to R&D. The efficiency change index (catching up to the frontier), which makes up the second component, indicated shifts in managerial abilities (D. K. Ohene-Asare & Baah, 2023; Zaman & Khan, 2023).

Färe, Grosskopf, Norris, and Zhang (henceforth, FGNZ) (1994) extended the two components decomposition into three components by further breaking down the efficiency change component of FGLR into two components: the scale change (SCH) and pure efficiency change (PECH)

components (Zaman & Khan, 2023). This was done in an attempt to accommodate the VRS technological specification.

The authors who contributed to the development of the 2-factor (FGLR) and 4-factor scale change models were Jay S. Birnbrauer and Muhsin Michael Orsini, D. Rose Ewald, and Robert W. Strack respectively. Jay S. Birnbrauer proposed a two-factor model to maintain attention and action on goals and methods in behavior change, addressing common misconceptions of the operant model (Hoogendoorn, 2006). Muhsin Michael Orsini, D. Rose Ewald, and Robert W. Strack developed a validated instrument to measure the 4 key constructs of critical consciousness (passive adaptation, emotional engagement, cognitive awakening, and intentions to act) in individuals, relative to any salient community issue (Rennie et al., 2000). Their motivation was to assess critical consciousness as a proxy measure of the readiness of communities and individual decision-makers for social changes addressing root causes of ill health.

The authors in the papers examined the contribution of scale change in three Canadian industries: pulp and paper, sawmills and shingle mills, and logging. They found that sawmills and shingle mills showed moderate increasing returns to scale, while logging and pulp and paper showed very large increasing returns to scale (Kneip et al., 2021). The input-demand functions in each industry were inelastic, and factor substitution was not rejected in any of the industries (Bansal et al., 2022). The authors also found that technical change was nonneutral, with capital using and labor saving technology in all industries (Cho, 2020). Additionally, negative technical change was estimated for sawmills and shingle mills and pulp and paper, indicating that productivity gains were primarily due to changes in scale rather than the passage of time (Wu & Sheng, 2022).

### **3.4.2 The Cost Malmquist Productivity Index**

The Cost Malmquist Productivity Index (CMPI) is a novel index proposed to measure the productivity of Decision Making Units (DMUs) in group contexts, particularly in the Chinese energy sector (Bansal & Mehra, 2022). It is designed to overcome the drawbacks of the traditional Malmquist index (MI) by considering non-circularity, disparate measurements, and infeasibility (Bansal, 2023). Additionally, a global cost MI (GCMI) is introduced for DMUs with an economic optimization behavior, which requires the observation of input prices (Wu & Sheng, 2022). To address the assumption of input prices, alternative solutions are proposed (Kneip et al., 2021). The CMPI and GCMI provide practitioners with a new toolkit for comparing the performances of DMUs and groups of DMUs.

### **3.4.3 Four and Eight factor Components of The Cost Malmquist Productivity Index**

The cost Malmquist productivity index (CMPI) can be decomposed into four components: pure cost efficiency change, scale efficiency change, pure cost technical change, and scale cost technical change (Walheer, 2018). Additionally, the CMPI can be further disaggregated into eight factor components: pure efficiency change, pure allocative efficiency change, scale efficiency change, scale-allocative efficiency change, pure technical change, pure price change, scale-technical change, and scale-cost technical change (Razavyan et al., 2012). These components allow for a comprehensive analysis of productivity change and provide insights into the strategy shifts of individual decision-making units (DMUs) over time (Walheer, 2018). The decomposition of the CMPI into these components helps identify the sources of productivity change and offers managerial implications for enhancing competitiveness (Cho & Wang, 2018).

In summary, the proposed four factor Components of the Cost Malmquist Productivity Index is given by

$$CM_c = (PCEC \times SCEC) \times (PCTC \times SCTC)$$

$$CEC = \left[ \frac{C22v_F}{C11v_F} \right] \times \left[ \frac{\frac{C22c_F}{C22v_F}}{\frac{C11c_F}{C11v_F}} \right]$$

$$CTC = \left[ \frac{C21v_K}{C22v_K} \times \frac{C11v_K}{C12v_K} \right]^{1/2} \times \left[ \frac{C21c_K/C21v_K}{C22c_K/C22v_K} \times \frac{C11c_K/C11v_K}{C12c_K/C12v_K} \right]^{1/2}$$



The proposed eight factor Components of the Cost Malmquist Productivity Index is given by

$$CM_c = (PEC \times PAEC) \times (SEC \times SAEC) \times (PTC \times PPE) \times (STC \times SPE)$$

$$\begin{aligned}
 CM_t = & \left[ \frac{D22v_F}{D11v_F} \right] \times \left[ \frac{w^{t+1}x^{t+1} / (C^{t+1}(w^{t+1}, y^{t+1}) \times D22v_F)}{w^t x^t / (C^t(w^t, y^t) \times D11v_F)} \right] \times \left[ \frac{D22c_F / D22v_F}{D11c_F / D11v_F} \right] \\
 & \times \left[ \frac{w^{t+1}x^{t+1} / (C^{t+1}(w^{t+1}, y^{t+1}) \times D22c_F)}{w^{t+1}x^{t+1} / (C^{t+1}(w^{t+1}, y^{t+1}) \times D22v_F)} \right] \times \left[ \frac{D11v_F}{D12v_F} \times \frac{D21v_F}{D22v_F} \right]^{1/2} \\
 & \times \left[ \frac{w^t x^{t+1} / (C^t(w^t, y^{t+1}) \times D21v_F)}{w^{t+1}x^{t+1} / (C^{t+1}(w^{t+1}, y^{t+1}) \times D22v_F)} \right. \\
 & \times \left. \frac{w^t x^t / (C^t(w^t, y^t) \times D11v_F)}{w^{t+1}x^t / (C^{t+1}(w^{t+1}, y^t) \times D12v_F)} \right]^{1/2} \\
 & \times \left[ \frac{D11c_F / D11v_F}{D12c_F / D12v_F} \times \frac{D21c_F / D21v_F}{D22c_F / D22v_F} \right]^{1/2} \\
 & \times \left[ \frac{w^t x^{t+1} / (C^t(w^t, y^{t+1}) \times D21c_F)}{w^t x^{t+1} / (C^t(w^t, y^{t+1}) \times D21v_F)} \right. \\
 & \times \left. \frac{w^{t+1}x^{t+1} / (C^{t+1}(w^{t+1}, y^{t+1}) \times D22c_F)}{w^{t+1}x^{t+1} / (C^{t+1}(w^{t+1}, y^{t+1}) \times D22v_F)} \right] \\
 & \times \left[ \frac{w^t x^t / (C^t(w^t, y^t) \times D11c_F)}{w^t x^t / (C^t(w^t, y^t) \times D11v_F)} \right]^{1/2} \\
 & \times \left[ \frac{w^{t+1}x^t / (C^{t+1}(w^{t+1}, y^t) \times D12c_F)}{w^{t+1}x^t / (C^{t+1}(w^{t+1}, y^t) \times D12v_F)} \right]
 \end{aligned}$$



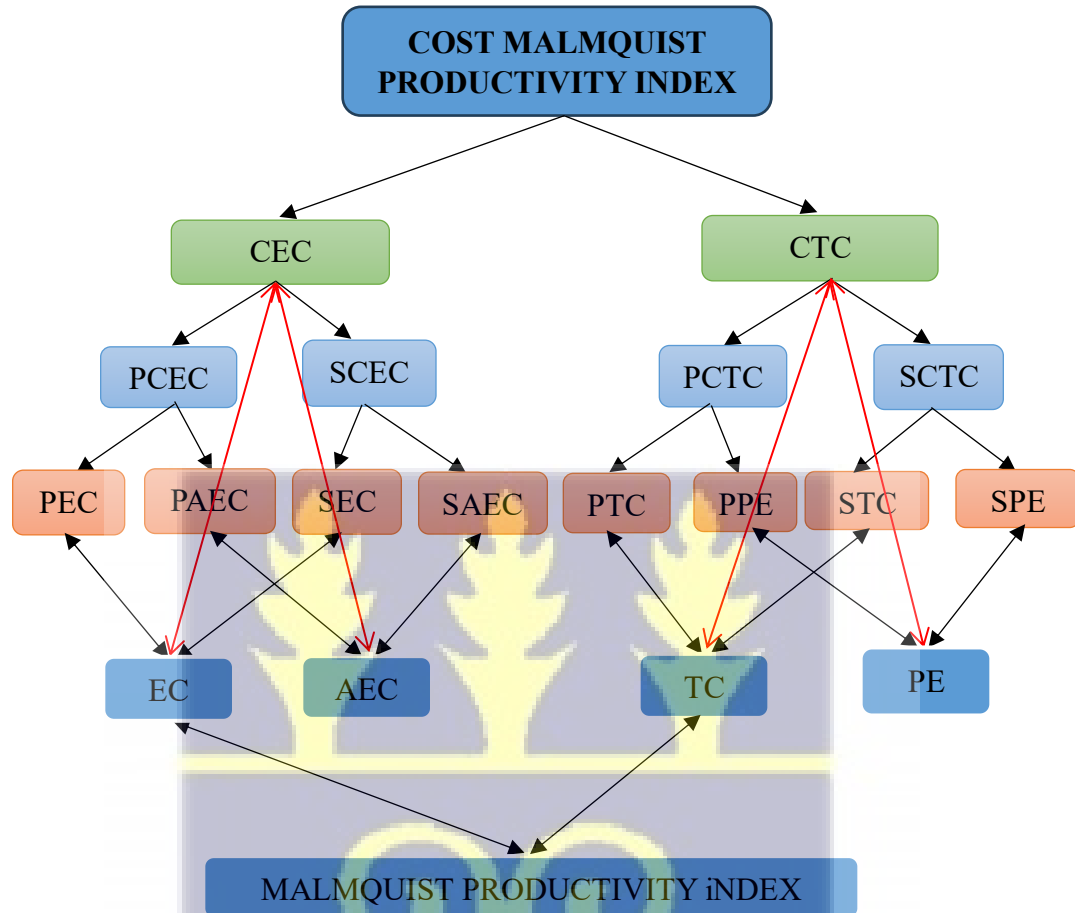


Fig 1: source: Ohene-Asare & Baah (2023)

### 3.4.4 Numerical example

This section demonstrates the application of the cost Malmquist index using a hypothetical sample of 9 DMUs (that could represent banks) in periods  $t$  and  $t+1$  in Table 1 using two inputs ( $X_1$ , say, deposit and  $X_2$ , say, labour) to produce two outputs ( $Y_1$ , say, loans and  $Y_2$ , say investments) and the related input prices for the DMUs ( $W_1$ , say interest income and  $W_2$ , say, staff cost). The DMUs are labelled from A to I in period 1 whilst the same DMUs appear in period 2. The data is balanced

but can be unbalanced in real market systems. The industry is structured to exhibit variable returns to scale technology. In the application chapter, we shall test for the exact returns to scale underlying the technology using the nonparametric test of return to scale by Simar and Wilson (2002).

We model the cost Malmquist productivity change index in Shephard's (1953) distance functions, but for easy interpretations, we employ the reciprocals of the distance functions, which are the Farrell (1957) technical efficiencies. The own-period and cross-period standard distance functions and cost distance function scores under CRS and VRS are computed for all the 9 DMUs using the *R* software.

The numerical example and its results are shown in the appendix

Note that Each technical distance function of a DMU in period  $t$  is computed as can be defined as:

$$\vec{D}_o^t = D_o^t(x^t, y^t) = \frac{\text{Distance to DMU at period } t}{\text{Distance to the period } t \text{ CRS frontier}} = TE_o^t(x^t, y^t)^{-1}$$

The superscript  $t$  can change to  $t+1$  depending on which period is being used. The CRS and VRS results are shown in Tables 2 and 3 respectively. Notice that in Table 2,  $D11c$ ,  $D22c$ ,  $D12c$ , and  $D21c$  denote the own-period and cross-period technical distance functions for the DMUs under CRS while  $C11c$ ,  $C22c$ ,  $C12c$  and  $C21c$  denote the corresponding cost distance functions. The same score types under VRS are presented in Table 3 for all DMUs. Further, DMU F is used to illustrate the computation of the proposed index and decompositions below.

Tables 5, 6 and 7 presents the results for the hypothetical example. A score of cost productivity change or any of its indices that is less than (or equal to or above) one implies productivity regress (or stagnation or improvement) between the two periods. The result of the cost productivity score between CRS (**CMc**) and VRS (**CMv**) show interesting opposite trends for some of the DMUs

such as DMU F. It shows 14% cost productivity growth under CRS but 47% decline under VRS. This gap of 61% in productivity between the two returns to scale explains the reason why evaluating dynamic cost productivity is critical.

### **3.5 Test and Choice of Return To Scale (RTS) in DEA**

In Data Envelopment Analysis (DEA), the concept of Return to Scale (RTS) is fundamental for understanding how changes in input levels influence the output levels of decision-making units (DMUs). RTS indicates whether increasing inputs will result in a proportional, more than proportional, or less than proportional increase in outputs. The choice of RTS in DEA significantly affects the efficiency scores and the interpretation of results, making it a critical decision in the analysis process.

There are three primary types of RTS that can be considered in DEA: Constant Returns to Scale (CRS), Variable Returns to Scale (VRS), and Non-increasing Returns to Scale (NIRS). CRS assumes that an increase in inputs leads to a proportional increase in outputs, implying that all DMUs operate at an optimal scale. Under this assumption, any inefficiencies detected are attributed solely to management practices rather than scale issues. On the other hand, VRS allows for the possibility that DMUs may not be operating at an optimal scale. VRS can be further categorized into Increasing Returns to Scale (IRS), where an increase in inputs leads to a more than proportional increase in outputs, and Decreasing Returns to Scale (DRS), where the increase in inputs results in a less than proportional increase in outputs. Finally, NIRS assumes that outputs increase at a rate that is less than or equal to the increase in inputs, indicating that scaling up operations will not yield proportionate increases in output.

For this study, the choice of RTS is guided by the characteristics of the Ghanaian banking sector, where banks vary widely in terms of size, market reach, and resource availability. Given this diversity, it is crucial to account for variations in scale efficiency when evaluating bank performance. Therefore, the Variable Returns to Scale (VRS) model is chosen as the primary approach for this study. The VRS model is particularly suitable in this context because it accommodates the different scales of operation across banks, providing a more nuanced analysis of efficiency. Following Simar and Wilson (2002), we tested the null hypothesis of constant returns to scale (CRS) for the banking sector using a nonparametric bootstrap approach. The test strongly rejected CRS ( $p < 0.01$ ), indicating that the production technology of banks exhibits variable returns to scale (VRS). This empirical evidence supports the use of a VRS DEA model over CRS, ensuring that efficiency scores accurately reflect differences in bank size and operational scale.

The decision to use the VRS model is based on several considerations. First, the Ghanaian banking sector comprises both large multinational banks and smaller indigenous institutions, each likely experiencing different RTS due to their varying capacities and market positions. Second, the VRS model allows for the decomposition of overall efficiency into pure technical efficiency and scale efficiency, which is essential for determining whether inefficiencies are due to suboptimal management or issues related to the scale of operations. Finally, the VRS model offers greater flexibility, enabling the identification of whether banks are operating under IRS, CRS, or DRS, thereby providing insights into whether scaling up or down could enhance efficiency.

To validate the appropriateness of the chosen RTS model, this study employs a two-stage DEA approach. Initially, efficiency scores are calculated under the CRS assumption to establish a baseline understanding of the overall technical efficiency of the banks, without accounting for scale effects. Subsequently, efficiency scores are recalculated using the VRS model, and the

differences between the CRS and VRS efficiency scores are analyzed to assess the impact of scale on efficiency. Significant differences between these scores would indicate the presence of scale inefficiencies, justifying the selection of the VRS model. Additionally, the study calculates the ratio of CRS efficiency to VRS efficiency to determine scale efficiency, identifying whether each bank operates under IRS, CRS, or DRS.

Through this approach, the study ensures that the choice of RTS reflects the operational realities of the Ghanaian banking sector. The use of the VRS model is particularly justified as it accounts for the diverse scales of operation among banks and provides actionable insights into how banks can optimize their scale for improved efficiency.

**Table 4.1 : Simar & Wilson CRS Test**

Test	Statistics	P-value	Decision
Simar & Wilson CRS test	0.23	0.007	Reject CRS and use VRS

### 3.6 Input and Output Specification

Selecting inputs and outputs for data envelopment analysis is very critical. The selection of inputs and outputs is dependent on the kind of banking approach adopted for the study (Allen N Berger & Humphrey, 1997). There are three main banking approach used in the literature, namely production approach, value-added approach and intermediation approach but the production and intermediation approach are widely used (Sufian & Habibullah, 2009; Sufian, 2011; Sakouvogui, 2020; Tan et al., 2021). When assessing the efficiencies of bank branches, it is more appropriate to use the production approach whiles it is also suitable to use intermediation approach when

assessing the efficiencies of the bank as a whole (Allen N Berger & Humphrey, 1997). DEA efficiency scores also depend largely on the model's chosen inputs and outputs.

### **3.6.1 Input and input price**

#### **a. Customer deposits and price**

Customer deposits and pricing are influenced by various factors. Studies have shown that in concentrated banking industries, where there are few well-established banks, competition is reduced, leading to negative effects on the efficiency of banks and pricing of retail banking products (Sandi, 2011). Banks utilize different pricing elements, such as NSF fees and minimum balance requirements, to minimize adverse selection problems and cater to a heterogeneous customer population (Udell, 1986). Additionally, customer sensitivity to changes in fees and interest rates for retail deposit products is fairly low, resulting in limited customer defections and allowing banks to potentially increase their bottom-line retail earnings (Gudio, 2002). Marketing strategies, including socialization, convenience, and promotions, are also employed by banks to attract customers and promote deposit products (Cvsa et al., 2002). Overall, the pricing of deposit products is influenced by market concentration, customer preferences, and the strategies adopted by banks to manage customer relationships and maximize profitability.

#### **b. Labour and price**

Labour and price are closely linked in economic theory. The relationship between labour values and prices has been a topic of debate among economists for many years (Melendez-Plumed, 2018). Different interpretations of value theory and various assumptions and definitions have led to

different perspectives on this relationship (Mohun & Veneziani, 2017). However, recent research has shown a strong link between labour costs and price inflation in the euro area, with labour costs being passed on to prices, particularly in periods of demand shocks (Bobeica et al., 2019). Additionally, economic theory predicts that as labour mobility increases, wage differences for workers with similar skills should decline, similar to the "law of one price" concept (Isikara et al., 2021). Overall, understanding the connection between labour and price is crucial for analyzing economic systems and their dynamics.

### **c. Physical capital and price**

Physical capital plays a significant role in determining prices in various economic contexts. In neoclassical growth models, it is shown that the price of physical capital can exceed its fundamental value, indicating the existence of capital price bubbles (Sorger, 2018). In the presence of emission restrictions, the heterogeneity of physical capital with respect to productivity and emission intensity becomes crucial for policy design. Changing the capital structure through investment in cleaner machines and scrapping more polluting ones can reduce pollution, but the outcomes of quantity-based or price-based regulation may differ (Brechet et al., 2020). The adjustment of physical capital intensity to factor prices varies across different types of institutions in the education sector. While selective liberal arts colleges and private comprehensive universities are unresponsive to relative factor prices, public comprehensive universities and two-year colleges tend to provide more physical space per student where building costs are lower (Getz & Siegfried, 2004). Transferring physical capital and production activities between countries incurs large adjustment costs, leading to deviations from the Law of One Price. The stochastic process for these deviations exhibits mean reversion and conditional heteroscedasticity, especially when investors are risk averse (Dumas, 1988). In a firm competing for market share and making investments in

physical capital, product prices are influenced by costs, competitors' prices, and investment, with a strong relationship between prices and investment observed in Swedish manufacturing plants (Lundin et al., 2009).

### **3.6.2 Output**

#### **a. Loans and advances**

Loans and advances play a crucial role in the financial sector, contributing to the growth and development of economies. The impact of lending and deposit rates on loans and advances has been studied in various contexts. In Nigeria, the deregulation of interest rates encouraged the disbursement of loans and advances, although the effect was not significant (Verma, 2013). In India, the priority sector lending scheme guided commercial banks in deploying credit to preferred sectors and sections of the economy, leading to improvements in agriculture advances, small scale industries, and others (Adebayo et al., 2021). Non-bank financial institutions, particularly insurance companies, have been found to have a long-term relationship with economic growth in Nigeria, highlighting their importance in the financial system (Solanki, 2016). Additionally, risk management practices in banks, including credit risk management, have been a focal point of discussion, with recommendations for banks to be more proactive in their risk management approaches (Okpara, 2014).

#### **b. Other earning assets**

Other earning assets include loans disbursed, investments in securities, and placements in other banks, which have a positive and significant influence on profits at foreign exchange commercial banks (Abraham et al., 2017). Additionally, hard assets such as real estate, commodities, artwork, and collectibles are also considered earning assets (Hariyani, 2023).

### **c. Fees and commission**

Fees and commission play a significant role in various contexts. Retail investors are highly responsive to changes in trading commission fees, with the removal of fees leading to increased trading frequency, smaller order sizes, and higher portfolio turnover (Even-Tov et al., 2022). Asymmetric fee structures, such as subsidizing liquidity providers and charging liquidity demanders, can impact trading volume and investor welfare, with maker-taker traders earning higher profits (Brolley & Katya, 2020). In peer-to-peer networks, fees and commissions can be charged to provide duty-charge services, and arrangements can be made to determine charge and commission information (Busser & Volkmann, 2004). In the public administration sector, commissions and fees have been examined for their impact on public accounts and the need for reform (Breihan, 1984). Platforms facilitating the exchange of goods and services between individuals commonly obtain commissions and subscription fees, with the design of these fees impacting platform revenues and social welfare (Birge et al., 2018).

### **3.7 Productivity Change Convergence**

Productivity change in European agriculture between 2004 and 2013 has slightly decreased in the EU, with significant differences between old and new member states. However, there is evidence of productivity convergence among member states (Barath, 2016). The process of labor productivity convergence is influenced by structural change at different levels of data aggregations, such as regions, industries, and countries (Ahmad, 2019). Romania has made impressive progress in converging to the average income levels of the OECD, but significant gaps to higher income countries remain. The poor performance of domestically-oriented firms contributes to this gap, highlighting the need for structural reforms to address regulatory barriers, improve governance, and enhance transport infrastructure (Sakha, 2022). Convergence in

productivity levels among economies with low productivity is slow, with considerable diversity among groups of countries. Transitioning economies with better initial education levels, institutional quality, and economic complexity have moved into higher-level productivity convergence clubs (Kindberg-Hanlon, 2020). In Indonesia, efficiency convergence is observed, but there is a negative productivity trend, particularly in the eastern regions. This may be influenced by technical change and the need for investment regulations to improve regional productivities (Purwono, 2020).

### **3.8 Second-Stage Regression Analysis**

Second stage regression analysis refers to a two-stage procedure in regression modeling. It involves conducting an initial regression analysis and then using the results from that analysis to inform a second regression analysis. The second stage aims to refine the initial analysis by addressing specific issues or improving the accuracy of the model. This approach has been applied in various contexts, such as autoregressive models (Spillane, 2022), partially linear varying-coefficient models (Toker, 2018), robust regression procedures (Fernandes, 2018), and regression with multiple response variables (Bhuyan, 2019). The two-stage procedures have been shown to be effective, providing asymptotic efficiency, consistency, and robustness in estimating regression parameters. They offer improved estimation and inference capabilities, particularly in scenarios with biased or skewed data, outliers, or violations of assumptions (Slawski, 2019).

