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ESTIMATING GLOBAL COST FRONTIER SHIFT AND GLOBAL COST MALMQUIST INDICES OF FIRMS: AN APPLICATION TO GHANAIAN BANKS

BY

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DECLARATION

I, Francis Wayem, do hereby declare that this work is the result of my research and has not been presented by anyone, either in part or in whole, for any academic award in this or any other university. All references used in the work have been duly and fully acknowledged. I bear sole responsibility for any shortcomings.

23RD MAY 2025

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CERTIFICATION

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

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DEDICATION

I dedicate this work to God Almighty, my parents and siblings, Mr. Samuel Wayem, and Madam Rose Aku Tetteh for their immense support and encouragement. Special dedications also to my mentors and advisors, Dr. Godfred Amewu, Dr. Kwaku Ohene-Asare, Esq Yaw Sarpong Boateng, Mr. Kofi Amoah Sarpong, and Mr. Kow Sackey for trusting in my capabilities and advising and guiding me through my academic and social life.

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LIST OF ACRONYMS AND ABBREVIATIONS

AE	- Allocative efficiency
CE	- Cost efficiency
CM	- Cost Malmquist
CMPI	- Cost Malmquist Productivity Index
CRS	- Constant Returns to Scale
CTI	- Cost Technical Index
DEA	- Data Envelopment Analysis
DMU	- Decision Making Unit
FDH	- Free Disposable Hull
GAEC	- Global Allocative Efficiency Change
GCEC	- Global Cost Efficiency Change
GCFS	- Global Cost Frontier Shift
GCMI	- Global Cost Malmquist Index
GEC	- Global Efficiency Change
GFS	- Global Frontier Shift
GMI	- Global Malmquist Index
GPCEC	- Global Pure Cost Efficiency Change
GPCTC	- Global Pure Cost Technical Change
GPE	- Global Price Effect

GSCEC - Global Scale Cost Efficiency Change

LPP - Linear Programming Problem

MPI - Malmquist Productivity Index

ROA - Return on Assets

ROE - Return on Equity

RTS - Returns to Scale

SFA - Stochastic Frontier Analysis

TCE - Transaction Cost Economics

TCT - Transactions Cost Theory

TE - Technical Efficiency

TI - Technical Index

VRS - Variable Returns to Scale

ABSTRACT

This study proposes a novel Global Cost Malmquist Index (GCMI) to assess productivity changes for firms, incorporating both cost efficiency and technological change from a global perspective. The GCMI extends existing productivity measures by considering cost factors and providing a comprehensive view across all firms and time periods.

Applied to the Ghanaian banking sector from 2000 to 2022, the GCMI revealed an average annual productivity decline of 5.5%. This decline can be attributed to regulatory reforms, economic instability, the financial sector clean-up, and global events like the 2008 financial crisis and the COVID-19 pandemic. The comparative analysis demonstrated the GCMI's superior sensitivity to short-term productivity shifts compared to existing cost measures.

This research contributes to productivity measurement literature and provides valuable insights for policymakers and bank managers in developing economies. The GCMI offers a more nuanced understanding of banking sector performance, enabling more informed decision-making and targeted interventions to enhance productivity and competitiveness.

CHAPTER ONE

INTRODUCTION

1.1 Background

Performance, which encompasses productivity and efficiency is fundamentally about achieving more with the resources available, it represents the relationship between outputs and inputs. Measuring performance is essential for identifying how effectively resources are being utilised, and highlighting areas for improvement (Tangen, 2005). Measuring also provides data-driven insights that support decision-making, goal-setting, and strategic planning. Consistent measurement enables benchmarking, allowing comparisons over time or against industry standards. Ultimately, tracking productivity ensures that efforts lead to meaningful outcomes and supports continuous improvement and sustainable development (Purba et al., 2021).

The approach to efficiency measurement can be categorised into a single input-output measure or a multiple input-output measure depending on the complexity of the inputs and outputs involved. The parametric and non-parametric methodologies are approaches employed to assess efficiency. The single input-output approach is the simplest of measuring efficiency as the ratio of a single output to a single input. The multiple input-output approach is a more complex way of measuring efficiency where firms employ multiple inputs to produce multiple outputs (Yeşilyurt et al., 2021). The single input-output approach is straightforward with clearly defined inputs and outputs. Still, it cannot provide a comprehensive view of efficiency in systems, whereas the multiple input-output approach offers a more comprehensive view of efficiency in multifaceted systems. The parametric methodology relies on a specified functional form and statistical techniques, an example is the Stochastic Frontier Analysis (SFA), which separates inefficiency from random error in productivity estimates. Parametric methods are useful when there is a need to model the relationship between inputs and outputs based on economic theory. The non-parametric methodology does not assume a specific functional form, a key example is the Data Envelopment Analysis (DEA), which uses linear programming to evaluate the relative efficiency of decision-making units. Non-parametric methods are flexible and data-driven, ideal for benchmarking and comparing entities with similar functions (Cova-Alonso et al., 2021; Wanke et al., 2020; Yeşilyurt et al., 2021).

Data Envelopment Analysis (DEA) is a nonparametric Linear Programming (LP) frontier optimisation approach for evaluating the relative efficiency of homogeneous decision-making units (DMUs) (Camanho & D'Inverno, 2023; Daraio et al., 2020). These firms use multiple inputs to generate multiple outputs based on the minimum extrapolation principle of convexity and strong monotonicity (Zhu et al., 2022). DEA was first propounded by Charnes, Cooper and Rhodes (CCR) (1978) under constant return to scale (CRS), and extended by Banker, Charnes and Cooper (BCC) (1984) under variable return to scale (VRS