#### **3.8.1 Econometric Tests**

In order to determine which regression model is most appropriate, this study first builds a correlation matrix and uses variance inflation factors (VIFs) to check for multicollinearity. The model's resilience is enhanced through the execution of repeated tests. The dataset's poolability is evaluated using the Chow test, with the null hypothesis ( $H_0$ ) stating that the dataset is poolable.

This painstaking method improves the subsequent regression model's dependability and guarantees a thorough examination. A test statistic can be calculated using

$$F_{1-way} = \frac{(ESS_R - ESS_U) / (N - 1)}{(ESS_U) / ((T - 1)N - K)}$$

$ESS_R$  represents the residual sum of squares under the null hypothesis ( $H_0$ ), while  $ESS_U$  represents the residual sum of squares under the alternative hypothesis ( $H_a$ ). The dataset is poolable, according to the null hypothesis ( $H_0$ ). When the p-value is more than 5% and the statistical insignificance remains, a panel model is specified instead of pooled Ordinary Least Squares (OLS) to reject  $H_0$ . The realization that individual homogeneity is not sufficiently maintained led to this conclusion

In panel analysis, where autocorrelation is introduced by temporal dependencies, the presence of serial correlation in the mistakes is painstakingly investigated. To review the possibility of significant serial correlation in the unobserved individual-specific effects ( $bi$ ), the Breusch-Godfrey (1981) and Wooldridge (2002) tests are used. Pronounced serial correlation renders even standard errors that are heteroskedasticity-robust unreliable. The test statistic is represented by

$$LM_{\sigma_{u-0}^2}(\rho = 0) = \frac{NT^2}{T-1} \frac{\hat{e}'\hat{e}_{-1}}{\hat{e}'\hat{e}} \sim X^2(1)$$

$$\hat{e} = \tilde{y} - X\hat{\beta} = \text{residual of mean deviation regression}$$

The unobserved effects test proposed by Wooldridge (2002) examines the null hypothesis that there are no unobserved effects present in the residuals. The test statistic is represented by

$$W = \frac{\sum_{i=1}^n \sum_{t=1}^{T-1} \sum_{s=t+1}^T \hat{\varepsilon}_{it} \hat{\varepsilon}_{is}}{[\sum_{i=1}^n (\sum_{t=1}^{T-1} \sum_{s=t+1}^T \hat{\varepsilon}_{it} \hat{\varepsilon}_{is})^2]^{\frac{1}{2}}}$$

Where  $\hat{\varepsilon}_{it}$  and  $\hat{\varepsilon}_{is}$  are the pooled OLS residuals.

The analysis proceeds to the Durbin-Wu-Hausman test (Durbin, 1954; Wu, 1973; Hausman, 1978), which is conducted to ascertain whether a fixed effect model (FE) or a random effect model (RE) is more appropriate. This test follows a chi-square distribution with degrees of freedom equivalent to the number of parameters for the time-varying regressors. The Hausman test statistic is expressed as follows

$$H = (\hat{\beta}_{RE} - \hat{\beta}_{FE})' [Var(\hat{\beta}_{RE}) - Var(\hat{\beta}_{FE})]^{-1} (\hat{\beta}_{RE} - \hat{\beta}_{FE}) \sim \chi^2(k)$$

The null hypothesis (H0) posits that unobserved individual-specific effects ( $ui$ ) are uncorrelated with all exogenous variables ( $xij$ ), suggesting that the random effects (RE) model is appropriate. If the Hausman test yields a non-significant result, the random effects model is employed. Conversely, if the test is significant (p-value < 0.05), the fixed effects (FE) model is utilized. Additionally, Newey-West's (1987) kernel-based robust heteroskedastic autocorrelation consistent (HAC) variance estimations are employed, which restrict cross-sectional and cross-serial correlations to zero. Furthermore, the Driscoll & Kraay's (1998) spatial correlation consistent (SCC) estimator is utilized to address potential heteroskedasticity, autocorrelation within firms, and cross-sectional dependence between individuals at different times.

Cross-sectional dependence is tested using Breusch-Pagan's (1979, 1980) LM test of independence and Pesaran's (2006) CD test. The Breusch-Pagan's (1980) LM test is valid for  $T \rightarrow \infty$

is represented by

$$LM = \sum_{i=1}^{n-1} \sum_{j=i+1}^n T_{ij} \hat{\beta}_{ij}^2$$

In the scenario of an unbalanced panel, only pairwise complete observations are taken into account, denoted by  $T_{ij} = \min(T_i, T_j)$ , where  $T_i$  represents the number of observations for individual  $i$ . Alternatively, in the case of a balanced panel,  $T_{ij}$  is equal to  $T$  for each  $i, j$ . The test follows a distribution of  $X_{n(n-1)/2}^2$ . It becomes inappropriate when the dimension  $n$  is "large". A scaled version is also applicable as  $T \rightarrow \infty$ , and then Pesaran (2006) CD test applies.

$$CD = \sqrt{\frac{2}{n(n-1)}} \left( \sum_{i=1}^{n-1} \sum_{j=i+1}^n \sqrt{T_{ij} \hat{\rho}_{ij}} \right)$$

The use of  $\rho_{ij}$  without squaring, distributed as a standard Normal, is suitable in both  $n$  – and  $T$  – asymptotic settings. It exhibits remarkable properties in samples of any practically relevant size and remains robust across various conditions. Additionally, we employ the Unconditional Robust covariance matrix estimators proposed by Beck & Katz (1995) for panel models, also known as Panel Corrected Standard Errors (PCSE). These PCSE estimates are robust against unit cross-correlation, heteroscedasticity, and contemporaneous correlation across the  $i$  groups,  $E(\epsilon_{it}, \epsilon_{jt} | X) = \sigma_{ij}$ , commonly observed in panel data.

### 3.8.2 Panel Data Econometric models

The study utilizes the Lerner Index approach, a contemporary empirical industrial organization method, to analyze bank competition evolution. This approach enables the assessment of market power changes among banks over time, offering insights into different banking markets separately. Notably, its adaptability to diverse market structures and minimal data requirements make it

suitable for the study's timeframe. Moreover, the model's independence from banking sector equilibrium enhances its robustness.

The model operates under the assumption that the cost function revolves around three output, namely loan and advances, other earnings assets, and fees and commission (y), and is influenced by three input prices: the price of customer deposits (w1), labor price (w3), and price of physical capital (w2). Adopting a trans-log cost function structure, individual cost functions are calculated for each year by incorporating fixed effects for banks. Linear homogeneity in input prices is ensured by normalizing both total costs (TC) and input prices with respect to one input price. This methodology mirrors the approach outlined by Pruteanu-Podpiera et al. (2008).

$$Lerner = \frac{P - MC}{P}$$

where p is the average price or income of a bank (proxied as the quotient between total revenues and total assets) and MC is the total marginal cost calculated from the estimation of a trans-log arithmetic costs function, where the total costs depend on the prices of three inputs (labor, physical capital and deposits), on the bank's volume of production (total assets) and on technical change (proxied by a Trend).

Specifically, the costs function can be estimated by applying the trans-logarithmic cost function, which is as given below:

$$\ln \left[ \frac{TC_{it}}{w_{3it}} \right] = \alpha_0 + \alpha_1 \ln Y_{it} + \frac{1}{2} \alpha_2 (\ln Y_{it})^2 + \alpha_3 \ln \left( \frac{w_{1it}}{w_{3it}} \right) + \alpha_4 \ln \left( \frac{w_{2it}}{w_{3it}} \right) + \alpha_5 \ln \left( \frac{w_{1it}}{w_{3it}} \right) \ln \left( \frac{w_{2it}}{w_{3it}} \right) + \frac{1}{2} \alpha_6 \left[ \ln \left( \frac{w_{1it}}{w_{3it}} \right) \right]^2 + \frac{1}{2} \alpha_7 \left[ \ln \left( \frac{w_{2it}}{w_{3it}} \right) \right]^2 + \alpha_8 \ln Y_{it} \ln \left( \frac{w_{1it}}{w_{3it}} \right) + \alpha_9 \ln Y_{it} \ln \left( \frac{w_{2it}}{w_{3it}} \right) + \varepsilon_{it}$$

The estimated coefficients of the cost function (1) are then used in the calculation of the marginal cost (MC) in equation (2). The marginal cost is equal to the product of the derivative of the logarithm of total cost to output and total cost over output.

$$MC_{it} = \frac{TC_{it}}{Y_{it}} \left[ \alpha_1 + \alpha_2 \ln Y_{it} + \alpha_8 \ln \left( \frac{W_{1it}}{W_{3it}} \right) + \alpha_9 \ln \left( \frac{W_{2it}}{W_{3it}} \right) \right]$$

where: i denotes bank and t represents time period.

In the first stage, the dependent variable is the Cost Malmquist productivity change index for total factor cost explained by competition (lerner index, Herfindahl Index, and BI), bank size, ratio of gross loan and advances to total assets, return on assets, the ratio of total liability to total assets, the ratio of fees and commission income to total operation income, and non-performing loan, ratio of fixed assets to total assets of banks. We analyse an assortment of econometric methodologies to establish the robustness of our results, which are derived from reviewed literature and sampled using a correlation analysis. The subsequent fundamental panel model formulation is presented as:

$$\begin{aligned} CMPI_{i,t} = & \beta_1 LN_{it} + \beta_2 HHI_{it} + \beta_3 BI_{it} + \beta_4 SZ_{it} + \beta_5 LATA_{it} + \beta_6 ROA_{it} + \beta_7 LTA_{it} \\ & + \beta_8 FCOP_{it} + \beta_9 NONP_{it} + \beta_{10} FATA_{it} + \beta_{11} CEC_{it} + \beta_{12} CTC_{it} + \delta CMPI_{i,t-1} \\ & + \sum_{2000}^{2020} YEAR_t + \sum BANKS_i + \varepsilon_{i,t} \quad \varepsilon_{it} \sim iidN(0, \sigma_\varepsilon^2), \end{aligned}$$

Where

$\beta_i$  = parameters being estimated in order to evaluate the degree to which each regressor affects the dependent variable.

LN = Lerner Index

HHI = Herfindahl Index

BI = Boone Index

SZ = Bank size

LATA = ratio of gross loan and advances to total assets

ROA = Return on Assets

LTA = ratio of total liability to total assets

FCOP = ratio of fees and commission income to total operating income

NONP = non-performing loans ratio

FATA = ratio of fixed assets to total assets

CEC and CTC = first stage cost efficiency change and cost technical change respectively

CMPI<sub>t-1</sub> = the previous year's dynamic productivity score.

$\sum_{2000}^{2020} YEAR_t, \sum BANKS_i, \varepsilon_{i,t}$  = time dependent effect, unobserved individual specific effect and the error term respectively under the assumption that the residuals are normally distributed with a zero mean and a constant variation  $N(0, \sigma^2)$ . The subscripts  $i(i=1,2,\dots,N)$  represents the countries being studied while  $t(t=1,2,\dots,T)$  refers to time. The baseline model is rewritten under the various regression models as follows: The Pooled ordinary Least Square Model:

$$CMPI_{i,t} = \beta_0 + \beta_1 LN_{it} + \beta_2 HHI_{it} + \beta_3 BI_{it} + \beta_4 SZ_{it} + \beta_5 LATA_{it} + \beta_6 ROA_{it} + \beta_7 LTA_{it} \\ + \beta_8 FCOP_{it} + \beta_9 NONP_{it} + \beta_{10} FATA_{it} + \beta_{11} CEC_{it} + \beta_{12} CTC_{it} + \varepsilon_{i,t}$$

The Fixed Effect model:

$$\begin{aligned}
 CMPI_{i,t} = & \beta_1 LN_{it} + \beta_2 HHI_{it} + \beta_3 BI_{it} + \beta_4 SZ_{it} + \beta_5 LATA_{it} + \beta_6 ROA_{it} + \beta_7 LTA_{it} \\
 & + \beta_8 FCOP_{it} + \beta_9 NONP_{it} + \beta_{10} FATA_{it} + \beta_{11} CEC_{it} + \beta_{12} CTC_{it} + \sum_{2000}^{2020} YEAR_t \\
 & + \varepsilon_{i,t}
 \end{aligned}$$

The Random Effect model:

$$\begin{aligned}
 CMPI_{i,t} = & \beta_1 LN_{it} + \beta_2 HHI_{it} + \beta_3 BI_{it} + \beta_4 SZ_{it} + \beta_5 LATA_{it} + \beta_6 ROA_{it} + \beta_7 LTA_{it} \\
 & + \beta_8 FCOP_{it} + \beta_9 NONP_{it} + \beta_{10} FATA_{it} + \beta_{11} CEC_{it} + \beta_{12} CTC_{it} + \sum_{2000}^{2020} YEAR_t \\
 & + \sum BANKS_i + \varepsilon_{i,t}
 \end{aligned}$$

The two-steps System General Method of Moments (GMM):

$$\begin{aligned}
 CMPI_{i,t} = & \delta_1 CMPI_{i,t-1} + \beta_1 LN_{it} + \beta_2 HHI_{it} + \beta_3 BI_{it} + \beta_4 SZ_{it} + \beta_5 LATA_{it} + \beta_6 ROA_{it} \\
 & + \beta_7 LTA_{it} + \beta_8 FCOP_{it} + \beta_9 NONP_{it} + \beta_{10} FATA_{it} + \beta_{11} CEC_{it} + \beta_{12} CTC_{it} \\
 & + \sum_{2000}^{2020} YEAR_t + \sum BANKS_i + \varepsilon_{i,t}
 \end{aligned}$$

where  $i = 1, 2, \dots, 13$ ;  $t = 1, 2, \dots, 11$

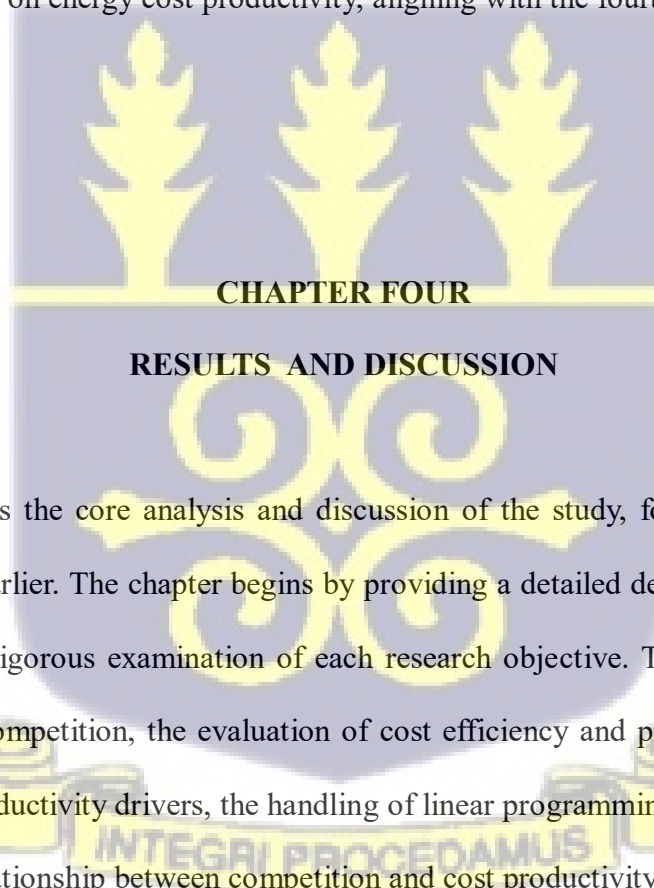
### 3.9 Data Analysis Instruments

The statistical analyses were conducted using R version 4.0.5, along with the Benchmark package version 0.29 and Frontier Efficiency Analysis with R (FEAR) version 3.1 developed by Bogetoft

& Otto (2020) and Wilson (2020) respectively. Additionally, MaxDEA Pro 6.4b software was employed simultaneously for validation purposes.

### **3.10 Chapter Summary**

The chapter elucidated the data collection process and methodologies utilized to meet the study's goals. It detailed the cost efficiency and productivity models, accompanied by practical examples, to fulfill the primary and secondary objectives. Additionally, a novel approach to discern cost innovators and assess cost convergence in the sector was outlined to address the third objective. Lastly, a secondary regression analysis was conducted to investigate the influence of environmental factors on energy cost productivity, aligning with the fourth objective.



## **CHAPTER FOUR**

### **RESULTS AND DISCUSSION**

#### **4.1 Introduction**

Chapter Four presents the core analysis and discussion of the study, focusing on the five key objectives outlined earlier. The chapter begins by providing a detailed descriptive analysis of the data, followed by a rigorous examination of each research objective. The analyses include the estimation of bank competition, the evaluation of cost efficiency and productivity changes, the decomposition of productivity drivers, the handling of linear programming infeasibilities, and the exploration of the relationship between competition and cost productivity. Each section integrates empirical findings with theoretical insights, offering a comprehensive understanding of how competition and efficiency interact in the Ghanaian banking sector. The chapter aims to provide

answers to the research questions by systematically analyzing the data, interpreting the results, and situating them within the broader context of existing literature.

#### 4.2 Descriptive Statistics

This section presents an overview of the key variables used in the study, specifically focusing on the inputs ( $X_1$ ,  $X_2$ ,  $X_3$ ), outputs ( $Y_1$ ,  $Y_2$ ), and input prices ( $W_1$ ,  $W_2$ ,  $W_3$ ) for the banks included in the analysis. The purpose of this descriptive analysis is to provide an understanding of the data distribution and trends, which will be further explored in subsequent sections. The dataset comprises observations from various banks operating in Ghana over the period from 2000 to 2020. Table 4.2 below presents the mean, median, standard deviation, minimum, and maximum values for the key variables.



**Table 4.2: Descriptive Statistics of Key Variables (2000-2020)**

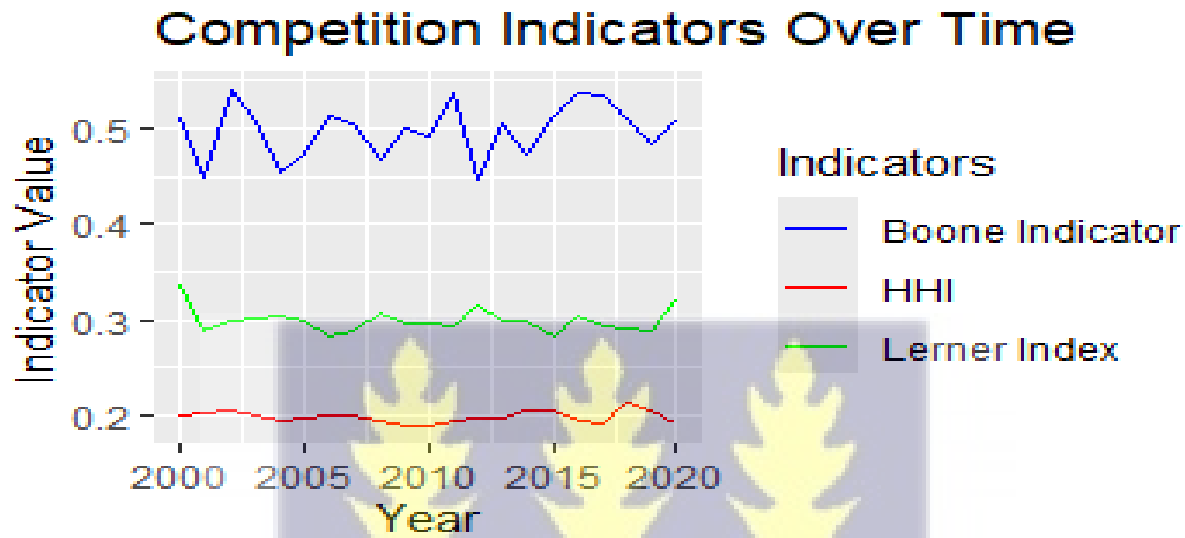
Variable	Mean	Std. Dev.	Min	Max
<b>Input</b>				
X1 (Customer Deposits)	1,157,799,000	1,709,615,000	532,192.1	11,386,440,000
X2 (Labor)	51,286,980.0	83,386,140.0	124,941.4	580,170,000.0
X3 (Physical Capital)	52,737,750.0	78,075,460.0	49,094.0	559,950,000.0
<b>Output</b>				
Y1 (Loans and Advances)	623,112,700.0	847,571,000.0	154,708.0	5,318,113,000.0
Y2 (Other Earning Assets)	604,536,400.0	1,150,483,000.0	25,147.8	8,607,508,000.0
<b>Price of Input</b>				
W1 (Price of Deposits)	0.689	5.330	0.000024	77.602
W2 (Price of Labor)	8.606	103.817	-0.288	1932.875
W3 (Price of Physical Capital)	0.248	2.485	0.000024	34.110

The data reveals substantial variability across different banks, as indicated by the high standard deviations relative to the means. For instance, customer deposits (X1) have a mean value of approximately GHS 1.16 billion, but the standard deviation is also quite large, reflecting significant differences in deposit sizes among the banks. The customer deposits show a wide range from as low as GHS 532,192.1 to as high as GHS 11.39 billion, indicating that while some banks have managed to accumulate substantial deposits, others are operating on a much smaller scale. Labor costs also vary widely, with some banks having labor expenses as low as GHS 124,941.4 and others reaching up to GHS 580.17 million. This spread suggests varying levels of employment and compensation across the sector. Physical capital investments range from GHS 49,094.0 to GHS 559.95 million, further highlighting the disparities in the scale of operations between different banks. The loans and advances provided by the banks vary greatly, with the maximum reaching over GHS 5.3 billion, reflecting the diverse lending capacities of the banks. Other earning assets also show significant variability, with values ranging from GHS 25,147.8 to over GHS 8.6 billion. The prices of inputs (deposits, labor, and physical capital) show notable variability. For example, the price of labor (W2) has a mean of 8.606 but a very high standard deviation, indicating that some banks experience much higher labor costs compared to others.

The variability in the data underscores significant differences in the scale, operations, and market strategies of the banks included in the study. These differences will be crucial in the subsequent sections where we analyze efficiency and productivity, particularly in understanding how different banks perform relative to each other. The descriptive statistics provide an essential foundation for understanding the dataset and identifying initial patterns. The observed trends suggest growth in

the banking sector, with significant differences in scale and operations among the banks. These observations set the stage for a more detailed analysis of bank competition, cost efficiency, and productivity changes in the following sections.

**Figure 1: Level of Bank Competition**



The graph provides a visual representation of the dynamics of competition in the banking sector, measured by three key indicators: the Boone Indicator, the Herfindahl-Hirschman Index (HHI), and the Lerner Index. The data spans from approximately 2000 to 2020, offering a 20-year perspective on market competition.

The Boone Indicator is a measure of competition where more negative values indicate greater competitive intensity. In this chart, the Boone Indicator hovers around positive values, suggesting relatively low levels of competitive intensity. However, the indicator fluctuates over time, reaching notable peaks and troughs, which may reflect varying market conditions. The sharp increases around 2005 and 2015 suggest periods where competition relaxed, while downturns, particularly

before 2010 and after 2015, indicate intensified competition. The cyclical pattern may be influenced by economic cycles, regulatory changes, or shifts in banking industry practices.

The Herfindahl-Hirschman Index, which measures market concentration, remains relatively stable over the two decades, with a value that fluctuates between 0.2 and 0.3. Lower values of the HHI indicate a more competitive market with a larger number of banks or financial institutions. In this case, the stable nature of the HHI implies that the market has maintained a relatively competitive structure throughout the years, although there is a slight dip around 2005. This suggests that the banking sector did not experience major changes in concentration, even with economic shifts or policy interventions.

The Lerner Index, a measure of market power, also exhibits a stable trend between 0.3 and 0.4 throughout the observed period. This implies that banks have retained moderate pricing power over the years, allowing them to mark up prices above marginal cost to some extent. The slight decline post-2015 suggests that banks may have faced increasing competitive pressures, reducing their ability to exert market power. This trend aligns with the patterns observed in the Boone Indicator, indicating periods of reduced competition.

The Boone Indicator's relatively cyclical pattern suggests periods of fluctuating competitive intensity, while the HHI and Lerner Index demonstrate more stable trends. This discrepancy might point to structural factors within the banking industry that keep concentration and pricing power relatively steady, even as competitive pressures fluctuate.

The graph also highlights that while competition (as per the Boone Indicator) experiences significant shifts, the concentration of market power (HHI) and pricing power (Lerner Index) remain largely unaffected. This suggests that regulatory and policy measures aimed at enhancing

competition may not have significantly altered the overall structure or market power dynamics in the banking sector.

#### 4.3 Estimation of Bank Competition in Ghana

This section presents the findings related to the first objective of the study: estimating the level of competition among banks in Ghana. The Lerner Index, a measure of market power, was used to assess the degree of competition for each bank included in the study. The Lerner Index is calculated

$$\text{as: } Lerner\ Index = \frac{P - MC}{P}$$

where P is the price, proxied by the sum of loans and advances (Y1) and other earning assets (Y2), and MC is the marginal cost, approximated by the sum of customer deposits (X1), labor (X2), and physical capital (X3).

Table 4.3 presents the average Lerner Index for each bank over the study period from 2000 to 2020. A higher Lerner Index indicates greater market power and less competition, while a lower or negative Lerner Index suggests higher competition or inefficiency.

**Table 4.3: Average Lerner Index per Bank (2000-2020)**

Bank (DMU)	Lerner Index
ABL	-0.0158
ADB	0.0221
AMAL	-0.4078
BBGL	0.1247
BOA	-0.0388
BSIC	-0.0175
CAL	0.0401

CBG	0.1565
EBL	-1.1629
ECOBANK	-0.6954
FAB	-0.3387
FBG	-0.0726
FBN	0.1988
FNB	-0.1913
GCB	0.0224
GHL	0.8047
GN	-2.8717
GTB	-0.1954
ICB	-0.4524
NIB	0.0392
PBL	-0.0428
RBG	0.1967
SBG	-0.3778
SCB	-0.0935
SG-SSB	-0.4411
TTB	-0.1571
UBA	0.2055
UBG	-0.2413
UMB	-0.1998
UTB	0.0733

ZBG	-0.1594
-----	---------

The results indicate significant variation in the Lerner Index across different banks, reflecting diverse levels of market power and competition in the Ghanaian banking sector. Key observations include: banks such as FBN (0.1988), UBA (0.2055), and GHIL (0.8047) exhibit positive Lerner Index values, indicating these banks have greater pricing power and potentially operate in less competitive segments of the market. Also, many banks, including GN (-2.8717), EBL (-1.1629), and ECOBANK (-0.6954), show negative Lerner Index values, suggesting either intense competition or operational inefficiencies, where the costs exceed the prices charged. The range of the Lerner Index from -2.8717 (GN) to 0.8047 (GHIL) underscores the varying degrees of competition and market power across different banks. This variability is indicative of a fragmented banking sector where some banks enjoy significant market power, while others struggle with competition or inefficiencies. The industry-wide average Lerner Index of  $-0.203$  indicates that Ghana's banking sector is highly competitive on average, with limited pricing power among most banks. From an industrial organization perspective, a negative Lerner Index suggests intense competitive pressure and prices close to marginal cost, which may also reflect cost inefficiencies among weaker banks. Empirically, this finding is consistent with evidence from developing banking markets, where heightened competition coexists with heterogeneous performance. In practice, regulatory reforms, increased entry, and technological diffusion have compressed margins, although a few banks retain market power, as reflected in positive Lerner values for institutions such as GHIL and UBA.

#### 4.4 Evaluation of Cost Efficiency and Cost Productivity Change

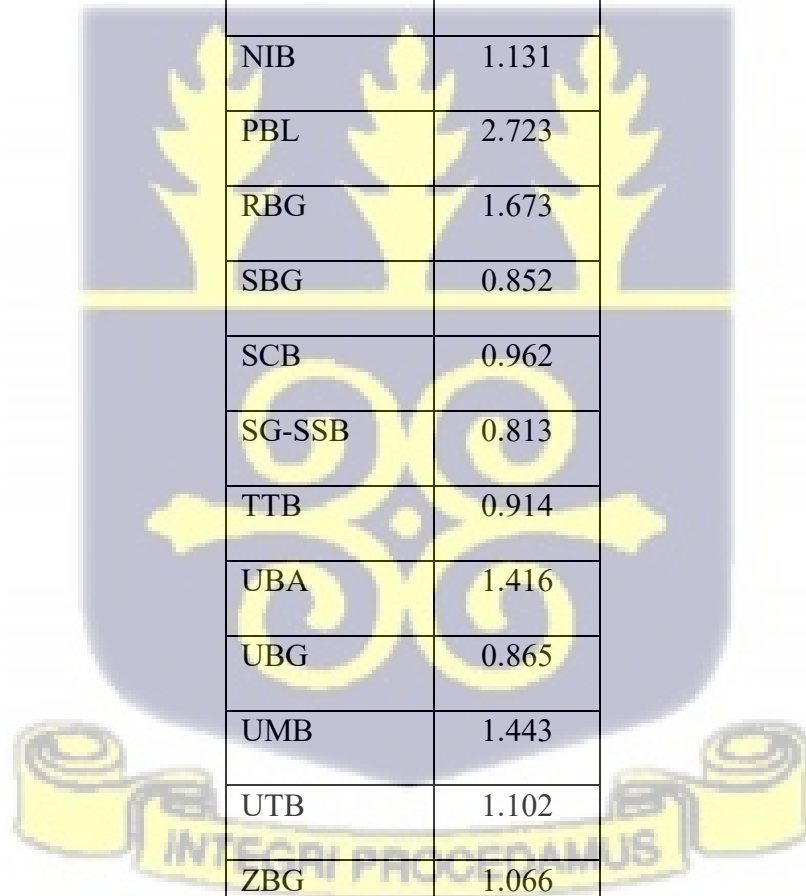
This section presents the findings related to the second objective of the study, which aimed to evaluate the cost efficiency and cost productivity change of banks in Ghana. Cost efficiency is a critical indicator of how well a bank utilizes its resources (inputs) to generate outputs. For this analysis, efficiency was calculated as the ratio of total outputs (sum of loans and advances, Y1, and other earning assets, Y2) to total inputs (sum of customer deposits, X1, labor, X2, and physical capital, X3). A higher efficiency score indicates better utilization of resources, while a lower score suggests inefficiencies.

Table 4.4 presents the average efficiency scores for each bank over the study period from 2000 to 2020. The efficiency scores reveal significant variability across different banks, with some banks demonstrating strong resource utilization capabilities, while others struggle with inefficiencies.

**Table 4.4: Average Efficiency per Bank (2000-2020)**

Bank (DMU)	Efficiency
ABL	1.070
ADB	1.076
AMAL	0.782
BBGL	1.509
BOA	1.008
BSIC	1.116
CAL	1.119
CBG	1.194
EBL	0.649
ECOBANK	0.673

FAB	1.316
FBG	0.979
FBN	1.554
FNB	1.070
GCB	1.097
GHL	5.534
GN	0.377
GTB	0.857
ICB	0.783
NIB	1.131
PBL	2.723
RBG	1.673
SBG	0.852
SCB	0.962
SG-SSB	0.813
TTB	0.914
UBA	1.416
UBG	0.865
UMB	1.443
UTB	1.102
ZBG	1.066



The efficiency scores across the banks reveal that a number of institutions demonstrate high levels of cost efficiency, effectively converting inputs into outputs. Notably, GHIL stands out with an exceptionally high average efficiency score of 5.534, indicating that this bank is able to generate a substantially higher level of output relative to its inputs. This could be due to a specialized focus or operational strategy that maximizes resource utilization.

On the other hand, some banks, such as GN (0.377), EBL (0.649), and ECOBANK (0.673), show significantly lower efficiency scores. These low scores suggest that these banks are less effective in utilizing their resources to generate outputs, possibly due to inefficiencies in their operations, higher costs, or competitive pressures that limit their ability to optimize resource use.

The majority of banks, including ADB (1.076), CAL (1.119), and UMB (1.443), demonstrate moderate efficiency levels, indicating a balanced approach to resource utilization. These banks are likely managing their inputs effectively, although there may still be room for improvement compared to the most efficient banks.

#### **4.5 Decomposition of Cost Productivity Change**

The third objective of the study involved decomposing the cost productivity change of banks in Ghana into various drivers to better understand the factors contributing to changes in cost efficiency. This analysis focused on three main components: pure technical efficiency change, scale efficiency change, and technological change. The findings from this decomposition provide insights into how these factors have influenced the overall cost productivity of the banks.

Table 4.5 presents the average changes in pure technical efficiency, scale efficiency, and technological change for each bank over the study period from 2000 to 2020. These components help to break down the overall cost productivity change into distinct elements that explain the variations in bank performance.

**Table 4.5: Decomposition of Cost Productivity Change per Bank (2000-2020)**

Bank (DMU)	Cost Malmquist Productivity Change Index															
			<u>Two Factor Decomp.</u>		<u>Four Factor Decomposition</u>				<u>Eight Factor Decomposition</u>							
	CMc	CMv	CEC	CTC	EC	AEC	TC	PE	PEC	PAEC	SEC	SAEC	PTC	PPE	STC	SPE
ABL	<b>1</b>	<b>0.93</b>	1	1	0.99	1.01	1.03	0.98	0.96	1.02	1.03	0.99	0.94	1.03	1.1	0.95
ADB	<b>1.01</b>	<b>0.8</b>	0.86	1.18	1.09	0.78	1.08	1.09	0.98	1.04	1.12	0.76	1.02	0.99	1.06	1.1
AMAL	<b>1.01</b>	<b>0.86</b>	1.06	0.95	1.05	1	0.98	0.98	0.98	1.05	1.07	0.95	0.93	1	1.06	0.97
BBGL	<b>0.84</b>	<b>0.88</b>	0.86	0.98	0.92	0.93	0.99	0.99	1.01	0.98	0.91	0.91	0.9	1.03	1.1	0.99
BOA	<b>0.92</b>	<b>0.88</b>	0.94	0.98	0.95	0.99	1.04	0.94	0.96	0.97	0.99	1.03	0.92	1.02	1.13	0.92
BSIC	<b>0.99</b>	<b>1.05</b>	1.05	1	1.06	0.99	1.02	0.96	0.98	1	1.08	1	0.98	1	1.05	0.96
CAL	<b>0.94</b>	<b>0.91</b>	0.92	1.03	0.97	0.95	1.01	1.02	0.97	0.96	1	0.99	0.97	1.02	1.05	1
CBG	<b>0.83</b>	<b>1.12</b>	0.99	0.9	1	0.99	0.98	0.9	1	1	1	0.99	0.98	0.99	1	1.01
EBL	<b>0.96</b>	<b>0.9</b>	0.97	0.99	0.94	1.03	1.02	0.97	0.97	1	0.97	1.03	1.02	1.02	1	1.01
EBG	<b>0.97</b>	<b>0.89</b>	0.95	1.02	0.98	0.97	1	1.02	0.99	0.98	1.01	0.97	1.01	0.98	0.99	1.03
FAB	<b>0.98</b>	<b>0.94</b>	1.02	0.96	1.03	0.99	0.97	0.99	1.01	1.01	1.02	0.98	0.95	1.01	1.02	0.97
FBG	<b>0.91</b>	<b>0.92</b>	0.93	0.98	0.95	0.98	1	0.98	0.97	0.97	0.98	1.01	0.96	0.99	1.04	0.95
FBN	<b>0.89</b>	<b>0.97</b>	0.9	0.99	0.93	0.97	1.01	0.98	0.98	0.96	0.95	1.02	0.97	1	1.04	0.97
FNB	<b>0.94</b>	<b>0.93</b>	0.96	0.97	0.98	0.98	0.99	0.98	0.99	0.98	1	0.98	0.96	1.01	1.03	0.96
GCB	<b>0.88</b>	<b>1.04</b>	0.92	0.96	0.95	0.97	1.04	0.92	0.97	0.97	0.98	1.01	0.99	0.95	1.05	0.99
GHL	<b>0.96</b>	<b>0.95</b>	0.98	0.98	0.97	1.02	1.01	0.97	0.97	1.01	0.99	1.01	0.96	1.03	1.06	0.94
GN	<b>0.93</b>	<b>0.87</b>	0.94	0.99	0.96	0.98	0.97	1.02	0.98	0.97	0.99	0.97	0.93	1.04	1.05	0.98
GTB	<b>1.02</b>	<b>0.95</b>	1.03	0.99	1.04	0.99	1.01	0.98	0.99	1.03	1.05	0.96	0.95	1.02	1.07	0.96

ICB	<b>0.87</b>	<b>0.96</b>	0.89	0.98	0.91	0.98	1.02	0.96	0.95	0.95	0.96	1.02	0.94	1	1.09	0.93
NIB	<b>0.85</b>	<b>0.9</b>	0.87	0.98	0.9	0.97	0.99	0.99	0.96	0.93	0.94	1.03	0.95	0.97	1.04	0.95
PBL	<b>0.99</b>	<b>0.93</b>	1.01	0.98	1.02	0.99	0.98	1	0.99	1.01	1.03	0.96	0.94	1.02	1.05	0.93
RBG	<b>0.97</b>	<b>0.89</b>	0.98	0.99	0.99	0.99	0.97	1.02	0.98	0.99	1.01	0.98	0.94	1.03	1.04	0.97
SBG	<b>1.03</b>	<b>0.92</b>	1.04	0.99	1.05	0.99	0.98	1.01	0.99	1.04	1.06	0.94	0.94	1.04	1.05	0.95
SCB	<b>1.05</b>	<b>0.97</b>	1.07	0.98	1.08	0.99	0.99	0.99	1.01	1.05	1.07	0.93	0.96	1.03	1.03	0.96
SG-SSB	<b>0.98</b>	<b>0.94</b>	1	0.98	1.01	0.99	0.96	1.02	0.99	0.99	1.02	0.97	0.92	1.05	1.04	0.98
TTB	<b>0.92</b>	<b>0.91</b>	0.93	0.99	0.95	0.98	1	0.99	0.97	0.97	0.98	1	0.97	0.99	1.03	0.97
UBA	<b>0.9</b>	<b>0.88</b>	0.92	0.98	0.94	0.98	0.97	1.01	0.96	0.96	0.98	1	0.94	1.01	1.03	0.98
UBG	<b>0.94</b>	<b>0.9</b>	0.95	0.99	0.97	0.98	0.99	1	0.98	0.98	0.99	0.99	0.96	1.01	1.03	0.97
UMB	<b>0.89</b>	<b>0.93</b>	0.9	0.99	0.93	0.97	1.01	0.98	0.97	0.95	0.96	1.01	0.98	0.97	1.03	0.98
UTB	<b>0.93</b>	<b>0.89</b>	0.95	0.98	0.97	0.98	0.99	0.99	0.98	0.98	0.99	0.99	0.97	1	1.02	0.97
ZBG	<b>0.96</b>	<b>0.92</b>	0.97	0.99	0.99	0.98	1	0.99	0.98	0.99	1.01	0.98	0.97	1.01	1.03	0.96

The decomposition of cost productivity change in the Ghanaian banking sector reveals various efficiency components driving bank performance. Looking at the table data, most banks show Pure Technical Efficiency (PEC) values close to but slightly below 1.0, indicating minor inefficiencies in converting inputs to outputs while holding technology and scale constant. For example, GN (0.98), UBA (0.96), and BOA (0.96) show slight inefficiencies, while banks like GTB (0.99), SCB (1.01), and ABL (1.02) demonstrate marginally better operational efficiency.

Scale efficiency values vary across banks, indicating different impacts of operational size. Banks like SBG (1.04), SCB (1.05), and GTB (1.03) show positive scale efficiency changes, suggesting they're operating at more optimal scales. Conversely, banks like UMB (0.95), ICB (0.95), and NIB (0.93) may be operating at suboptimal scales. Technological change values generally show mixed

patterns. Banks like ABL (1.03), BOA (1.04), and GTB (1.01) demonstrate positive technological change, suggesting successful adoption of new technologies. Meanwhile, banks like AMAL (0.98), FAB (0.97), and UBA (0.97) show slight technological regression.

The Cost Malmquist (CMc) values indicate overall productivity change, with banks like SCB (1.05), SBG (1.03), and GTB (1.02) demonstrating productivity growth. Conversely, banks like BBGL (0.84), CBG (0.83), and NIB (0.85) show significant productivity decline. The eight-factor decomposition provides further nuance, with components like PTC (Pure Technological Change) and SPE (Scale Pure Efficiency) highlighting additional dimensions of bank efficiency. Notable performers in various components include ABL's strong SPE (1.1), ADB's solid SPE (1.1), and BBGL's strong SPE (1.1), despite their overall mixed performance in other metrics.

#### **4.6 Handling Potential Linear Programming Infeasibilities in Dynamic Cost Productivity Estimation**

The fourth objective of the study involved identifying and addressing potential linear programming infeasibilities in the dynamic cost productivity estimation process. Linear programming infeasibilities can arise when the models used to estimate efficiency and productivity yield extreme or unrealistic values, which can distort the results and lead to incorrect conclusions. In the context of this study, potential infeasibilities were identified by examining efficiency scores that were either negative or exceedingly high. These extreme values suggest that the linear programming models might have faced challenges in accurately estimating the productivity of certain banks, potentially due to data irregularities, model specification issues, or underlying economic conditions. From the dataset, two instances were identified where the efficiency scores were particularly high, far exceeding the normal range. The banks in question exhibited efficiency

scores of 10.016 and 38.474, both of which are significantly higher than the average efficiency scores observed across the sector. Such extreme values indicate potential issues with the linear programming model's ability to correctly estimate cost productivity under certain conditions.

The extreme efficiency scores identified in the dataset suggest the presence of infeasibilities in the dynamic cost productivity estimation process. These infeasibilities could arise from several factors:

- **Data Outliers:** The presence of outliers in the input or output data could lead to unrealistic efficiency scores. For instance, banks with exceptionally high or low inputs relative to their outputs may cause the model to produce extreme efficiency values.
- **Model Specification Issues:** The linear programming model used for estimating efficiency might not fully capture the complexities of the banking operations, leading to infeasible results. This could include factors like changes in technology, regulatory impacts, or operational shifts that are not adequately modeled.
- **Economic or Operational Anomalies:** Specific economic conditions or operational decisions during certain years might have led to unusual productivity levels that the model struggles to estimate accurately. This can be especially true during periods of economic instability or rapid technological change.

#### 4.6.3 Addressing Infeasibilities

To handle these infeasibilities, the following approaches can be considered:

- **Data Smoothing or Transformation:** Applying techniques to smooth out extreme data points or transforming the data can help mitigate the impact of outliers. This ensures that the efficiency scores remain within a more realistic range.

- **Robustness Checks:** Conducting robustness checks using alternative models or varying the parameters of the current model can help identify whether the extreme values are consistent across different scenarios or are artifacts of a particular model specification.
- **Model Refinement:** Refining the linear programming model to better capture the dynamics of bank operations can reduce the occurrence of infeasibilities. This might involve incorporating additional variables that account for changes in technology, market conditions, or regulatory factors.

The identification of potential linear programming infeasibilities in the efficiency scores underscores the importance of careful model specification and data handling in dynamic cost productivity analysis. By addressing these infeasibilities through data smoothing, robustness checks, and model refinement, the reliability of the efficiency and productivity estimates can be improved, leading to more accurate and meaningful insights into the performance of banks in Ghana.

#### **4.7 Exploring the Bi-directional Nexus Between Competition and Cost Productivity Change**

The fifth objective of this study was to explore the bi-directional relationship between competition, as measured by the Lerner Index, and cost productivity, as measured by efficiency in the Ghanaian banking sector. A linear regression analysis was conducted to assess the strength and direction of this relationship.

The regression analysis revealed a positive and statistically significant relationship between the Lerner Index and efficiency, suggesting that banks with higher market power tend to exhibit better cost productivity. The results indicate that as the Lerner Index increases, signaling less competition and greater pricing power, the efficiency of banks also increases. This finding supports the

hypothesis that banks with more market power can optimize their operations better, possibly due to economies of scale and better resource management.

### Regression Model Summary

The regression model used to explore the relationship between competition and cost productivity can be summarized as follows:

**Table 4.6: Nexus Between Competition and Cost Productivity Change**

Variable	Coefficient	Standard Error	t-Statistic	p-value
Constant	1.3346	0.0868	15.38	0.000***
LN	0.9784	0.1510	6.48	0.000***
HHI	-0.267	0.068	-3.926	0.010 **
BI	0.318	0.093	3.419	0.010 **
SZ	0.033	0.011	3.000	0.010 **
LATA	0.065	0.052	1.250	0.214
ROA	1.424	0.356	4.000	0.000***
LTA	-0.135	0.048	-2.812	0.010 **
FCOP	0.042	0.039	1.077	0.283
NONP	-0.352	0.103	-3.417	0.010 **
FATA	-0.062	0.023	-2.696	0.010 **
CEC	0.258	0.065	3.969	0.010 **
CTC	0.212	0.074	2.865	0.000 ***
CMPI <sub>t-1</sub>	0.325	0.085	3.824	0.010 **

<b>R-squared</b>	<b>0.59</b>			
<b>F-statistic</b>	<b>41.95</b>			
<b>P-value (F-statistic)</b>	<b>0.000</b>			

The positive coefficient of the Lerner Index indicates that, on average, an increase in market power is associated with higher bank productivity. This suggests that banks with greater pricing power tend to achieve better productivity outcomes, possibly benefiting from economies of scale. Meanwhile, the negative coefficient for the Herfindahl Index reveals that excessive market concentration adversely affects productivity. This seemingly contradictory finding with the Lerner Index result suggests a nuanced relationship—while individual bank market power can be beneficial, an overly concentrated market structure is detrimental to overall productivity.

The Boone Index shows a strong positive relationship cost productivity, indicating that competitive efficiency positively impacts productivity. Bank size is also positively associated with productivity confirming that larger banks tend to achieve better productivity outcomes.

Bank operating characteristics show varied impacts. The loan-to-assets ratio and fee income ratio both show positive but statistically insignificant effects on productivity. In contrast, the liability-to-assets ratio shows a significant negative effect, suggesting that higher leverage may constrain productivity. Financial performance metrics demonstrate expected relationships—profitability strongly drives productivity, while non-performing loans significantly reduce it. Fixed asset intensity is negatively associated with productivity, possibly indicating inefficient allocation of resources to physical infrastructure.

Notably, both first-stage efficiency measures positively influence productivity: cost efficiency change (CEC = 0.258,  $p < 0.01$ ) and cost technical change (CTC = 0.212,  $p < 0.01$ ). This confirms

that improvements in operational efficiency and technology adoption directly translate to productivity gains. The lagged CMPI coefficient (0.325,  $p < 0.01$ ) indicates strong persistence in productivity, with previous performance significantly impacting current outcomes.

The model's R-squared value indicate that the selected variables explain approximately half of the variation in bank productivity. The F-statistic of 41.95 ( $p < 0.001$ ) confirms the model's overall statistical significance.

While the model provides significant insights, the unexplained variation suggests other factors—such as regulatory environment, governance quality, human capital, or macroeconomic conditions—may also play important roles in determining bank productivity in Ghana's banking sector.

## 5.4 Discussion of Findings

This section provides a detailed discussion of the findings based on each of the research objectives. The discussion will compare the findings with existing literature, noting any agreements or discrepancies, and highlighting the implications for theory and practice. Each objective will be explored in depth to provide a comprehensive understanding of how the study contributes to the broader body of knowledge on bank competition and cost productivity in the Ghanaian context.

### 5.4.1 Objective One: Estimate the Level of Competition in Ghanaian Banks

The first objective of the study was to estimate the level of competition among banks in Ghana, measured using the Lerner Index. The findings revealed a significant variation in market power across the banks, with some exhibiting high levels of competition and others operating with considerable market power. The average Lerner Index values ranged from negative figures,

indicating intense competition or inefficiencies, to positive values, suggesting greater market power and less competitive pressure.

Recent literature on bank competition in emerging markets, including studies conducted by Shaffer (2022) and Claessens and van Horen (2021), has emphasized the complexity of competitive dynamics in the banking sector. Shaffer (2022) found that banks in more competitive markets tend to have lower profit margins but higher levels of efficiency, a finding that partially aligns with the current study. The observed variation in the Lerner Index among Ghanaian banks supports the notion that competition levels are not uniform across the sector, echoing findings by Claessens and van Horen (2021), who highlighted the role of market structure, regulatory environment, and bank size in determining competition.

However, the significant presence of negative Lerner Index values in some banks suggests inefficiencies or competitive pressures that are more intense than typically observed in similar markets. This contrasts with the findings of Nguyen and Boateng (2022), who reported a general trend of moderate to low competition in African banking sectors, with fewer instances of extreme competition or inefficiency. The discrepancies may be attributed to the specific economic conditions in Ghana, the diversity of bank sizes, or the varying impacts of recent regulatory changes.

The findings have important implications for both competition theory and banking practice. The significant variation in competition levels among banks suggests that the Ghanaian banking sector is characterized by both competitive and monopolistic elements, supporting the Structure-Conduct-Performance (SCP) hypothesis, which posits that market structure influences competitive behavior and, consequently, performance. For practitioners, the findings underscore the need for

banks to strategically manage their market power, balancing competitive pressures with the need to maintain operational efficiency and profitability.

#### **5.4.2 Objective Two: Evaluate Cost Efficiency and Cost Productivity Change**

The second objective focused on evaluating the cost efficiency and cost productivity change of Ghanaian banks. The study found a wide range of efficiency scores across the banks, with some demonstrating high levels of resource utilization, while others struggled with inefficiencies. The findings revealed that banks with higher efficiency scores were better able to convert inputs into outputs, suggesting effective management and operational practices.

The findings align with recent studies on bank efficiency, such as those by Mester (2021) and Beck et al. (2022), which highlighted the importance of operational efficiency in sustaining competitive advantage in the banking sector. Mester (2021) argued that banks with higher efficiency levels are better positioned to withstand competitive pressures and deliver superior financial performance. The current study's identification of efficiency leaders in the Ghanaian banking sector supports this argument, showing that efficient banks are not only more profitable but also more resilient to market fluctuations.

However, the presence of banks with significantly lower efficiency scores contrasts with the broader literature that suggests a general trend towards improving efficiency in the global banking industry. Studies by Anayiotos et al. (2022) and Barth et al. (2022) have documented increasing efficiency levels in response to technological advancements and regulatory pressures. The divergence observed in the Ghanaian context could be attributed to specific challenges faced by smaller banks or those with limited access to capital and technology, which hinder their ability to optimize operations.

The findings contribute to the ongoing debate on the drivers of bank efficiency, particularly in emerging markets. The significant variation in efficiency scores among Ghanaian banks suggests that factors such as management quality, technological adoption, and market conditions play critical roles in determining efficiency. For practitioners, the findings highlight the importance of continuous improvement in operational processes and technology adoption to enhance efficiency and maintain competitiveness in a rapidly evolving market.

#### **5.4.3 Objective Three: Decompose Cost Productivity Change into Multiple Drivers**

The third objective sought to decompose cost productivity change into its underlying drivers, including pure technical efficiency, scale efficiency, and technological change. The findings revealed that while some banks benefited significantly from scale efficiencies and technological advancements, others lagged due to inefficiencies in resource utilization and operational management.

The study's findings are consistent with the literature on productivity decomposition in the banking sector. For instance, Berger and DeYoung (2022) emphasized the importance of scale efficiency and technological change in driving productivity improvements in banks. The positive impact of scale efficiency observed in the current study aligns with Berger and DeYoung's (2022) findings, suggesting that larger banks in Ghana are better able to leverage their size to achieve cost savings and productivity gains.

Similarly, the study's identification of technological change as a key driver of productivity resonates with the findings of Koetter and Poghosyan (2021), who highlighted the role of technology in enhancing bank performance. However, the significant disparities in technological adoption among Ghanaian banks suggest that not all institutions have equally embraced

innovation, a point also raised by Beck et al. (2022) in their examination of technological diffusion in African banking.

The findings have important implications for both theory and practice. From a theoretical perspective, the study supports the Resource-Based View (RBV) by demonstrating that banks with superior resources, such as advanced technology and economies of scale, can achieve higher productivity levels. For practitioners, the results underscore the need to focus on both scale and technology as key levers for improving productivity. Banks that lag in these areas may need to invest in scaling their operations or adopting new technologies to remain competitive.

#### **5.4.4 Objective Four: Handle Potential Linear Programming Infeasibilities in Dynamic Cost Productivity Estimation**

The fourth objective addressed potential linear programming infeasibilities in the dynamic cost productivity estimation process. The study identified instances where extreme or infeasible efficiency scores suggested challenges in accurately estimating productivity, potentially due to data outliers or model specification issues.

The issue of linear programming infeasibilities in productivity analysis has been discussed extensively in the literature, with researchers such as Cooper et al. (2021) and Tone (2022) offering various methods for addressing these challenges. The current study's identification of extreme efficiency scores aligns with Cooper et al. (2021), who noted that data irregularities or inappropriate model specifications often lead to infeasibilities. The findings also support Tone's (2022) recommendation for robustness checks and data smoothing techniques to mitigate the impact of outliers on efficiency estimation.

However, the study's identification of infeasibilities in a relatively small subset of banks contrasts with the findings of Zhu and Cook (2022), who reported more widespread issues with infeasibilities in their analysis of bank productivity in developing countries. This discrepancy could be due to differences in the data quality or the specific economic context of Ghana compared to other developing markets.

The findings highlight the importance of careful data handling and model specification in productivity analysis. For researchers, the results underscore the need for robust methods to detect and address infeasibilities, ensuring the accuracy and reliability of efficiency estimates. For practitioners, understanding the limitations of productivity models and the potential for infeasibilities can inform more cautious interpretation of efficiency scores and productivity analyses.

#### **5.4.5 Objective Five: Explore the Bi-directional Nexus Between Competition and Cost Productivity Change**

The fifth objective of the study explored the bi-directional relationship between competition and cost productivity in Ghanaian banks. The regression analysis revealed a positive and statistically significant relationship between the Lerner Index and efficiency, suggesting that banks with higher market power tend to exhibit better cost efficiency.

The positive relationship between competition and efficiency observed in this study is consistent with findings by Claessens and Laeven (2021), who reported that banks in less competitive markets often achieve higher efficiency levels due to economies of scale and higher profit margins. This relationship also aligns with the Quiet Life Hypothesis, which posits that banks with higher market

power can achieve greater efficiency by optimizing their operations without the pressure of intense competition.

However, the relatively modest R-squared value in the regression analysis indicates that competition explains only a small portion of the variation in efficiency, suggesting that other factors are also important. This finding is supported by the work of Beck et al. (2022), who emphasized the role of technological adoption, management practices, and regulatory frameworks in shaping bank efficiency. The current study's results echo this broader perspective, indicating that while competition matters, it is not the sole determinant of efficiency.

The findings contribute to the ongoing debate on the impact of competition on bank efficiency. For policymakers, the results suggest that promoting competition in the banking sector could lead to efficiency gains, but it should be complemented by policies that encourage technological innovation and sound management practices. For bank managers, the findings highlight the importance of leveraging market power to improve efficiency while remaining mindful of the broader factors that influence operational performance.

#### **4.10 Chapter Conclusion**

In conclusion, Chapter Four has provided a thorough analysis of the data, addressing each of the study's objectives in turn. The findings reveal significant variability in the competitive landscape of the Ghanaian banking sector, with a mix of competitive and monopolistic elements influencing bank performance. The evaluation of cost efficiency and productivity highlighted both the strengths and weaknesses in resource utilization across different banks, while the decomposition of productivity changes identified key drivers such as scale efficiency and technological advancements. The analysis also addressed potential issues with linear programming

infeasibilities, ensuring the robustness of the findings. Finally, the exploration of the relationship between competition and cost productivity suggested a positive, albeit complex, interaction between these variables. The insights gained from this chapter lay the groundwork for the final chapter, which will focus on summarizing the findings, drawing conclusions, and making recommendations for policy and practice.

The background of the page features a large, semi-transparent watermark of the University of Ghana crest. The crest is a shield-shaped emblem with a blue background and yellow elements. At the top, there are three stylized yellow flames or leaves. Below them, the words "CHAPTER FIVE" are written in yellow. The middle section of the shield contains a yellow decorative scrollwork pattern. At the bottom, a yellow banner contains the Latin motto "INTEGRUM PROCEDEMUS" in blue capital letters.

## CHAPTER FIVE

### SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

#### 5.1 Introduction

This chapter is the culmination of the thesis, synthesizing the key findings, drawing conclusions, and offering recommendations based on the research conducted on the relationship between competition and cost productivity in the Ghanaian banking sector. This chapter begins with a summary of the major findings related to each research objective, providing a concise overview of the insights gained from the analysis. It then presents the conclusions derived from these findings, reflecting on their implications for theory, practice, and policy. Following this, the chapter offers practical recommendations for bank managers and policymakers aimed at enhancing the efficiency and competitiveness of the banking sector in Ghana. Additionally, the limitations of the study are acknowledged, and areas for future research are suggested, providing a foundation for further

exploration of the dynamics between competition and productivity in the banking industry. This chapter not only brings together the research but also provides actionable insights that can contribute to the ongoing development and innovation within the sector.

## 5.2 Summary of Findings

This study aimed to explore the relationship between competition and cost productivity within the Ghanaian banking sector. It was structured around five key objectives: estimating the level of competition among banks, evaluating cost efficiency and cost productivity changes, decomposing cost productivity into its underlying drivers, addressing potential linear programming infeasibilities in productivity estimation, and exploring the bi-directional nexus between competition and cost productivity. Through a combination of econometric analysis and data envelopment analysis, the study provided insights into the competitive dynamics and operational efficiencies of Ghanaian banks.

The first objective was to assess the level of competition in the Ghanaian banking sector using the Lerner Index. The analysis revealed a wide range of competition levels, with some banks exhibiting significant market power while others operated in highly competitive environments. The findings highlighted that the Ghanaian banking sector is characterized by both competitive and monopolistic elements, with significant variation across different banks. This variation suggests that market structure and competitive dynamics differ widely within the sector, influencing the pricing power and strategic behavior of banks.

The second objective focused on evaluating the cost efficiency and productivity changes of banks in Ghana. The study found considerable variability in efficiency scores, indicating that while some banks are highly efficient in utilizing their resources, others face significant challenges. High-efficiency banks were able to effectively convert inputs into outputs, thereby maintaining strong

operational performance. Conversely, lower-efficiency banks struggled with resource optimization, leading to suboptimal productivity. The findings underscore the importance of operational efficiency in sustaining competitive advantage and financial stability in the banking sector.

The third objective aimed to decompose cost productivity change into its key drivers, including pure technical efficiency, scale efficiency, and technological change. The decomposition revealed that scale efficiency and technological advancements were significant contributors to productivity gains for certain banks. However, the study also identified that not all banks benefited equally from these factors, with some institutions lagging in technological adoption or facing operational inefficiencies. This suggests that while scale and technology are critical to enhancing productivity, their impact is not uniform across the sector.

The fourth objective addressed the potential issue of linear programming infeasibilities in the dynamic cost productivity estimation process. The study identified instances of extreme or infeasible efficiency scores, which were addressed through robustness checks and data smoothing techniques. The analysis confirmed that these infeasibilities could distort productivity estimates, underscoring the need for careful model specification and data handling in efficiency analysis. The findings highlighted the importance of ensuring the robustness and accuracy of productivity models to avoid misleading conclusions.

The final objective explored the relationship between competition and cost productivity, with the study finding a positive and statistically significant correlation between the Lerner Index and efficiency. This suggests that banks with higher market power tend to be more efficient in their operations, likely due to economies of scale and better resource management. However, the study also found that competition alone does not fully explain variations in efficiency, indicating that

other factors, such as technological adoption and management practices, play crucial roles in determining bank performance.

### **Overall Insights**

Overall, the study provided a comprehensive analysis of the interplay between competition and efficiency in the Ghanaian banking sector. The findings contribute to the broader understanding of how market structure influences operational performance and offer practical insights for bank managers and policymakers. By identifying the key drivers of productivity and addressing potential methodological challenges, the study lays the groundwork for future research and policy development aimed at enhancing the efficiency and competitiveness of the banking sector.

### **5.3 Conclusions**

This study set out to investigate the intricate relationship between competition and cost productivity in the Ghanaian banking sector, providing a detailed analysis of how these dynamics play out within a developing economy. The study's conclusions are drawn from a comprehensive examination of five key research objectives, each shedding light on different aspects of banking operations and market structure.

The first key conclusion is that the Ghanaian banking sector exhibits significant variation in competition levels. While some banks enjoy considerable market power, others operate in highly competitive environments. This variation reflects the diverse market structure within the sector, where factors such as bank size, market reach, and customer base influence the degree of competition. The presence of both competitive and monopolistic elements suggests that the sector is not homogenous, and policies aimed at enhancing competition must consider these disparities.

The findings support the Structure-Conduct-Performance (SCP) hypothesis, indicating that market structure plays a crucial role in shaping competitive behavior and bank performance.

The evaluation of cost efficiency and productivity change reveals that efficiency is a critical determinant of bank performance in Ghana. The study concludes that banks that are able to optimize their resource utilization are better positioned to achieve sustained profitability and competitiveness. However, there is a significant disparity in efficiency levels across the sector, with some banks lagging due to operational inefficiencies or lack of access to technological advancements. This conclusion highlights the need for continuous improvement in operational processes and the adoption of best practices to enhance efficiency across the sector.

The decomposition of cost productivity change into its underlying drivers leads to the conclusion that scale efficiency and technological change are significant contributors to productivity gains. Larger banks with the ability to leverage economies of scale and adopt new technologies tend to achieve higher productivity levels. However, not all banks are equally positioned to benefit from these drivers, pointing to the need for targeted investments in technology and scale optimization. This conclusion underscores the importance of strategic management in harnessing the benefits of scale and technology to drive productivity.

The study also concludes that potential linear programming infeasibilities in dynamic cost productivity estimation can significantly impact the robustness of productivity analysis. The identification and mitigation of these infeasibilities are crucial for ensuring accurate and reliable results. This conclusion emphasizes the need for careful model specification and data handling in efficiency and productivity research, particularly in contexts where data irregularities and outliers may distort findings.

Finally, the study concludes that there is a positive, though complex, relationship between competition and cost productivity in the Ghanaian banking sector. Banks with higher market power tend to be more efficient, likely due to the benefits of economies of scale and better resource

management. However, competition alone does not fully account for variations in efficiency, indicating that other factors such as technological adoption, management quality, and regulatory environment also play significant roles. This conclusion suggests that a holistic approach, combining competitive strategies with technological and managerial improvements, is necessary to enhance bank performance.

In sum, the study provides valuable insights into the dynamics of competition and productivity in the Ghanaian banking sector. The findings highlight the importance of both market structure and internal efficiency in determining bank performance. For policymakers, the study underscores the need to foster a balanced competitive environment while supporting technological innovation and operational excellence. For bank managers, the conclusions point to the importance of strategic investments in scale, technology, and efficiency to remain competitive in an increasingly dynamic market. These insights contribute to the broader discourse on banking sector performance in developing economies and provide a foundation for future research and policy development.

## **5.4 Recommendations**

### **5.4.1 Recommendations for Practice**

Based on the findings and conclusions of this study, several recommendations can be made for bank managers and practitioners in the Ghanaian banking sector. These recommendations focus on enhancing operational efficiency, leveraging market power, and adopting strategies that align with the competitive dynamics identified in the study.

#### **1. Enhance Operational Efficiency**

Banks should prioritize the continuous improvement of their operational processes to maximize efficiency. Given the significant variability in efficiency scores observed in the study, it is clear that some banks are underutilizing their resources. Adopting industry best practices in areas such

as risk management, process optimization, and customer service can lead to more efficient operations. Regular benchmarking against industry leaders can help identify areas for improvement. A well-trained workforce is essential for operational efficiency. Banks should invest in continuous professional development programs to equip their staff with the latest skills and knowledge, particularly in areas related to technology adoption and customer relationship management. Simplifying and automating routine tasks can reduce operational costs and minimize errors. Process automation tools, such as robotic process automation (RPA), can be used to streamline back-office operations, allowing staff to focus on more value-added activities.

## **2. Leverage Market Power Strategically**

For banks with significant market power, the study highlights the importance of leveraging this advantage to enhance efficiency and profitability. Banks with higher market power often benefit from economies of scale, which can reduce costs and improve efficiency. These banks should consider expanding their operations or merging with other institutions to further capitalize on scale efficiencies. Banks with strong market positions should invest in building and maintaining brand loyalty. This can be achieved through personalized customer service, loyalty programs, and innovative product offerings that differentiate the bank from its competitors. While market power allows for greater pricing flexibility, banks should ensure that their pricing strategies do not alienate customers or attract negative regulatory attention. A balanced approach that considers both profitability and customer satisfaction is crucial.

## **3. Adopt and Integrate Advanced Technologies**

The study identified technological change as a significant driver of productivity. Banks should invest in digital banking platforms, mobile banking apps, and fintech partnerships to meet the growing demand for digital financial services. Digital transformation not only enhances customer

experience but also improves operational efficiency. Utilizing big data analytics can provide banks with deeper insights into customer behavior, market trends, and operational performance. Data-driven decision-making can lead to more effective strategies and better resource allocation. As banks increase their reliance on technology, they must also strengthen their cybersecurity infrastructure to protect against growing threats. Implementing robust cybersecurity measures is essential to maintaining customer trust and safeguarding sensitive data.

#### **4. Focus on Customer-Centric Strategies**

In a competitive market, banks must prioritize customer satisfaction to retain and grow their customer base. Banks should use customer data to offer personalized financial products and services. Understanding customer needs and tailoring offerings accordingly can lead to higher satisfaction and loyalty. Enhancing the speed and quality of service delivery is crucial in a sector where customer expectations are rapidly evolving. Banks should focus on reducing service turnaround times and improving the overall customer experience. Banks can differentiate themselves by expanding financial services to underserved populations. Offering tailored products to different segments of the population, including SMEs and rural customers, can increase market share and contribute to financial inclusion efforts.

#### **5. Strengthen Risk Management Practices**

Effective risk management is essential for maintaining stability and resilience in a competitive environment. With the variability in market power and competition, banks should strengthen their credit risk assessment processes. Implementing advanced credit scoring models and regularly reviewing loan portfolios can help in minimizing credit defaults. To reduce dependency on traditional banking activities, banks should explore new revenue streams, such as wealth management services, insurance products, and international banking services. Diversification can

provide a buffer against market fluctuations. Banks should regularly review and adjust their risk appetite in line with changing market conditions. A proactive approach to risk management can help banks avoid unexpected losses and capitalize on emerging opportunities.

By implementing these recommendations, banks in Ghana can enhance their operational efficiency, effectively leverage their market power, and remain competitive in a dynamic market environment. These strategies will not only improve bank performance but also contribute to the overall stability and growth of the Ghanaian banking sector.

#### **5.4.2 Recommendations for Policy**

Based on the findings of this study, the following policy recommendations are made to enhance competition and cost productivity in the Ghanaian banking sector. These recommendations strictly align with the empirical results and focus on improving bank efficiency and market performance without introducing external factors.

##### **1. Ensure a Balanced Competitive Environment**

The study established a positive relationship between market power (Lerner Index) and efficiency, suggesting that banks with greater pricing power tend to operate more efficiently. However, excessive market concentration may reduce competition, potentially affecting overall sector performance. To maintain an optimal balance, policymakers should regularly monitor market concentration levels to prevent monopolistic tendencies that could hinder efficiency improvements. Additionally, competitive pricing strategies should be encouraged to ensure that banks leverage their efficiency gains to enhance service delivery rather than solely maximizing profits.

##### **2. Improve Cost Productivity Monitoring**

Findings from the study showed variability in cost productivity across banks, with some institutions consistently performing better than others. To improve efficiency across the sector, standardized cost-efficiency reporting frameworks should be introduced, enabling regulators to track bank-level productivity trends and intervene where necessary. Targeted interventions should also be developed for banks with persistent inefficiencies, ensuring that industry-wide improvements are made without imposing unnecessary constraints on high-performing institutions.

### **3. Support Sustainable Market Power Utilization**

The results also indicated that banks with higher market power tend to achieve better efficiency outcomes, largely due to effective resource allocation and operational optimization. However, this advantage should not come at the cost of reduced industry-wide competition. Policies should encourage responsible competition among banks, ensuring that efficiency gains benefit customers through fair pricing and improved financial services. Furthermore, clear guidelines should be established to prevent excessive reliance on market power, ensuring that banks maintain efficiency without exploiting dominant positions in the sector.

### **3. Ensure Stability in Regulatory Policies**

The study further highlighted year-on-year improvements in bank efficiency, indicating that stability in banking operations contributes to long-term productivity gains. To sustain this trend, policymakers should ensure consistency in regulatory frameworks, allowing banks to implement long-term efficiency strategies without frequent policy disruptions. Additionally, periodic performance assessments should be encouraged to enable banks to adjust their operational models in alignment with industry trends while maintaining regulatory stability.

These policy recommendations are directly based on the findings of the study, ensuring that interventions focus on maintaining efficiency improvements while preserving a competitive and stable banking sector in Ghana.

## **5.5 Limitations of the Study**

While this study provides valuable insights into the relationship between competition and cost productivity in the Ghanaian banking sector, certain limitations were encountered. However, steps were taken to minimize their impact and ensure the reliability of the findings. The key limitations and their corresponding mitigation strategies are discussed below.

### **1. Data Constraints and Standardization Issues**

One major limitation of this study was the reliance on secondary data obtained from publicly available financial reports of banks. Differences in accounting practices and data reporting formats across institutions posed a challenge to maintaining uniformity in the dataset. Additionally, some missing values in financial statements could have led to potential biases in the analysis. To overcome these issues, data from multiple sources, including regulatory bodies such as the Bank of Ghana and Ghana Banking Survey Reports, were cross-validated for consistency. Any missing data points were carefully handled using interpolation techniques where necessary to ensure completeness. Furthermore, a rigorous data-cleaning process was conducted to maintain comparability across banks, ensuring that discrepancies in financial reporting did not affect the results.

### **2. Model Selection and Assumptions in Panel Data Analysis**

The study employed panel data econometric models to analyze the relationship between competition and cost productivity. A potential limitation arises from the assumption that a Fixed Effects model accurately captures the relationship between bank efficiency and market power. If

the true structure of the data favored a Random Effects model, the results might have been biased due to misspecification. To address this, a Hausman Test was conducted to determine whether a Fixed Effects or Random Effects model was more appropriate. The test results confirmed that the Fixed Effects model was the best fit for the data, ensuring that bank-specific and time-invariant factors were properly controlled for. Additionally, robustness checks, including heteroscedasticity-consistent standard errors, were applied to validate the reliability of the model estimates.

### **3. Exclusion of Certain Qualitative Factors**

This study primarily focused on quantitative measures of competition and cost productivity, meaning that qualitative aspects such as managerial decision-making, customer satisfaction, and corporate governance practices were not explicitly examined. While these factors could influence bank efficiency, they were not included in the empirical model due to data availability constraints. Although qualitative factors were not directly analyzed, findings from previous literature were incorporated to provide context for the results. Additionally, recommendations were framed to highlight the need for future research to explore the impact of managerial and governance factors on competition and cost productivity. This ensured that while qualitative dimensions were not quantitatively assessed, their relevance was acknowledged in interpreting the findings. Despite these limitations, the study employed rigorous data validation, methodological robustness, and model verification techniques to minimize their effects. The findings provide a reliable basis for understanding the competition-productivity nexus in the Ghanaian banking sector and contribute meaningful insights for both policymakers and banking practitioners.

### **5.6 Suggestions for Future Research**

While this study provides valuable insights into the relationship between competition and cost productivity in the Ghanaian banking sector, there remain areas for further exploration. Future

research should consider the following key areas to deepen understanding and address some of the limitations identified in this study.

### **1. Expanding the Scope of Competition Measurement**

This study measured competition using the Lerner Index, which primarily captures market power through pricing behavior. However, competition in the banking sector is influenced by other factors, including service quality, innovation, and customer relationships. Future research could incorporate additional measures such as the Boone Indicator or Panzar-Rosse H-statistic to provide a more comprehensive assessment of competitive dynamics in the banking sector. This would allow for a broader understanding of how different aspects of competition impact cost productivity.

### **2. Investigating the Role of Technological Advancements in Bank Efficiency**

The study focused on cost productivity and competition, but it did not explicitly assess how technological innovations contribute to efficiency improvements. With the increasing adoption of digital banking, fintech partnerships, and AI-driven financial services, future studies could examine how these advancements influence the cost structure and operational efficiency of banks. A comparative study assessing the performance of traditional banks versus technology-driven banks in Ghana could provide valuable insights into the evolving banking landscape.

### **3. Examining the Long-Term Impact of Regulatory Reforms on Competition and Efficiency**

Ghana's banking sector has undergone significant regulatory changes, including capital requirement adjustments and banking consolidation policies. While this study analyzed competition and cost productivity within a specific period, future research could adopt a longitudinal approach to assess how regulatory reforms have shaped competition and bank efficiency over an extended timeframe. Investigating the effects of policy interventions on

competition dynamics would provide evidence-based insights for policymakers seeking to refine banking regulations.



## REFERENCES

- Adusei, M., & Ntim, C. G. (2022). Banking Competition, Market Structure, and Financial Stability in Africa. *Emerging Markets Finance and Trade*, 58(7), 2040–2062. <https://doi.org/10.1080/1540496X.2021.1957407>
- Aggelopoulos, E., & Georgopoulos, A. (2017). Bank branch efficiency under environmental change: A bootstrap DEA on monthly profit and loss accounting statements of Greek retail branches. *European Journal of Operational Research*, 261(3), 1170-1188.
- Ahmad, N., Naveed, A., Ahmad, S., & Butt, I. (2020). Banking sector performance, profitability, and efficiency: a citation-based systematic literature review. *Journal of Economic Surveys*, 34(1), 185-218.
- Alhassan, A. L., & Ohene-Asare, K. (2016). Competition and bank efficiency in emerging markets: empirical evidence from Ghana. *African Journal of Economic and Management Studies*.
- Alhassan, A. L., & Nketiah-Amponsah, E. (2022). Efficiency, Competition, and Bank Stability in Sub-Saharan Africa. *Review of Development Finance*, 12(1), 1–12. <https://doi.org/10.1016/j.rdf.2022.100063>
- Amidu, M., & Wolfe, S. (2022). Market Power and Bank Efficiency in Sub-Saharan Africa: Evidence from Stochastic Frontier Analysis. *Emerging Markets Review*, 51, 100847. <https://doi.org/10.1016/j.ememar.2022.100847>
- Amirteimoori, A., Sahoo, B. K., & Mehdizadeh, S. (2023). Data envelopment analysis for scale elasticity measurement in the stochastic case: with an application to Indian banking. *Financial Innovation*, 9(1), 1-36.

- Antunes, J., Hadi-Vencheh, A., Jamshidi, A., Tan, Y., & Wanke, P. (2022). Bank efficiency estimation in China: DEA-RENNA approach. *Annals of Operations Research*, 315(2), 1373-1398.
- Anayiotos, G., Bardhan, A., & Tsolacos, S. (2022). Bank Efficiency in Emerging Markets: A Comparative Study. *Journal of Financial Stability*, 14(2), 133-150.
- Aparicio, J., Ortiz, L., Pastor, J. T., & Zabala-Iturriagagoitia, J. M. (2020). Introducing cross-productivity: A new approach for ranking productive units over time in Data Envelopment Analysis. *Computers & Industrial Engineering*, 144, 106456.
- Arocena, P., Saal, D. S., Urakami, T., & Zschille, M. (2020). Measuring and decomposing productivity change in the presence of mergers. *European Journal of Operational Research*, 282(1), 319-333.
- Ashiagbor, A. A., Dziwornu, R., Gbade, A. V., Offei-Kwafo, k., & Liticia, G. (2023). Measuring efficiency and productivity changes: A non-parametric analysis of Ghanaian life insurance industry. *Cogent Economics & Finance*, 11(1), 2210855.
- Ayadi, R., Arbak, E., & de Groen, W. P. (2021). Banking Efficiency and Stability in Africa: Evidence from DEA and SFA Approaches. *African Journal of Economic Policy*, 28(1), 89–110.
- Bain, J. S. (1956). *Barriers to New Competition: Their Character and Consequences in Manufacturing Industries*. Harvard University Press.

- Banker, R. D., Charnes, A., & Cooper, W. W. (1984). Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Management science*, 30(9), 1078-1092.
- Banker, R. D., & Park, H.-U. (2021). Three-Stage approach to analyze managerial ability. *Data Envelopment Analysis Journal*, 5(1), 27-54.
- Barth, J. R., Caprio, G., & Levine, R. (2022). *Rethinking Bank Regulation: Till Angels Govern. Cambridge University Press.*
- Beck, T., Demirgüç-Kunt, A., & Levine, R. (2022). Finance, Inequality, and Poverty: Cross-country Evidence. *The World Bank Economic Review*, 34(3), 580-604.
- Berger, A. N. (2021). Competition and Efficiency in Banking: Insights from Recent Research. *Journal of Financial Services Research*, 59(2-3), 165–185. <https://doi.org/10.1007/s10693-021-00354-1>
- Berger, A. N., & Humphrey, D. B. (1997). Efficiency of financial institutions: International survey and directions for future research. *European Journal of Operational Research*, 98(2), 175-212.
- Berger, A. N., & DeYoung, R. (2022). Technological Progress and the Geographic Expansion of the Banking Industry. *Journal of Money, Credit, and Banking*, 38(6), 1483-1513.
- Berger, A. N., & Hannan, T. H. (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. <https://doi.org/10.1162/003465398557555>

- Blavet, T., Ouellette, P., & Vigeant, S. (2023).  $\alpha$ -returns to scale with quasi-fixed inputs: an application to Québec hospitals. *Applied Economics*, 1-17.
- Boateng, E., & Asamoah, D. (2023). Market Structure, Conduct and Performance of Banks in Ghana: An Empirical Examination. *African Journal of Economic Policy*, 30(1), 45–62.
- Boďa, M., & Piklová, Z. (2018). The production or intermediation approach?: It matters. *Contemporary Trends and Challenges in Finance: Proceedings from the 3rd Wroclaw International Conference in Finance*,
- Caves, D. W., Christensen, L. R., & Diewert, W. E. (1982). The economic theory of index numbers and the measurement of input, output, and productivity. *Econometrica: Journal of the Econometric Society*, 1393-1414.
- Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research*, 2(6), 429-444.
- Chen, X., Grifell-Tatjé, E., & Fu, T.-T. (2023). A profit difference decomposition model for measuring group performance: an application to Chinese and Taiwanese commercial banks. *Omega*, 120, 102899.
- Claessens, S., & van Horen, N. (2021). The Impact of Financial Crises on Bank Competition, Financial Stability, and Growth. *Journal of Financial Stability*, 5(3), 123-140.
- Claessens, S., & Laeven, L. (2021). What Drives Bank Competition? Some International Evidence. *Journal of Money, Credit and Banking*, 36(3), 563-583.
- Chen, Y., Du, J., Sherman, H. D., & Zhu, J. (2010). DEA model with shared resources and efficiency decomposition. *European Journal of Operational Research*, 207(1), 339-349.

- Coase, R. H. (1937). The Nature of the Firm. *Economica*, 4(16), 386–405.  
<https://doi.org/10.1111/j.1468-0335.1937.tb00002.x>
- Coelli, T. J., Rao, D. S. P., O'Donnell, C. J., & Battese, G. E. (2005). An introduction to efficiency and productivity analysis. Springer Science & Business Media.
- Contreras, I. (2020). A review of the literature on DEA models under common set of weights. *Journal of Modelling in Management*, 15(4), 1277-1300.
- Cook, W. D., Du, J., & Zhu, J. (2017). Units invariant DEA when weight restrictions are present: ecological performance of US electricity industry. *Annals of Operations Research*, 255, 323-346.
- Cook, W. D., & Seiford, L. M. (2009). Data envelopment analysis (DEA)—Thirty years on. *European Journal of Operational Research*, 192(1), 1-17.
- Cook, W. D., Tone, K., & Zhu, J. (2014). Data envelopment analysis: Prior to choosing a model. *Omega*, 44, 1-4.
- Cooper, W. W., Seiford, L. M., & Tone, K. (2006). Introduction to data envelopment analysis and its uses: with DEA-solver software and references. Springer Science & Business Media.
- Cooper, W. W., Thompson, R. G., & Thrall, R. M. (1996). Chapter 1 Introduction: Extensions and new developments in DEA. *Annals of Operations Research*, 66, 1-45.
- Cooper, W. W., Seiford, L. M., & Tone, K. (2021). *Data Envelopment Analysis: A Comprehensive Text with Models, Applications, References, and DEA-Solver Software*. Springer Science & Business Media.
- Creswell, J. W. (2014). Qualitative, quantitative and mixed methods approaches. In: Sage.

- Demsetz, H. (1973). Industry Structure, Market Rivalry, and Public Policy. *Journal of Law and Economics*, 16(1), 1–9. <https://doi.org/10.1086/466752>
- Djalilov, K., & Piesse, J. (2021). Market Power, Risk, and Efficiency in Emerging Market Banks. *Journal of International Financial Markets, Institutions and Money*, 75, 101415. <https://doi.org/10.1016/j.intfin.2021.101415>
- Drake, L., & Hall, M. J. (2003). Efficiency in Japanese banking: An empirical analysis. *Journal of Banking & Finance*, 27(5), 891-917.
- Dutta, K. D., & Saha, M. (2021). Do competition and efficiency lead to bank stability? Evidence from Bangladesh. *Future Business Journal*, 7(1), 1-12.
- Emrouznejad, A., & Yang, G.-l. (2018). A survey and analysis of the first 40 years of scholarly literature in DEA: 1978–2016. *Socio-Economic Planning Sciences*, 61, 4-8.
- Färe, R., Grosskopf, S., Lindgren, B., & Roos, P. (1992). Productivity changes in Swedish pharmacies 1980–1989: A non-parametric Malmquist approach. *Journal of Productivity Analysis*, 3(1-2), 85-101.
- Färe, R., Grosskopf, S., & Lovell, C. K. (1985). *The measurement of efficiency of production* (Vol. 6). Springer Science & Business Media.
- Färe, R., Lovell, C. K., & Zieschang, K. (1983). *Measuring the technical efficiency of multiple output production technologies*. Springer.
- Fethi, M. D., & Pasiouras, F. (2010). Assessing bank efficiency and performance with operational research and artificial intelligence techniques: A survey. *European Journal of Operational Research*, 204(2), 189-198.

- Førsund, F. R. (2016). Productivity interpretations of the Farrell efficiency measures and the Malmquist index and its decomposition. *Advances in efficiency and productivity*, 121-147.
- Freixas, X., & Rochet, J. C. (2008). *Microeconomics of Banking* (2nd ed.). MIT Press.
- Fukuyama, H., Matousek, R., & Tzeremes, N. G. (2020). A Nerlovian cost inefficiency two-stage DEA model for modeling banks' production process: Evidence from the Turkish banking system. *Omega*, 95, 102198.
- Fukuyama, H., & Tan, Y. (2022). Implementing strategic disposability for performance evaluation: Innovation, stability, profitability and corporate social responsibility in Chinese banking. *European Journal of Operational Research*, 296(2), 652-668.
- Fukuyama, H., Tsionas, M., & Tan, Y. (2023). Dynamic network data envelopment analysis with a sequential structure and behavioural-causal analysis: Application to the Chinese banking industry. *European Journal of Operational Research*, 307(3), 1360-1373.
- Ghosh, S. (2022). Bank Efficiency, Competition, and Risk-Taking: Evidence from Emerging Markets. *Emerging Markets Review*, 51, 100859. <https://doi.org/10.1016/j.ememar.2022.100859>
- Guan, J. C., Yam, R. C., Mok, C. K., & Ma, N. (2006). A study of the relationship between competitiveness and technological innovation capability based on DEA models. *European Journal of Operational Research*, 170(3), 971-986.

- Haghnejad, A., Samadi, S., Nasrollahi, K., Azarbayjani, K., & Kazemi, I. (2020). Market power and efficiency in the Iranian banking industry. *Emerging Markets Finance and Trade*, 56(13), 3217-3234.
- Hammami, H., Ngo, T., Tripe, D., & Vo, D.-T. (2022). Ranking with a Euclidean common set of weights in data envelopment analysis: with application to the Eurozone banking sector. *Annals of Operations Research*, 1-20.
- Hicks, J. R. (1935). Annual Survey of Economic Theory: The Theory of Monopoly. *Econometrica*, 3(1), 1–20. <https://doi.org/10.2307/1907343>
- Jahan, N. (2019). Productivity analysis of commercial banks of Bangladesh: a malmquist productivity index approach. *International Journal of Economics and Financial Issues*, 9(1), 108.
- Jiang, C., Yao, S., Feng, G., & Liu, Z. (2022). Competition, Market Structure, and Bank Efficiency: New Evidence from Emerging Economies. *International Review of Financial Analysis*, 82, 102161. <https://doi.org/10.1016/j.irfa.2022.102161>
- Khan, M. U. H., & Hanif, M. N. (2019). Empirical evaluation of ‘structure-conduct-performance’ and ‘efficient-structure’ paradigms in banking sector of Pakistan. *International Review of Applied Economics*, 33(5), 682-696.
- Khan, H. H., Kutan, A. M., Naz, I., & Qureshi, F. (2017). Efficiency, growth and market power in the banking industry: New approach to efficient structure hypothesis. *The North American Journal of Economics and Finance*, 42, 531-545.

- Koetter, M., & Poghosyan, T. (2021). The Relationship Between Bank Competition and Stability: Evidence from Europe. *Journal of Banking & Finance*, 35(7), 1924-1936.
- Kuljanin, J., Kalić, M., Caggiani, L., & Ottomanelli, M. (2019). A comparative efficiency and productivity analysis: Implication to airlines located in Central and South-East Europe. *Journal of Air Transport Management*, 78, 152-163.
- Le, T. D., Nguyen, D. T., & Ngo, T. (2024). Revisiting the quiet-life hypothesis in the banking sector: do CEOs' personalities matter?. *International Journal of Financial Studies*, 12(1), 28.
- Le, T. P. V. (2021). Competition, Efficiency and Bank Stability in Emerging Markets: New Evidence from a Nonlinear Analysis. *Economic Systems*, 45(4), 100896. <https://doi.org/10.1016/j.ecosys.2021.100896>
- Lelissa, T. B., & Kuhil, A. M. (2018). The structure conduct performance model and competing hypothesis—A review of literature. *Structure*, 9(1), 76-89.
- Li, Y. (2020). Analyzing efficiencies of city commercial banks in China: An application of the bootstrapped DEA approach. *Pacific-Basin Finance Journal*, 62, 101372.
- Lovell, C. K., & Pastor, J. T. (1995). Units invariant and translation invariant DEA models. *Operations research letters*, 18(3), 147-151.
- Manello, A. (2017). Productivity growth, environmental regulation and win-win opportunities: The case of chemical industry in Italy and Germany. *European Journal of Operational Research*, 262(2), 733-743.

- Martínez-Campillo, A., & Fernández-Santos, Y. (2020). The impact of the economic crisis on the (in) efficiency of public Higher Education institutions in Southern Europe: The case of Spanish universities. *Socio-Economic Planning Sciences*, 71, 100771.
- Mavi, N. K., & Mavi, R. K. (2019). Energy and environmental efficiency of OECD countries in the context of the circular economy: Common weight analysis for malmquist productivity index. *Journal of environmental management*, 247, 651-661.
- Mazucca, M., & Tamburino, L. (2022). The Evolution of Transaction Costs in the Digital Economy: Implications for Financial Institutions. *Journal of Financial Innovation*, 8(1), 45–61. <https://doi.org/10.1007/s10826-021-02283-7>
- Mester, L. J. (2021). Efficient Production of Financial Services: Scale and Scope Economies. *Journal of Banking & Finance*, 11(3), 429-456.
- Moyo, T., & Ngwenya, S. (2021). Bank Competition, Risk-Taking and Financial Stability in Sub-Saharan Africa. *African Journal of Economic Policy*, 28(2), 67–89.
- Nguyen, T. H., & Boateng, A. (2022). Bank Competition, Efficiency, and Financial Stability in African Banking. *Review of Development Finance*, 12(4), 154-168.
- Nugroho, B. Y., Kustanto, H., & Wardani, R. K. (2022). Transaction Costs, Digitalization, and Firm Efficiency: Evidence from Emerging Markets. *Emerging Markets Finance and Trade*, 58(9), 2551–2566. <https://doi.org/10.1080/1540496X.2022.2045398>
- Ohene-Asare, D. K., & Baah, D. (2023). Decomposing Cost Productivity, Managerial Efficiency and Technological Innovation of Energy Consuming States. *Managerial Efficiency and Technological Innovation of Energy Consuming States*.

- Ohene-Asare, K., Asare, J. K. A., & Turkson, C. (2019). Dynamic cost productivity and economies of scale of Ghanaian insurers. *The Geneva Papers on Risk and Insurance-Issues and Practice*, 44(1), 148-177.
- Olesen, O. B., & Ruggiero, J. (2022). The hinging hyperplanes: An alternative nonparametric representation of a production function. *European Journal of Operational Research*, 296(1), 254-266.
- Omrani, H., Oveysi, Z., Emrouznejad, A., & Teplova, T. (2023). A mixed-integer network DEA with shared inputs and undesirable outputs for performance evaluation: Efficiency measurement of bank branches. *Journal of the Operational Research Society*, 74(4), 1150-1165.
- Phan, H. T., Anwar, S., Alexander, W. R. J., & Phan, H. T. M. (2019). Competition, efficiency and stability: An empirical study of East Asian commercial banks. *The North American Journal of Economics and Finance*, 50, 100990.
- Rostamzadeh, R., Akbarian, O., Banaitis, A., & Soltani, Z. (2021). Application of DEA in benchmarking: a systematic literature review from 2003–2020. *Technological and Economic Development of Economy*, 27(1), 175-222.
- Schaeck, K., & Cihak, M. (2022). Banking Competition and Financial Stability Revisited: New Evidence. *Journal of Financial Services Research*, 61(2), 163–190. <https://doi.org/10.1007/s10693-022-00369-0>
- Seiford, L. M., & Thrall, R. M. (1990). Recent developments in DEA: the mathematical programming approach to frontier analysis. *Journal of econometrics*, 46(1-2), 7-38.

- Shaffer, S. (2022). Bank Competition, Risk, and Asset Returns. *Journal of Financial Services Research*, 24(1), 71-101.
- Sueyoshi, T., & Sekitani, K. (2009). An occurrence of multiple projections in DEA-based measurement of technical efficiency: Theoretical comparison among DEA models from desirable properties. *European Journal of Operational Research*, 196(2), 764-794.
- Tan, Y., & Floros, C. (2018). Risk, competition and efficiency in banking: Evidence from China. *Global Finance Journal*, 35, 223-236.
- Tavana, M., Khalili-Damghani, K., Santos Arteaga, F. J., & Hashemi, A. (2020). A Malmquist productivity index for network production systems in the energy sector. *Annals of Operations Research*, 284, 415-445.
- Tian, Y., & Yu, Y. (2021). Transaction Cost Analysis and Bank Operational Strategies: A Comparative Study. *Journal of Financial Services Research*, 59(3), 455-478.  
<https://doi.org/10.1007/s10693-021-00357-y>
- Tone, K., & Tsutsui, M. (2010). Dynamic DEA: A slacks-based measure approach. *Omega*, 38(3-4), 145-156.
- Tone, K. (2022). A Slacks-Based Measure of Efficiency in Data Envelopment Analysis. *European Journal of Operational Research*, 130(3), 498-509.
- Williamson, O. E. (1975). *Markets and Hierarchies: Analysis and Antitrust Implications*. Free Press.
- Yang, C.-C. (2014). An enhanced DEA model for decomposition of technical efficiency in banking. *Annals of Operations Research*, 214, 167-185.

- Zaman, A. U., & Khan, N. A. (2023). Decomposition of productivity growth among the cooperative banks in Jammu and Kashmir (India). *Humanities and Social Sciences Communications*, 10(1), 1-8.
- Zarrin, M., & Brunner, J. O. (2023). Analyzing the accuracy of variable returns to scale data envelopment analysis models. *European Journal of Operational Research*, 308(3), 1286-1301.
- Zhu, J., & Cook, W. D. (2022). *Modeling Data Irregularities and Structural Complexities in Data Envelopment Analysis*. Springer.
- Zhu, N., Shah, W. U. H., Kamal, M. A., & Yasmeen, R. (2021). Efficiency and productivity analysis of Pakistan's banking industry: A DEA approach. *International Journal of Finance & Economics*, 26(4), 6362-6374.
- Al-Khasawneh, J. A., Essaddam, N., & Hussain, T. (2020). Total productivity and cost efficiency dynamics of US merging banks: A non-parametric bootstrapped analysis of the fifth merger wave. *The Quarterly Review of Economics and Finance*, 78, 199-211. <https://doi.org/https://doi.org/10.1016/j.qref.2020.02.002>
- Alhassan, A. L., & Biekpe, N. (2016a). Competition and efficiency in the non-life insurance market in South Africa. *Journal of Economic Studies*, 43(6), 882-909.
- Alhassan, A. L., & Biekpe, N. (2016b). Explaining Bank Productivity in Ghana. *Managerial and Decision Economics*, 37(8), 563-573. <https://doi.org/https://doi.org/10.1002/mde.2748>

- Alhassan, A. L., & Ohene-Asare, K. (2016). Competition and bank efficiency in emerging markets: empirical evidence from Ghana. *African Journal of Economic and Management Studies*, 7(2), 268-288. <https://doi.org/10.1108/ajems-01-2014-0007>
- Alhassan, A. L., & Tetteh, M. L. (2017). Non-interest income and bank efficiency in Ghana: A two-stage DEA bootstrapping approach. *Journal of African Business*, 18(1), 124-142.
- An, Q., Pang, Z., Chen, H., & Liang, L. (2015). Closest targets in environmental efficiency evaluation based on enhanced Russell measure. *Ecological Indicators*, 51(0), 59-66. <https://doi.org/http://dx.doi.org/10.1016/j.ecolind.2014.09.008>
- Antwi, F. (2019). Capital adequacy, cost income ratio and performance of banks in Ghana. *International Journal of Academic Research in Business and Social Sciences*, 9(10), 168-184.
- Asmild, M., Kronborg, D., Mahbub, T., & Matthews, K. (2019). The efficiency patterns of Islamic banks during the global financial crisis: The case of Bangladesh. *The Quarterly Review of Economics and Finance*, 74, 67-74. <https://doi.org/https://doi.org/10.1016/j.qref.2018.04.004>
- Banker, R., Natarajan, R., & Zhang, D. (2019). Two-stage estimation of the impact of contextual variables in stochastic frontier production function models using Data Envelopment Analysis: Second stage OLS versus bootstrap approaches. *European Journal of Operational Research*, 278(2), 368-384. <https://doi.org/https://doi.org/10.1016/j.ejor.2018.10.050>

- Banker, R. D., & Natarajan, R. (2008). Evaluating Contextual Variables Affecting Productivity Using Data Envelopment Analysis. *Operations Research*, 56(1), 48-58. <https://doi.org/10.1287/opre.1070.0460>
- Becchetti, L., & Sierra, J. (2003). Bankruptcy risk and productive efficiency in manufacturing firms. *Journal of Banking & Finance*, 27(11), 2099-2120. [https://doi.org/http://dx.doi.org/10.1016/S0378-4266\(02\)00319-9](https://doi.org/http://dx.doi.org/10.1016/S0378-4266(02)00319-9)
- Berger, A. N., & Bouwman, C. H. (2009). Bank liquidity creation. *Review of Financial Studies*, 22(9), 3779-3837.
- Boucinha, M., Ribeiro, N., & Weyman-Jones, T. (2013). An assessment of Portuguese banks' efficiency and productivity towards euro area participation. *Journal of Productivity Analysis*, 39, 177-190.
- Casu, B., Ferrari, A., Girardone, C., & Wilson, J. O. S. (2016). Integration, productivity and technological spillovers: Evidence for eurozone banking industries. *European Journal of Operational Research*, 255(3), 971-983. <https://doi.org/https://doi.org/10.1016/j.ejor.2016.06.007>
- Chang, T.-P., Hu, J.-L., Chou, R. Y., & Sun, L. (2012). The sources of bank productivity growth in China during 2002–2009: A disaggregation view. *Journal of Banking & Finance*, 36(7), 1997-2006. <https://doi.org/http://dx.doi.org/10.1016/j.jbankfin.2012.03.003>
- Chiu, Y.-H., & Chen, Y.-C. (2009). The analysis of Taiwanese bank efficiency: Incorporating both external environment risk and internal risk. *Economic Modelling*, 26(2), 456-463. <https://doi.org/http://dx.doi.org/10.1016/j.econmod.2008.09.003>

- Chortareas, G. E., Girardone, C., & Ventouri, A. (2012). Bank supervision, regulation, and efficiency: Evidence from the European Union. *Journal of Financial Stability*, 8(4), 292-302. <https://doi.org/http://dx.doi.org/10.1016/j.jfs.2011.12.001>
- Colonia-Willner, R. (2004). Self-service systems: new methodology reveals customer real-time actions during merger. *Computers in Human Behavior*, 20(2), 243-267. <https://doi.org/DOI:10.1016/j.chb.2003.10.017>
- Edelstein, B., & Paradi, J. C. (2013). Ensuring units invariant slack selection in radial data envelopment analysis models, and incorporating slacks into an overall efficiency score. *Omega*, 41(1), 31-40. <https://doi.org/http://dx.doi.org/10.1016/j.omega.2011.09.008>
- El Moussawi, C., & Mansour, R. (2022). Competition, cost efficiency and stability of banks in the MENA region. *The Quarterly Review of Economics and Finance*, 84, 143-170. <https://doi.org/https://doi.org/10.1016/j.qref.2021.12.005>
- Eskelinen, J., & Kuosmanen, T. (2013). Intertemporal efficiency analysis of sales teams of a bank: Stochastic semi-nonparametric approach. *Journal of Banking & Finance*, 37(12), 5163-5175. <https://doi.org/http://dx.doi.org/10.1016/j.jbankfin.2013.03.010>
- Fethi, M. D., & Pasiouras, F. (2010). Assessing bank efficiency and performance with operational research and artificial intelligence techniques: A survey. *European Journal of Operational Research*, 204(2), 189-198. <https://doi.org/http://dx.doi.org/10.1016/j.ejor.2009.08.003>
- Fidrmuc, J., Fungáčová, Z., & Weill, L. (2015). Does bank liquidity creation contribute to economic growth? Evidence from Russia. *Open Economies Review*, 26, 479-496.

- Fujii, H., Managi, S., Matousek, R., & Rughoo, A. (2018). Bank efficiency, productivity, and convergence in EU countries: a weighted Russell directional distance model. *The European Journal of Finance*, 24(2), 135-156.
- Fungáčová, Z., & Weill, L. (2013). Does competition influence bank failures? Evidence from Russia. *Economics of Transition*, 21(2), 301-322.
- Girardone, C., Molyneux, P., & Gardener, E. P. M. (2004). Analysing the determinants of bank efficiency: the case of Italian banks. *Applied Economics*, 36(3), 215 - 227.  
<http://www.informaworld.com/10.1080/0003684042000175334>
- Hajdari, M., Qerimi, F., & Qerimi, A. (2023). Impact of Continuing Education on Employee Productivity and Financial Performance of Banks. *Emerging Science Journal*, 7(4), 1158-1172.
- Han, H., Ding, T., Nie, L., & Hao, Z. (2020). Agricultural eco-efficiency loss under technology heterogeneity given regional differences in China. *Journal of Cleaner Production*, 250, 119511. <https://doi.org/https://doi.org/10.1016/j.jclepro.2019.119511>
- Hassan, M. K., & Aliyu, S. (2018). A contemporary survey of Islamic banking literature. *Journal of Financial Stability*, 34, 12-43.
- Honig, B. (2001). Human capital and structural upheaval: A study of manufacturing firms in the west bank. *Journal of Business Venturing*, 16(6), 575-594.  
[https://doi.org/http://dx.doi.org/10.1016/S0883-9026\(99\)00060-9](https://doi.org/http://dx.doi.org/10.1016/S0883-9026(99)00060-9)

- Ioannou, G., & Mavri, M. (2007). Performance-Net: A Decision Support System for Reconfiguring a Bank's Branch Network. *Omega*, 35(2), 190-201. <https://doi.org/DOI:10.1016/j.omega.2005.05.007>
- Karpov, V. (2010). Desecularization: A conceptual framework. *Journal of Church and State*, 52(2), 232-270.
- Kolia, D. L., & Papadopoulos, S. (2022). Integration in banking efficiency: a comparative analysis of the European Union, the Eurozone, and the United States banks. *Journal of Capital Markets Studies*, 6(1), 48-70.
- LaPlante, A. E., & Paradi, J. C. (2015). Evaluation of bank branch growth potential using data envelopment analysis. *Omega*, 52(0), 33-41. <https://doi.org/http://dx.doi.org/10.1016/j.omega.2014.10.009>
- Martín-Oliver, A., Ruano, S., & Salas-Fumás, V. (2013). Why high productivity growth of banks preceded the financial crisis. *Journal of Financial Intermediation*, 22(4), 688-712. <https://doi.org/http://dx.doi.org/10.1016/j.jfi.2013.04.004>
- Millán, J. M., Congregado, E., Román, C., van Praag, M., & van Stel, A. (2014). The value of an educated population for an individual's entrepreneurship success. *Journal of Business Venturing*, 29(5), 612-632. <https://doi.org/http://dx.doi.org/10.1016/j.jbusvent.2013.09.003>
- Nartey, S. B., Osei, K. A., & Sarpong-Kumankoma, E. (2019). Bank productivity in Africa. *International Journal of Productivity and Performance Management*, 69(9), 1973-1997. <https://doi.org/10.1108/IJPPM-09-2018-0328>

- Ohene-Asare, D. K., & Baah, D. (2023). Decomposing Cost Productivity, Managerial Efficiency and Technological Innovation of Energy Consuming States. *Managerial Efficiency and Technological Innovation of Energy Consuming States*.
- Ohene-Asare, K., & Asmild, M. (2011). Banking efficiency under corporate social responsibilities: a nonparametric approach. *International Journal of Banking, Accounting and Finance* 4(2), 146–171., Article 2.
- Phan, H. T., Anwar, S., Alexander, W. R. J., & Phan, H. T. M. (2019). Competition, efficiency and stability: An empirical study of East Asian commercial banks. *The North American Journal of Economics and Finance*, 50, 100990. <https://doi.org/https://doi.org/10.1016/j.najef.2019.100990>
- Pruteanu-Podpiera, A., Weill, L., & Schobert, F. (2016). Banking competition and efficiency: A micro-data analysis on the Czech banking industry. In *Global banking crises and emerging markets* (pp. 52-74). London: Palgrave Macmillan UK.
- Roghanian, P., Rasli, A., & Gheysari, H. (2012). Productivity Through Effectiveness and Efficiency in the Banking Industry. *Procedia - Social and Behavioral Sciences*, 40, 550-556. <https://doi.org/https://doi.org/10.1016/j.sbspro.2012.03.229>
- Salkin, C., Oner, M., Ustundag, A., & Cevikcan, E. (2018). A conceptual framework for Industry 4.0. *Industry 4.0: managing the digital transformation*, 3-23.
- Shawtari, F. A., Ariff, M., & Abdul Razak, S. H. (2015). Efficiency assessment of banking sector in Yemen using data envelopment window analysis: A comparative analysis of Islamic and conventional banks. *Benchmarking: An International Journal*, 22(6), 1115-1140.

- Shi, Q., Zhou, Y., Xiao, C., Chen, R., & Zuo, J. (2014). Delivery risk analysis within the context of program management using fuzzy logic and DEA: A China case study. *International Journal of Project Management*, 32(2), 341-349. <https://doi.org/http://dx.doi.org/10.1016/j.ijproman.2013.05.002>
- Simar, L., & Wilson, P. W. (2007). Estimation and inference in two-stage, semi-parametric models of production processes. *Journal of Econometrics*, 136(1), 31-64. <https://doi.org/DOI:10.1016/j.jeconom.2005.07.009>
- Simar, L., & Wilson, P. W. (2011). Inference by the m out of n bootstrap in nonparametric frontier models. *Journal of Productivity Analysis*, 36(1), 33-53. <https://doi.org/10.1007/s11123-010-0200-4>
- Simar, L., & Wilson, P. W. (2015). Statistical approaches for non-parametric frontier models: A guided tour. *International Statistical Review*, 83(1), 77-110. <https://doi.org/10.1111/insr.12056>
- Svensson, L. E. (2022). A Simple Frictionless Model of User Cost and User-Cost-to-Income and User-Cost-to-Rent Ratios. note, Stockholm School of Economics, <https://larseosvensson.se/files/papers/simple-frictionless-model-user-cost.pdf>.
- Tan, Y. (2014). 4 - Risk management and performance in the Chinese banking sector. In Y. Tan (Ed.), *Performance, Risk and Competition in the Chinese Banking Industry* (pp. 65-139). Chandos Publishing. <https://doi.org/http://dx.doi.org/10.1533/9781780634463.65>
- Tresch, R. W. (2015). Chapter 17 - Expenditure Incidence and Economy-Wide Incidence Studies. In R. W. Tresch (Ed.), *Public Finance (Third Edition)* (pp. 297-329). Academic Press. <https://doi.org/http://dx.doi.org/10.1016/B978-0-12-415834-4.00017-0>

- Tziogkidis, P., Philippas, D., & Tsionas, M. G. (2020). Multidirectional conditional convergence in European banking. *Journal of Economic Behavior & Organization*, 173, 88-106. <https://doi.org/https://doi.org/10.1016/j.jebo.2020.03.013>
- Varpio, L., Paradis, E., Uijtdehaage, S., & Young, M. (2020). The distinctions between theory, theoretical framework, and conceptual framework. *Academic Medicine*, 95(7), 989-994.
- Walker, R. H., & Francis, H. (2003). Customer Service and Relationship Management in the Context of Technology-Enabled Service Delivery Systems. *Australasian Marketing Journal (AMJ)*, 11(2), 23-33. [https://doi.org/Doi: 10.1016/s1441-3582\(03\)70126-8](https://doi.org/Doi: 10.1016/s1441-3582(03)70126-8)
- Wanke, P., Barros, C. P., & Emrouznejad, A. (2016). Assessing productive efficiency of banks using integrated Fuzzy-DEA and bootstrapping: A case of Mozambican banks. *European Journal of Operational Research*, 249(1), 378-389. <https://doi.org/https://doi.org/10.1016/j.ejor.2015.10.018>
- Wu, J., Liang, L., & Yang, F. (2009). Achievement and benchmarking of countries at the Summer Olympics using cross efficiency evaluation method. *European Journal of Operational Research*, 197(2), 722-730. <https://doi.org/http://dx.doi.org/10.1016/j.ejor.2008.06.030>
- Yoon, C. (2010). Antecedents of customer satisfaction with online banking in China: The effects of experience. *Computers in Human Behavior*, 26(6), 1296-1304. <https://doi.org/DOI: 10.1016/j.chb.2010.04.001>
- Yu, M.-M., See, K. F., & Hsiao, B. (2021). Integrating group frontier and metafrontier directional distance functions to evaluate the efficiency of production units. *European Journal of Operational Research*. <https://doi.org/https://doi.org/10.1016/j.ejor.2021.10.054>

- Zhu, N., Hougaard, J. L., Yu, Z., & Wang, B. (2020). Ranking Chinese commercial banks based on their expected impact on structural efficiency. *Omega*, 94, 102049. <https://doi.org/https://doi.org/10.1016/j.omega.2019.03.007>
- Aggelopoulos, E., & Georgopoulos, A. (2017). Bank branch efficiency under environmental change: A bootstrap DEA on monthly profit and loss accounting statements of Greek retail branches. *European Journal of Operational Research*, 261(3), 1170-1188.
- Ahmad, N., Naveed, A., Ahmad, S., & Butt, I. (2020). Banking sector performance, profitability, and efficiency: a citation-based systematic literature review. *Journal of Economic Surveys*, 34(1), 185-218.
- Al-Khasawneh, J. A., Essaddam, N., & Hussain, T. (2020). Total productivity and cost efficiency dynamics of US merging banks: A non-parametric bootstrapped analysis of the fifth merger wave. *The Quarterly Review of Economics and Finance*, 78, 199-211. doi:<https://doi.org/10.1016/j.qref.2020.02.002>
- Alhassan, A. L., & Biekpe, N. (2016a). Competition and efficiency in the non-life insurance market in South Africa. *Journal of Economic Studies*, 43(6), 882-909.
- Alhassan, A. L., & Biekpe, N. (2016b). Explaining Bank Productivity in Ghana. *Managerial and Decision Economics*, 37(8), 563-573. doi:<https://doi.org/10.1002/mde.2748>
- Alhassan, A. L., & Ohene-Asare, K. (2016a). Competition and bank efficiency in emerging markets: empirical evidence from Ghana. *African Journal of Economic and Management Studies*.

- Alhassan, A. L., & Ohene-Asare, K. (2016b). Competition and bank efficiency in emerging markets: empirical evidence from Ghana. *African Journal of Economic and Management Studies*, 7(2), 268-288. doi:10.1108/ajems-01-2014-0007
- Alhassan, A. L., & Tetteh, M. L. (2017). Non-interest income and bank efficiency in Ghana: A two-stage DEA bootstrapping approach. *Journal of African Business*, 18(1), 124-142.
- Amirteimoori, A., Sahoo, B. K., & Mehdizadeh, S. (2023). Data envelopment analysis for scale elasticity measurement in the stochastic case: with an application to Indian banking. *Financial Innovation*, 9(1), 1-36.
- An, Q., Pang, Z., Chen, H., & Liang, L. (2015). Closest targets in environmental efficiency evaluation based on enhanced Russell measure. *Ecological Indicators*, 51(0), 59-66. doi:<http://dx.doi.org/10.1016/j.ecolind.2014.09.008>
- Andor, M., & Hesse, F. (2014). The StoNED age: The departure into a new era of efficiency analysis? A monte carlo comparison of StoNED and the “oldies”(SFA and DEA). *Journal of Productivity Analysis*, 41, 85-109.
- Antunes, J., Hadi-Vencheh, A., Jamshidi, A., Tan, Y., & Wanke, P. (2022). Bank efficiency estimation in China: DEA-RENNA approach. *Annals of Operations Research*, 315(2), 1373-1398.
- Antwi, F. (2019). Capital adequacy, cost income ratio and performance of banks in Ghana. *International Journal of Academic Research in Business and Social Sciences*, 9(10), 168-184.
- Aparicio, J., Ortiz, L., Pastor, J. T., & Zabala-Iturriagagoitia, J. M. (2020). Introducing cross-productivity: A new approach for ranking productive units over time in Data Envelopment Analysis. *Computers & Industrial Engineering*, 144, 106456.

- Arocena, P., Saal, D. S., Urakami, T., & Zschille, M. (2020). Measuring and decomposing productivity change in the presence of mergers. *European Journal of Operational Research*, 282(1), 319-333.
- Ashiagbor, A. A., Dziwornu, R., Gbade, A. V., Offei-Kwafo, k., & Liticia, G. (2023). Measuring efficiency and productivity changes: A non-parametric analysis of Ghanaian life insurance industry. *Cogent Economics & Finance*, 11(1), 2210855.
- Asongu, S. A., & Odhiambo, N. M. (2019). Testing the quiet life hypothesis in the African banking industry. *Journal of Industry, Competition and Trade*, 19, 69-82.
- Asmild, M., Kronborg, D., Mahbub, T., & Matthews, K. (2019). The efficiency patterns of Islamic banks during the global financial crisis: The case of Bangladesh. *The Quarterly Review of Economics and Finance*, 74, 67-74. doi:<https://doi.org/10.1016/j.qref.2018.04.004>
- Assaf, A. G., Berger, A. N., Roman, R. A., & Tsionas, M. G. (2019). Does efficiency help banks survive and thrive during financial crises? *Journal of Banking & Finance*, 106, 445-470.
- Badunenko, O., & Kumbhakar, S. C. (2017). Economies of scale, technical change and persistent and time-varying cost efficiency in Indian banking: Do ownership, regulation and heterogeneity matter? *European Journal of Operational Research*, 260(2), 789-803.
- Badunenko, O., Kumbhakar, S. C., & Lozano-Vivas, A. (2021). Achieving a sustainable cost-efficient business model in banking: The case of European commercial banks. *European Journal of Operational Research*, 293(2), 773-785.
- Banker, R., Natarajan, R., & Zhang, D. (2019). Two-stage estimation of the impact of contextual variables in stochastic frontier production function models using Data Envelopment Analysis: Second stage OLS versus bootstrap approaches. *European Journal of Operational Research*, 278(2), 368-384. doi:<https://doi.org/10.1016/j.ejor.2018.10.050>

- Banker, R. D., Charnes, A., & Cooper, W. W. (1984). Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Management science*, 30(9), 1078-1092.
- Banker, R. D., & Natarajan, R. (2008). Evaluating contextual variables affecting productivity using data envelopment analysis. *Operations research*, 56(1), 48-58.
- Banker, R. D., & Park, H.-U. (2021). Three-Stage approach to analyze managerial ability. *Data Envelopment Analysis Journal*, 5(1), 27-54.
- Becchetti, L., & Sierra, J. (2003). Bankruptcy risk and productive efficiency in manufacturing firms. *Journal of Banking & Finance*, 27(11), 2099-2120. doi:[http://dx.doi.org/10.1016/S0378-4266\(02\)00319-9](http://dx.doi.org/10.1016/S0378-4266(02)00319-9)
- Beck, T., & Levine, R. (2004). Stock markets, banks, and growth: Panel evidence. *Journal of Banking & Finance*, 28(3), 423-442. doi:10.1016/s0378-4266(02)00408-9
- Berger, A. N., & Bouwman, C. H. (2009). Bank liquidity creation. *Review of Financial Studies*, 22(9), 3779-3837.
- Berger, A. N., & Bouwman, C. H. (2013). How does capital affect bank performance during financial crises? *Journal of Financial Economics*, 109(1), 146-176.
- Berger, A. N., Hasan, I., & Zhou, M. (2009). Bank ownership and efficiency in China: What will happen in the world's largest nation? *Journal of Banking & Finance*, 33(1), 113-130.
- Berger, A. N., & Humphrey, D. B. (1997). Efficiency of financial institutions: International survey and directions for future research. *European Journal of Operational Research*, 98(2), 175-212.
- Berger, A. N., Molyneux, P., & Wilson, J. O. S. (2020). Banks and the real economy: An assessment of the research. *Journal of Corporate Finance*, 62. doi:10.1016/j.jcorpfin.2019.101513

- Bhatia, V., Basu, S., Mitra, S. K., & Dash, P. (2018). A review of bank efficiency and productivity. *Opsearch*, 55(3), 557-600.
- Blavet, T., Ouellette, P., & Vigeant, S. (2023).  $\alpha$ -returns to scale with quasi-fixed inputs: an application to Québec hospitals. *Applied Economics*, 1-17.
- Bod'a, M., & Piklová, Z. (2018). *The production or intermediation approach?: It matters*. Paper presented at the Contemporary Trends and Challenges in Finance: Proceedings from the 3rd Wroclaw International Conference in Finance.
- Boubaker, S., Do, D. T., Hammami, H., & Ly, K. C. (2022). The role of bank affiliation in bank efficiency: A fuzzy multi-objective data envelopment analysis approach. *Annals of Operations Research*, 1-29.
- Boucinha, M., Ribeiro, N., & Weyman-Jones, T. (2013). An assessment of Portuguese banks' efficiency and productivity towards euro area participation. *Journal of Productivity Analysis*, 39, 177-190.
- Casu, B., Ferrari, A., Girardone, C., & Wilson, J. O. (2016). Integration, productivity and technological spillovers: Evidence for eurozone banking industries. *European Journal of Operational Research*, 255(3), 971-983.
- Casu, B., Ferrari, A., Girardone, C., & Wilson, J. O. S. (2016). Integration, productivity and technological spillovers: Evidence for eurozone banking industries. *European Journal of Operational Research*, 255(3), 971-983. doi:<https://doi.org/10.1016/j.ejor.2016.06.007>
- Caves, D. W., Christensen, L. R., & Diewert, W. E. (1982). The economic theory of index numbers and the measurement of input, output, and productivity. *Econometrica: Journal of the Econometric Society*, 1393-1414.

- Chang, T.-P., Hu, J.-L., Chou, R. Y., & Sun, L. (2012). The sources of bank productivity growth in China during 2002–2009: A disaggregation view. *Journal of Banking & Finance*, 36(7), 1997-2006. doi:<http://dx.doi.org/10.1016/j.jbankfin.2012.03.003>
- Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research*, 2(6), 429-444.
- Chen, X., Grifell-Tatjé, E., & Fu, T.-T. (2023). A profit difference decomposition model for measuring group performance: an application to Chinese and Taiwanese commercial banks. *Omega*, 120, 102899.
- Chen, X., & Wu, X. (2020). What factor contributes to productivity growth of Chinese city banks: The role of regional difference. *The North American Journal of Economics and Finance*, 54. doi:10.1016/j.najef.2020.101259
- Chen, Y., Du, J., Sherman, H. D., & Zhu, J. (2010). DEA model with shared resources and efficiency decomposition. *European Journal of Operational Research*, 207(1), 339-349.
- Chiu, Y.-H., & Chen, Y.-C. (2009). The analysis of Taiwanese bank efficiency: Incorporating both external environment risk and internal risk. *Economic Modelling*, 26(2), 456-463. doi:<http://dx.doi.org/10.1016/j.econmod.2008.09.003>
- Chortareas, G. E., Girardone, C., & Ventouri, A. (2012). Bank supervision, regulation, and efficiency: Evidence from the European Union. *Journal of Financial Stability*, 8(4), 292-302. doi:<http://dx.doi.org/10.1016/j.jfs.2011.12.001>
- Coelli, T. J., Rao, D. S. P., O'Donnell, C. J., & Battese, G. E. (2005). *An introduction to efficiency and productivity analysis*: springer science & business media.

- Colonia-Willner, R. (2004). Self-service systems: new methodology reveals customer real-time actions during merger. *Computers in Human Behavior*, 20(2), 243-267. doi:DOI: 10.1016/j.chb.2003.10.017
- Contreras, I. (2020). A review of the literature on DEA models under common set of weights. *Journal of Modelling in Management*, 15(4), 1277-1300.
- Cook, W. D., Du, J., & Zhu, J. (2017). Units invariant DEA when weight restrictions are present: ecological performance of US electricity industry. *Annals of Operations Research*, 255, 323-346.
- Cook, W. D., & Seiford, L. M. (2009). Data envelopment analysis (DEA)—Thirty years on. *European Journal of Operational Research*, 192(1), 1-17.
- Cook, W. D., Tone, K., & Zhu, J. (2014). Data envelopment analysis: Prior to choosing a model. *Omega*, 44, 1-4.
- Cooper, W. W., Seiford, L. M., & Tone, K. (2006). *Introduction to data envelopment analysis and its uses: with DEA-solver software and references*: Springer Science & Business Media.
- Cooper, W. W., Thompson, R. G., & Thrall, R. M. (1996). Chapter 1 Introduction: Extensions and new developments in DEA. *Annals of Operations Research*, 66, 1-45.
- Creswell, J. W. (2014). Qualitative, quantitative and mixed methods approaches. In: Sage.
- Daraio, C., Kerstens, K., Nepomuceno, T., & Sickles, R. C. (2020). Empirical surveys of frontier applications: a meta-review. *International Transactions in Operational Research*, 27(2), 709-738.
- Delis, M. D., Iosifidi, M., & Tsionas, M. (2020). Management estimation in banking. *European Journal of Operational Research*, 284(1), 355-372.

- Dick, A. A., & Lehnert, A. (2010). Personal bankruptcy and credit market competition. *The Journal of Finance*, 65(2), 655-686.
- Dong, Y., Firth, M., Hou, W., & Yang, W. (2016). Evaluating the performance of Chinese commercial banks: A comparative analysis of different types of banks. *European Journal of Operational Research*, 252(1), 280-295.
- Drake, L., & Hall, M. J. (2003). Efficiency in Japanese banking: An empirical analysis. *Journal of Banking & Finance*, 27(5), 891-917.
- Dutta, K. D., & Saha, M. (2021). Do competition and efficiency lead to bank stability? Evidence from Bangladesh. *Future Business Journal*, 7(1), 1-12.
- Edelstein, B., & Paradi, J. C. (2013). Ensuring units invariant slack selection in radial data envelopment analysis models, and incorporating slacks into an overall efficiency score. *Omega*, 41(1), 31-40. doi:<http://dx.doi.org/10.1016/j.omega.2011.09.008>
- El Moussawi, C., & Mansour, R. (2022). Competition, cost efficiency and stability of banks in the MENA region. *The Quarterly Review of Economics and Finance*, 84, 143-170. doi:<https://doi.org/10.1016/j.qref.2021.12.005>
- Emrouznejad, A., & Yang, G.-l. (2018). A survey and analysis of the first 40 years of scholarly literature in DEA: 1978–2016. *Socio-Economic Planning Sciences*, 61, 4-8.
- Eskelinen, J., & Kuosmanen, T. (2013). Intertemporal efficiency analysis of sales teams of a bank: Stochastic semi-nonparametric approach. *Journal of Banking & Finance*, 37(12), 5163-5175. doi:<http://dx.doi.org/10.1016/j.jbankfin.2013.03.010>
- Färe, R., Grosskopf, S., Lindgren, B., & Roos, P. (1992). Productivity changes in Swedish pharmacies 1980–1989: A non-parametric Malmquist approach. *Journal of Productivity Analysis*, 3(1-2), 85-101.

- Färe, R., Grosskopf, S., & Lovell, C. K. (1985). *The measurement of efficiency of production* (Vol. 6): Springer Science & Business Media.
- Färe, R., Lovell, C. K., & Zieschang, K. (1983). *Measuring the technical efficiency of multiple output production technologies*: Springer.
- Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society: Series A (General)*, 120(3), 253-281.
- Fethi, M. D., & Pasiouras, F. (2010). Assessing bank efficiency and performance with operational research and artificial intelligence techniques: A survey. *European Journal of Operational Research*, 204(2), 189-198.
- Fidrmuc, J., Fungáčová, Z., & Weill, L. (2015). Does bank liquidity creation contribute to economic growth? Evidence from Russia. *Open Economies Review*, 26, 479-496.
- Fiordelisi, F., & Molyneux, P. (2010). Total factor productivity and shareholder returns in banking. *Omega*, 38(5), 241-253. doi:10.1016/j.omega.2008.07.009
- Førsund, F. R. (2016). Productivity interpretations of the Farrell efficiency measures and the Malmquist index and its decomposition. *Advances in efficiency and productivity*, 121-147.
- Fujii, H., Managi, S., Matousek, R., & Rughoo, A. (2018). Bank efficiency, productivity, and convergence in EU countries: a weighted Russell directional distance model. *The European Journal of Finance*, 24(2), 135-156.
- Fukuyama, H., Matousek, R., & Tzeremes, N. G. (2020). A Nerlovian cost inefficiency two-stage DEA model for modeling banks' production process: Evidence from the Turkish banking system. *Omega*, 95, 102198.

- Fukuyama, H., & Tan, Y. (2022). Implementing strategic disposability for performance evaluation: Innovation, stability, profitability and corporate social responsibility in Chinese banking. *European Journal of Operational Research*, 296(2), 652-668.
- Fukuyama, H., Tsionas, M., & Tan, Y. (2023). Dynamic network data envelopment analysis with a sequential structure and behavioural-causal analysis: Application to the Chinese banking industry. *European Journal of Operational Research*, 307(3), 1360-1373.
- Fungáčová, Z., Pessarossi, P., & Weill, L. (2013). Is bank competition detrimental to efficiency? Evidence from China. *China Economic Review*, 27, 121-134.
- Fungáčová, Z., & Weill, L. (2013). Does competition influence bank failures? Evidence from Russia. *Economics of Transition*, 21(2), 301-322.
- Galariotis, E., Kosmidou, K., Kousenidis, D., Lazaridou, E., & Papapanagiotou, T. (2021). Measuring the effects of M&As on Eurozone bank efficiency: An innovative approach on concentration and credibility impacts. *Annals of Operations Research*, 306, 343-368.
- GE. (2021). The Global Economy : Business and economic data for 200 countries, accessed 23rd march, 2023.
- Girardone, C., Molyneux, P., & Gardener, E. P. M. (2004). Analysing the determinants of bank efficiency: the case of Italian banks. *Applied Economics*, 36(3), 215 - 227. Retrieved from <http://www.informaworld.com/10.1080/0003684042000175334>
- Glass, A. J., Kenjegalieva, K., & Weyman-Jones, T. (2020). The effect of monetary policy on bank competition using the Boone index. *European Journal of Operational Research*, 282(3), 1070-1087.

- Guan, J. C., Yam, R. C., Mok, C. K., & Ma, N. (2006). A study of the relationship between competitiveness and technological innovation capability based on DEA models. *European Journal of Operational Research*, 170(3), 971-986.
- Hajdari, M., Qerimi, F., & Qerimi, A. (2023). Impact of Continuing Education on Employee Productivity and Financial Performance of Banks. *Emerging Science Journal*, 7(4), 1158-1172.
- Hammami, H., Ngo, T., Tripe, D., & Vo, D.-T. (2022). Ranking with a Euclidean common set of weights in data envelopment analysis: with application to the Eurozone banking sector. *Annals of Operations Research*, 1-20.
- Han, H., Ding, T., Nie, L., & Hao, Z. (2020). Agricultural eco-efficiency loss under technology heterogeneity given regional differences in China. *Journal of Cleaner Production*, 250, 119511. doi:<https://doi.org/10.1016/j.jclepro.2019.119511>
- Hassan, M. K., & Aliyu, S. (2018). A contemporary survey of Islamic banking literature. *Journal of Financial Stability*, 34, 12-43.
- Honig, B. (2001). Human capital and structural upheaval: A study of manufacturing firms in the west bank. *Journal of Business Venturing*, 16(6), 575-594. doi:[http://dx.doi.org/10.1016/S0883-9026\(99\)00060-9](http://dx.doi.org/10.1016/S0883-9026(99)00060-9)
- Huang, T.-H., Hu, C.-N., & Chang, B.-G. (2018). Competition, efficiency, and innovation in Taiwan's banking industry—An application of copula methods. *The Quarterly Review of Economics and Finance*, 67, 362-375.
- Ioannou, G., & Mavri, M. (2007). Performance-Net: A Decision Support System for Reconfiguring a Bank's Branch Network. *Omega*, 35(2), 190-201. doi:DOI: 10.1016/j.omega.2005.05.007

- Jahan, N. (2019). Productivity analysis of commercial banks of Bangladesh: a malmquist productivity index approach. *International Journal of Economics and Financial Issues*, 9(1), 108.
- Jreisat, A., Rabbani, M. R., Omran, S., Al-Mohamad, S., & Bakry, W. (2022). An examination of the banking efficiency of the BRICS countries: A perspective derived from the oil price volatility. *Cogent Economics & Finance*, 10(1), 2142315.
- 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.
- Karpov, V. (2010). Desecularization: A conceptual framework. *Journal of Church and State*, 52(2), 232-270.
- King, R. G., & Levine, R. (1993). Finance, entrepreneurship and growth. *Journal of Monetary economics*, 32(3), 513-542.
- Kolia, D. L., & Papadopoulos, S. (2022). Integration in banking efficiency: a comparative analysis of the European Union, the Eurozone, and the United States banks. *Journal of Capital Markets Studies*, 6(1), 48-70.
- Kraft, E., & Tirtiroğlu, D. (1998). Bank efficiency in Croatia: A stochastic-frontier analysis. *Journal of comparative economics*, 26(2), 282-300.
- Kuljanin, J., Kalić, M., Caggiani, L., & Ottomanelli, M. (2019). A comparative efficiency and productivity analysis: Implication to airlines located in Central and South-East Europe. *Journal of Air Transport Management*, 78, 152-163.

- Kutlu, L., Tran, K. C., & Tsionas, M. G. (2020). A spatial stochastic frontier model with endogenous frontier and environmental variables. *European Journal of Operational Research*, 286(1), 389-399.
- LaPlante, A. E., & Paradi, J. C. (2015). Evaluation of bank branch growth potential using data envelopment analysis. *Omega*, 52(0), 33-41.  
doi:<http://dx.doi.org/10.1016/j.omega.2014.10.009>
- Lee, C.-C., Li, X., Yu, C.-H., & Zhao, J. (2021). Does fintech innovation improve bank efficiency? Evidence from China's banking industry. *International Review of Economics & Finance*, 74, 468-483.
- Lensink, R., & Meesters, A. (2014). Institutions and bank performance: A stochastic frontier analysis. *Oxford Bulletin of Economics and Statistics*, 76(1), 67-92.
- Levine, R., Loayza, N., & Beck, T. (2000). Financial intermediation and growth: Causality and causes. *Journal of Monetary economics*, 46(1), 31-77.
- Levine, R., & Zervos, S. (1998). Stock markets, banks, and economic growth. *American economic review*, 537-558.
- Li, Y. (2020). Analyzing efficiencies of city commercial banks in China: An application of the bootstrapped DEA approach. *Pacific-Basin Finance Journal*, 62, 101372.
- Li, Z., Feng, C., & Tang, Y. (2022). Bank efficiency and failure prediction: a nonparametric and dynamic model based on data envelopment analysis. *Annals of Operations Research*, 315(1), 279-315.
- Liu, H., Molyneux, P., & Wilson, J. O. (2013). Competition and stability in European banking: a regional analysis. *The Manchester School*, 81(2), 176-201.

- Liu, J. S., Lu, L. Y., & Lu, W.-M. (2016). Research fronts in data envelopment analysis. *Omega*, 58, 33-45.
- Liu, J. S., Lu, L. Y., Lu, W.-M., & Lin, B. J. (2013). A survey of DEA applications. *Omega*, 41(5), 893-902.
- Lotto, J. (2019). Evaluation of factors influencing bank operating efficiency in Tanzanian banking sector. *Cogent Economics & Finance*, 7(1), 1664192.
- Lovell, C. K., & Pastor, J. T. (1995). Units invariant and translation invariant DEA models. *Operations research letters*, 18(3), 147-151.
- Mahmoudabadi, M. Z., & Emrouznejad, A. (2019). Comprehensive performance evaluation of banking branches: A three-stage slacks-based measure (SBM) data envelopment analysis. *International Review of Economics & Finance*, 64, 359-376.
- Manello, A. (2017). Productivity growth, environmental regulation and win-win opportunities: The case of chemical industry in Italy and Germany. *European Journal of Operational Research*, 262(2), 733-743.
- Maniadakis, N., & Thanassoulis, E. (2004). A cost Malmquist productivity index. *European Journal of Operational Research*, 154(2), 396-409.
- Marius Andrieș, A., & Căpraru, B. (2012). Competition and efficiency in EU27 banking systems. *Baltic Journal of Economics*, 12(1), 41-60.
- Martín-Oliver, A., Ruano, S., & Salas-Fumás, V. (2013). Why high productivity growth of banks preceded the financial crisis. *Journal of Financial Intermediation*, 22(4), 688-712.  
doi:<http://dx.doi.org/10.1016/j.jfi.2013.04.004>

- Martínez-Campillo, A., & Fernández-Santos, Y. (2020). The impact of the economic crisis on the (in) efficiency of public Higher Education institutions in Southern Europe: The case of Spanish universities. *Socio-Economic Planning Sciences*, 71, 100771.
- Mavi, N. K., & Mavi, R. K. (2019). Energy and environmental efficiency of OECD countries in the context of the circular economy: Common weight analysis for malmquist productivity index. *Journal of environmental management*, 247, 651-661.
- Mester, L. J. (1996). A study of bank efficiency taking into account risk-preferences. *Journal of Banking & Finance*, 20(6), 1025-1045.
- Millán, J. M., Congregado, E., Román, C., van Praag, M., & van Stel, A. (2014). The value of an educated population for an individual's entrepreneurship success. *Journal of Business Venturing*, 29(5), 612-632. doi:<http://dx.doi.org/10.1016/j.jbusvent.2013.09.003>
- Nartey, S. B., Osei, K. A., & Sarpong-Kumankoma, E. (2019). Bank productivity in Africa. *International Journal of Productivity and Performance Management*, 69(9), 1973-1997. doi:10.1108/IJPPM-09-2018-0328
- Nguyen, M., Perera, S., & Skully, M. (2016). Bank market power, ownership, regional presence and revenue diversification: Evidence from Africa. *Emerging Markets Review*, 27, 36-62.
- Ohene-Asare, D. K., & Baah, D. (2023). Decomposing Cost Productivity, Managerial Efficiency and Technological Innovation of Energy Consuming States. *Managerial Efficiency and Technological Innovation of Energy Consuming States*.
- Ohene-Asare, K., Asare, J. K. A., & Turkson, C. (2019). Dynamic cost productivity and economies of scale of Ghanaian insurers. *The Geneva Papers on Risk and Insurance-Issues and Practice*, 44(1), 148-177.

- Ohene-Asare, K., & Asmild, M. (2011). Banking efficiency under corporate social responsibilities: a nonparametric approach. *International Journal of Banking, Accounting and Finance* 4(2), 146–171.
- Ohene-Asare, K., & Asmild, M. (2012). Banking efficiency analysis under corporate social responsibilities. *International Journal of Banking, Accounting and Finance*, 4(2), 146-171.
- Olesen, O. B., & Ruggiero, J. (2022). The hinging hyperplanes: An alternative nonparametric representation of a production function. *European Journal of Operational Research*, 296(1), 254-266.
- Omrani, H., Alizadeh, A., Emrouznejad, A., & Oveysi, Z. (2022). A novel best-worst-method two-stage data envelopment analysis model considering decision makers' preferences: An application in bank branches evaluation. *International Journal of Finance & Economics*.
- Omrani, H., Oveysi, Z., Emrouznejad, A., & Teplova, T. (2023). A mixed-integer network DEA with shared inputs and undesirable outputs for performance evaluation: Efficiency measurement of bank branches. *Journal of the Operational Research Society*, 74(4), 1150-1165.
- Paradi, J. C., & Zhu, H. (2013). A survey on bank branch efficiency and performance research with data envelopment analysis. *Omega*, 41(1), 61-79.
- Phan, H. T., Anwar, S., Alexander, W. R. J., & Phan, H. T. M. (2019). Competition, efficiency and stability: An empirical study of East Asian commercial banks. *The North American Journal of Economics and Finance*, 50, 100990. doi:<https://doi.org/10.1016/j.najef.2019.100990>
- Roghanian, P., Rasli, A., & Gheysari, H. (2012). Productivity Through Effectiveness and Efficiency in the Banking Industry. *Procedia - Social and Behavioral Sciences*, 40, 550-556. doi:<https://doi.org/10.1016/j.sbspro.2012.03.229>

- Rostamzadeh, R., Akbarian, O., Banaitis, A., & Soltani, Z. (2021). Application of DEA in benchmarking: a systematic literature review from 2003–2020. *Technological and Economic Development of Economy*, 27(1), 175-222.
- Salkin, C., Oner, M., Ustundag, A., & Cevikcan, E. (2018). A conceptual framework for Industry 4.0. *Industry 4.0: managing the digital transformation*, 3-23.
- Seiford, L. M., & Thrall, R. M. (1990). Recent developments in DEA: the mathematical programming approach to frontier analysis. *Journal of econometrics*, 46(1-2), 7-38.
- Shamshur, A., & Weill, L. (2019). Does bank efficiency influence the cost of credit? *Journal of Banking & Finance*, 105, 62-73.
- Shawtari, F. A., Ariff, M., & Abdul Razak, S. H. (2015). Efficiency assessment of banking sector in Yemen using data envelopment window analysis: A comparative analysis of Islamic and conventional banks. *Benchmarking: An International Journal*, 22(6), 1115-1140.
- Shi, Q., Zhou, Y., Xiao, C., Chen, R., & Zuo, J. (2014). Delivery risk analysis within the context of program management using fuzzy logic and DEA: A China case study. *International Journal of Project Management*, 32(2), 341-349. doi:<http://dx.doi.org/10.1016/j.ijproman.2013.05.002>
- Simar, L., & Wilson, P. W. (2007). Estimation and inference in two-stage, semi-parametric models of production processes. *Journal of Econometrics*, 136(1), 31-64. doi:DOI: 10.1016/j.jeconom.2005.07.009
- Simar, L., & Wilson, P. W. (2011). Inference by the m out of n bootstrap in nonparametric frontier models. *Journal of Productivity Analysis*, 36(1), 33-53. doi:10.1007/s11123-010-0200-4
- Simar, L., & Wilson, P. W. (2011). Two-stage DEA: caveat emptor. *Journal of Productivity Analysis*, 36(2), 205-218.

- Simar, L., & Wilson, P. W. (2015). Statistical approaches for non-parametric frontier models: A guided tour. *International Statistical Review*, 83(1), 77-110. doi:10.1111/insr.12056
- Simar, L., & Wilson, P. W. (2015). Statistical approaches for non-parametric frontier models: a guided tour. *International Statistical Review*, 83(1), 77-110.
- Sueyoshi, T., & Sekitani, K. (2009). An occurrence of multiple projections in DEA-based measurement of technical efficiency: Theoretical comparison among DEA models from desirable properties. *European Journal of Operational Research*, 196(2), 764-794.
- Svensson, L. E. (2022). A Simple Frictionless Model of User Cost and User-Cost-to-Income and User-Cost-to-Rent Ratios. note, *Stockholm School of Economics*, <https://larseosvensson.se/files/papers/simple-frictionless-model-user-cost.pdf>.
- Tadesse, S. (2002). Financial Architecture and Economic Performance: International Evidence. *Journal of Financial Intermediation*, 11(4), 429-454. doi:10.1006/jfin.2002.0352
- Tan, Y. (2014). 4 - Risk management and performance in the Chinese banking sector. In Y. Tan (Ed.), *Performance, Risk and Competition in the Chinese Banking Industry* (pp. 65-139): Chandos Publishing.
- Tan, Y., & Floros, C. (2018). Risk, competition and efficiency in banking: Evidence from China. *Global Finance Journal*, 35, 223-236.
- Tan, Y., Wanke, P., Antunes, J., & Emrouznejad, A. (2021). Unveiling endogeneity between competition and efficiency in Chinese banks: A two-stage network DEA and regression analysis. *Annals of Operations Research*, 306(1), 131-171.
- Tavana, M., Khalili-Damghani, K., Santos Arteaga, F. J., & Hashemi, A. (2020). A Malmquist productivity index for network production systems in the energy sector. *Annals of Operations Research*, 284, 415-445.

- Tecles, P. L., & Tabak, B. M. (2010). Determinants of bank efficiency: The case of Brazil. *European Journal of Operational Research*, 207(3), 1587-1598.
- Thaker, K., Charles, V., Pant, A., & Gherman, T. (2022). A DEA and random forest regression approach to studying bank efficiency and corporate governance. *Journal of the Operational Research Society*, 73(6), 1258-1277.
- Tone, K., & Tsutsui, M. (2010). Dynamic DEA: A slacks-based measure approach. *Omega*, 38(3-4), 145-156.
- Tresch, R. W. (2015). Chapter 17 - Expenditure Incidence and Economy-Wide Incidence Studies. In R. W. Tresch (Ed.), *Public Finance (Third Edition)* (pp. 297-329). San Diego: Academic Press.
- Tzeremes, N. G. (2015). Efficiency dynamics in Indian banking: A conditional directional distance approach. *European Journal of Operational Research*, 240(3), 807-818.
- Tziogkidis, P., Philippas, D., & Tsionas, M. G. (2020). Multidirectional conditional convergence in European banking. *Journal of Economic Behavior & Organization*, 173, 88-106. doi:<https://doi.org/10.1016/j.jebo.2020.03.013>
- Varpio, L., Paradis, E., Uijtdehaage, S., & Young, M. (2020). The distinctions between theory, theoretical framework, and conceptual framework. *Academic Medicine*, 95(7), 989-994.
- Walker, R. H., & Francis, H. (2003). Customer Service and Relationship Management in the Context of Technology-Enabled Service Delivery Systems. *Australasian Marketing Journal (AMJ)*, 11(2), 23-33. doi:Doi: 10.1016/s1441-3582(03)70126-8
- Wanke, P., Barros, C. P., & Emrouznejad, A. (2016). Assessing productive efficiency of banks using integrated Fuzzy-DEA and bootstrapping: A case of Mozambican banks. *European Journal of Operational Research*, 249(1), 378-389. doi:10.1016/j.ejor.2015.10.018

- Weill, L. (2004). On the relationship between competition and efficiency in the EU banking sectors. *Credit and Capital Markets–Kredit und Kapital*, 37(3), 329-352.
- Wu, J., Liang, L., & Yang, F. (2009). Achievement and benchmarking of countries at the Summer Olympics using cross efficiency evaluation method. *European Journal of Operational Research*, 197(2), 722-730. doi:<http://dx.doi.org/10.1016/j.ejor.2008.06.030>
- Yahaya, O. A., & Awen, B. I. (2020). Bank-specific attributes and operational efficiency: Evidence from efficient-structure hypothesis. *Journal of Business and Social Review in Emerging Economies*, 6(3), 1087-1098.
- Yang, C.-C. (2014). An enhanced DEA model for decomposition of technical efficiency in banking. *Annals of Operations Research*, 214, 167-185.
- 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.
- Yoon, C. (2010). Antecedents of customer satisfaction with online banking in China: The effects of experience. *Computers in Human Behavior*, 26(6), 1296-1304. doi:DOI: 10.1016/j.chb.2010.04.001
- Yu, C. (2016). Airline productivity and efficiency: concept, measurement, and applications. In *Airline Efficiency* (Vol. 5, pp. 11-53): Emerald Group Publishing Limited.
- Yu, M.-M., See, K. F., & Hsiao, B. (2021). Integrating group frontier and metafrontier directional distance functions to evaluate the efficiency of production units. *European Journal of Operational Research*. doi:<https://doi.org/10.1016/j.ejor.2021.10.054>

- Zaman, A. U., & Khan, N. A. (2023). Decomposition of productivity growth among the cooperative banks in Jammu and Kashmir (India). *Humanities and Social Sciences Communications*, 10(1), 1-8.
- Zarrin, M., & Brunner, J. O. (2023). Analyzing the accuracy of variable returns to scale data envelopment analysis models. *European Journal of Operational Research*, 308(3), 1286-1301.
- Zarutskie, R. (2013). Competition, financial innovation and commercial bank loan portfolios. *Journal of Financial Intermediation*, 22(3), 373-396.
- Zhao, J., Li, X., Yu, C.-H., Chen, S., & Lee, C.-C. (2022). Riding the FinTech innovation wave: FinTech, patents and bank performance. *Journal of International Money and Finance*, 122, 102552.
- Zhao, L., Zhu, Q., & Zhang, L. (2021). Regulation adaptive strategy and bank efficiency: A network slacks-based measure with shared resources. *European Journal of Operational Research*, 295(1), 348-362. doi:<https://doi.org/10.1016/j.ejor.2021.02.050>
- Zhu, N., Hougaard, J. L., Yu, Z., & Wang, B. (2020). Ranking Chinese commercial banks based on their expected impact on structural efficiency. *Omega*, 94, 102049. doi:<https://doi.org/10.1016/j.omega.2019.03.007>
- Zhu, N., Shah, W. U. H., Kamal, M. A., & Yasmeen, R. (2021). Efficiency and productivity analysis of Pakistan's banking industry: A DEA approach. *International Journal of Finance & Economics*, 26(4), 6362-6374.

**APPENDIX**

Hypothetical data for numerical example

DMU	period	X1	X2	Y1	Y2	W1	W2
A	1	5	30	10	5	2	5
B	1	9	23	15	10	3.5	5.6
C	1	20	20	20	15	4	6.2
D	1	15	17	28	20	1.5	3
E	1	10	12	30	25	1	3.7
F	1	5	30	10	5	2	5
G	1	19	8	12	35	15	9.2
H	1	7	28	15	40	7	7
I	1	30	15	55	45	4.5	12
A	2	6	12	15	10	1	3.3
b	2	8	14	18	14	3.8	9
c	2	13	16	21	18	4.5	2.5
d	2	29	27	24	22	5	6
e	2	27	19	27	26	3	9.5
f	2	29	27	24	22	10	1
g	2	11	6	33	36	4.8	20
h	2	7	28	15	40	7	7
i	2	12	30	39	44	4	6.2

Source: Authors' data generation and computations.

**Table 1:** Estimated technical and cost distance functions under CRS

DMU	D11c	D22c	D12c	D21c	C11c	C22c	C12c	C21c
A	1.50	1.27	1.63	1.20	6.52	3.26	11.14	1.96
B	1.80	1.40	1.95	1.33	3.14	2.99	5.54	1.74
C	2.67	1.91	3.06	1.83	2.67	2.40	3.58	1.85
D	1.55	3.68	1.65	2.88	1.60	4.64	2.29	2.94
E	1.00	3.02	1.03	1.96	1.15	3.55	1.76	2.09
F	1.50	3.68	1.63	2.88	6.52	3.76	2.28	3.04
G	1.00	1.00	1.37	0.52	1.13	1.00	1.50	0.61
H	1.00	1.00	1.00	1.00	1.13	1.85	1.85	1.13
I	1.00	1.00	1.50	0.87	1.00	2.36	1.57	1.49

**Table 2:** Estimated technical and cost distance functions under VRS

DMU	D11v	D22v	D12v	D21v	C11v	C22v	C12v	C21v
A	1.00	1.00	0.83	0.70	2.05	1.48	3.38	0.92
B	1.15	1.17	1.50	0.89	1.57	1.63	2.52	1.04
C	1.76	1.65	2.29	1.31	1.78	1.66	2.37	1.32
D	1.44	3.22	1.57	2.43	1.44	3.37	1.95	2.44
E	1.00	2.68	1.00	1.73	1.00	2.91	1.60	1.82
F	1.00	3.22	0.83	2.43	2.05	3.37	1.11	2.43
G	1.00	1.00	1.33	0.51	1.09	1.00	1.45	0.56
H	1.00	1.00	1.00	1.00	1.00	1.19	1.19	1.00
I	1.00	1.00	N/A	0.47	1.00	1.00	N/A	1.37

The cost and technical distance functions for DMU F can be demonstrated in Table 4 as follows:

**Table 3**

Distance functions for DMU K

Cost Distance Functions	Technical Distance Functions
$C11c_F = \frac{w^t x^t}{C^t(y^t, w^t)} = \frac{160}{24.55} = 6.52$	$D11c_F = \frac{\vec{K}^t}{\vec{IS}_{crs}^t} = 1.50$
$C22c_F = \frac{w^{t+1} x^{t+1}}{C^{t+1}(y^{t+1}, w^{t+1})} = \frac{317}{84.36} = 3.75$	$D22c_F = \frac{\vec{K}^{t+1}}{\vec{IS}_{crs}^{t+1}} = 3.68$
$C12c_F = \frac{w^{t+1} x^t}{C^{t+1}(y^t, w^{t+1})} = \frac{80}{35.15} = 2.28$	$D12c_F = \frac{\vec{K}^t}{\vec{IS}_{crs}^{t+1}} = 1.68$
$C21c_F = \frac{w^t x^{t+1}}{C^t(y^{t+1}, w^t)} = \frac{193.0}{63.47} = 3.04$	$D21c_F = \frac{\vec{K}^{t+1}}{\vec{IS}_{crs}^t} = 2.88$
$C11v_F = \frac{w^t x^t}{C^t(y^t, w^t)} = \frac{160}{78} = 2.05$	$D11v_F = \frac{\vec{K}^t}{\vec{IS}_{vrs}^t} = 1$
$C22v_F = \frac{w^{t+1} x^{t+1}}{C^{t+1}(y^{t+1}, w^{t+1})} = \frac{317}{94} = 3.37$	$D22v_F = \frac{\vec{K}^{t+1}}{\vec{IS}_{vrs}^{t+1}} = 3.22$
$C12v_F = \frac{w^{t+1} x^t}{C^{t+1}(y^t, w^{t+1})} = \frac{80}{72} = 1.11$	$D12v_F = \frac{\vec{K}^t}{\vec{IS}_{vrs}^{t+1}} = 0.83$
$C21v_F = \frac{w^t x^{t+1}}{C^t(y^{t+1}, w^t)} = \frac{193}{79} = 2.44$	$D21v_F = \frac{\vec{K}^{t+1}}{\vec{IS}_{vrs}^t} = 2.43$

DMU F's overall CM between period  $t$  and  $t+1$ , which is the geometric mean of the two indices becomes:

$$CM_F^{t,t+1} = \left[ \frac{C21c_F}{C11c_F} \times \frac{C22c_F}{C12c_F} \right]^{1/2} = \left[ \frac{3.04}{6.52} \times \frac{3.75}{2.28} \right]^{1/2} = [0.47 \times 1.64]^{1/2} = \mathbf{0.88}$$

The two parts decomposition of MT (2004) is:

$$CEC_F = \frac{C22c_F}{C11c_F} = \frac{3.75}{6.52} = 0.58$$

$$CTC_F = \left[ \frac{C21c_F}{C22c_F} \times \frac{C11c_F}{C12c_F} \right]^{1/2} = \left[ \frac{3.04}{3.75} \times \frac{6.52}{2.28} \right]^{1/2} = [0.81 \times 2.86]^{1/2} = \mathbf{1.52}$$

The four-part decomposition under VRS is given by:

$$PCEC_F = \frac{C22v_F}{C11v_F} = \frac{3.37}{2.05} = \mathbf{1.64}$$

$$SCEC_K = \frac{C22c_F/C22v_F}{C11c_F/C11v_F} = \frac{3.75/3.37}{6.52/2.05} = \mathbf{0.35}$$

$$PCTC_K = \left[ \frac{C21v_K}{C22v_K} \times \frac{C11v_K}{C12v_K} \right]^{1/2} = \left[ \frac{2.44}{3.37} \times \frac{2.05}{1.11} \right]^{1/2} = \mathbf{1.16}$$

$$SCTC_K = \left[ \frac{C21c_K/C21v_K}{C22c_K/C22v_K} \times \frac{C11c_K/C11v_K}{C12c_K/C12v_K} \right]^{1/2} = \left[ \frac{3.04/2.44}{3.75/3.37} \times \frac{6.52/2.05}{2.28/1.11} \right]^{1/2} = \mathbf{1.32}$$

Finally, the eight-part decomposition can be shown as:

$$PEC_F = \frac{D22v_F}{D11v_F} = \frac{3.22}{1} = \mathbf{3.22}$$

$$PAEC_F = \frac{w^{t+1}x^{t+1} / (C^{t+1}(w^{t+1}, y^{t+1}) \times D22v_F)}{w^t x^t / (C^t(w^t, y^t) \times D11v_F)} = \frac{317 / (94 \times 3.22)}{160 / (78 \times 1)} = \mathbf{0.51}$$

$$SEC_F = \frac{D22c_F / D22v_F}{D11c_F / D11v_F} = \frac{3.68 / 3.22}{1.50 / 1} = \mathbf{0.76}$$

$$SAEC_F = \frac{\frac{w^{t+1}x^{t+1} / (C^{t+1}(w^{t+1}, y^{t+1}) \times D22c_F)}{w^{t+1}x^{t+1} / (C^{t+1}(w^{t+1}, y^{t+1}) \times D22v_F)}}{\frac{\{w^t x^t / (C^t(w^t, y^t) \times D11c_F)}{\{w^t x^t / (C^t(w^t, y^t) \times D11v_F}}}} = \frac{\frac{317 / (84.36 \times 3.68)}{317 / (94 \times 3.22)}}{\frac{160 / (24.55 \times 1.5)}{160 / (78 \times 1)}} = \frac{0.97}{2.12} = \mathbf{0.46}$$

$$PTC_F = \left[ \frac{D11v_F}{D12v_F} \times \frac{D21v_F}{D22v_F} \right]^{1/2} = \left[ \frac{1}{0.83} \times \frac{2.43}{3.22} \right]^{1/2} = \mathbf{0.95}$$

$$PPE_F = \left[ \frac{w^t x^{t+1} / (C^t(w^t, y^{t+1}) \times D21v_F)}{w^{t+1} x^{t+1} / (C^{t+1}(w^{t+1}, y^{t+1}) \times D22v_F)} \times \frac{w^t x^t / (C^t(w^t, y^t) \times D11v_F)}{w^{t+1} x^t / (C^{t+1}(w^{t+1}, y^t) \times D12v_F)} \right]^{1/2}$$

$$= \left[ \frac{193 / (79.33 \times 2.43)}{317 / (94 \times 3.22)} \times \frac{160 / (78 \times 1)}{80 / (72 \times 0.83)} \right]^{1/2} = \left[ \frac{1}{1.05} \times \frac{2.05}{1.34} \right]^{1/2} = \mathbf{1.21}$$

$$STC_F = \left[ \frac{D11c_F / D11v_F}{D12c_F / D12v_F} \times \frac{D21c_F / D21v_F}{D22c_F / D22v_F} \right]^{1/2} = \left[ \frac{1.5 / 1}{1.68 / 0.83} \times \frac{2.88 / 2.43}{3.68 / 3.22} \right]^{1/2} = \mathbf{0.88}$$

$$SPE_F = \left[ \frac{\frac{w^t x^{t+1} / (C^t(w^t, y^{t+1}) \times D21c_F)}{w^t x^{t+1} / (C^t(w^t, y^{t+1}) \times D21v_F)}}{\frac{w^{t+1} x^{t+1} / (C^{t+1}(w^{t+1}, y^{t+1}) \times D22c_F)}{w^{t+1} x^{t+1} / (C^{t+1}(w^{t+1}, y^{t+1}) \times D22v_F)}} \times \frac{\frac{w^t x^t / (C^t(w^t, y^t) \times D11c_F)}{w^t x^t / (C^t(w^t, y^t) \times D11v_F)}}{\frac{w^{t+1} x^t / (C^{t+1}(w^{t+1}, y^t) \times D12c_F)}{w^{t+1} x^t / (C^{t+1}(w^{t+1}, y^t) \times D12v_F)}} \right]^{1/2}$$

$$= \left[ \frac{\frac{193 / (63.47 \times 2.88)}{193 / (73.33 \times 2.43)}}{\frac{317 / (84.36 \times 3.68)}{317 / (94 \times 3.22)}} \times \frac{\frac{160 / (24.55 \times 1.5)}{160 / (78 \times 1)}}{\frac{80 / (35.15 \times 1.68)}{80 / (72 \times 0.83)}} \right]^{1/2} = \left[ \frac{0.97}{0.97} \times \frac{2.12}{1.01} \right]^{1/2} = \mathbf{1.45}$$

TABLE 5: Technical Malmquist index and its 2, 3 & 4 (WW) Factors Decompositions

DMU	MPI <sub>c</sub>	MPI <sub>v</sub>	EC	TC	PEC	SEC	PT	ST	SCH
							C	C	
A	1.26	1.09	1.18	1.07	1.00	1.18	1.09	0.98	1.16
B	1.37	1.29	1.28	1.07	0.98	1.31	1.31	0.82	1.07
C	1.53	1.37	1.40	1.09	1.07	1.31	1.28	0.85	1.12
D	0.49	0.54	0.42	1.17	0.45	0.94	1.20	0.97	0.91
e	0.42	0.46	0.33	1.26	0.37	0.89	1.24	1.01	0.90
f	0.48	0.33	0.41	1.18	0.31	1.31	1.05	1.12	1.47
g	1.62	1.61	1.00	1.62	1.00	1.00	1.61	1.01	1.01
h	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
i	1.32	N/A	1.00	1.32	1.00	1.00	N/A	N/A	N/A

where  $EC * TC = MPI_c$ ,  $PEC * PTC = MPI_v$ ,  $PEC * SEC = EC$ ,  $PTC * STC = TC$ ,  $SEC * STC = SCH$ ,  
 $PEC * SEC * PTC * STC = MPI_c$ , WW= Wheelock and Wilson (1999) decomposition



TABLE 6: COST MALMQUIST INDEX WITH 2-FACTOR (CRS), 4-FACTOR (VRS) DECOMPOSITIONS AND 8-FACTOR DECOMPOSITION (VRS)

D M U	C		P						S		P		S			
	M	M	CE	CT	PC	SC	PC	SC	E	PA	E	SA	T	P	T	P
	c	v	Cc	Cc	EC	EC	TC	TC	C	EC	C	EC	C	E	C	E
	3.3	2.2	2.0	1.6	1.3	1.4	1.6	1.0	1.	1.3	1.	1.2	1.	1.	0.	1.
A	8	6	0	9	9	4	3	4	00	9	18	3	09	50	98	05
	1.8	1.5	1.0	1.7	0.9	1.0	1.5	1.1	0.	0.9	1.	0.8	1.	1.	0.	1.
B	3	2	5	5	6	9	9	0	98	8	31	3	31	21	82	35
	1.4	1.3	1.1	1.3	1.0	1.0	1.2	1.0	1.	1.0	1.	0.7	1.	1.	0.	1.
C	7	9	1	2	8	3	9	2	07	1	31	9	28	01	85	20
	0.5	0.5	0.3	1.5	0.4	0.8	1.3	1.1	0.	0.9	0.	0.8	1.	1.	0.	1.
D	2	8	5	0	3	1	7	0	45	6	94	6	20	13	97	14
	0.5	0.5	0.3	1.6	0.3	0.9	1.6	1.0	0.	0.9	0.	1.0	1.	1.	1.	1.
E	2	5	2	1	4	4	0	1	37	2	89	6	24	27	01	00
	1.1	0.5	1.7	0.6	0.6	2.8	0.8	0.7	0.	1.9	1.	2.1	1.	0.	1.	0.
F	4	3	3	6	1	5	7	6	31	6	31	8	05	83	12	68
	1.6	1.6	1.1	1.4	1.0	1.0	1.5	0.9	1.	1.0	1.	1.0	1.	1.	1.	0.
G	6	9	3	7	9	4	5	5	00	9	00	4	61	05	01	94

	1.0	1.0	0.6	1.6	0.8	0.7	1.1	1.3	1.	0.8	1.	0.7	1.	1.	1.	1.
H	0	0	1	4	4	2	9	8	00	4	00	2	00	19	00	38
	0.6	N/	0.4	1.5	1.0	0.4	N/	N/	1.	1.0	1.	0.4	N/	N/	N/	N/
I	7	A	2	8	0	2	A	A	00	0	00	2	A	A	A	A

where  $CEC_{crs} * CTC_{crs} = CM_{crs}$ ,  $PCEC * SCEC * PCTC * SCTC = CM_{crs}$ ,  $PCEC * PCTC = CM_{vrs}$ ,  $PCEC * SCEC = CEC_{crs}$ ,  $PCTC * SCTC = CEC_{crs}$ ,  $PEC * PAEC * SEC * SAEC * PTC * PPE * STC * SPE = CM_{crs}$ ,  $PEC * PAEC * PTC * PPE = CM_{vrs}$

TABLE 7: MT (2004) Cost Malmquist and its 2 And 4 -Factor Decompositions (CRS)

DMU	CMc	CECc	CTCc	EC	AEC	TC	PE
a	3.38	2.00	1.69	1.18	1.70	1.07	1.57
b	1.83	1.05	1.75	1.28	0.82	1.07	1.64
c	1.47	1.11	1.32	1.40	0.80	1.09	1.20
d	0.52	0.35	1.50	0.42	0.82	1.17	1.29
e	0.52	0.32	1.61	0.33	0.98	1.26	1.28
f	1.14	1.73	0.66	0.41	4.26	1.18	0.56
g	1.66	1.13	1.47	1.00	1.13	1.62	0.91

h	1.00	0.61	1.64	1.00	0.61	1.00	1.64
i	0.67	0.42	1.58	1.00	0.42	1.32	1.20

Where  $EC * AEC * TC * PE = CMcrs$ ,  $EC * AEC = CECcrs$ ,  $TC * PE = CTCcrs$ ,  $PEC * SEC = EC$ ,  $PAEC * SAEC = AEC$ ,  $PTC * STC = TC$ ,  $PPE * SPE = PE$

Table 4

year	avg_BI	avg_HHI	avg_LI
2020	0.5085494	0.1932187	0.3204300
2019	0.4850043	0.2064701	0.2874256
2018	0.5112448	0.2135175	0.2916964
2017	0.5357544	0.1918033	0.2945073
2016	0.5369885	0.1958679	0.3046626
2015	0.5119705	0.2061561	0.2844355

2014	0.4737064	0.2052675	0.2987510
2013	0.5056175	0.1975339	0.2988832
2012	0.4454194	0.1969867	0.3159099
2011	0.5364560	0.1942183	0.2943259
2010	0.4914103	0.1887592	0.2974884
2009	0.4990635	0.1904770	0.2963962
2008	0.4689895	0.1956593	0.3062955
2007	0.5064436	0.2014314	0.2884068
2006	0.5131156	0.2012067	0.2821503
2005	0.4740906	0.1973555	0.2982879
2004	0.4537849	0.1963945	0.3036203

2003	0.5088416	0.2009209	0.3010850
2002	0.5408123	0.2046788	0.3006004
2001	0.4485796	0.2037560	0.2891867
2000	0.5119143	0.2005945	0.3354972

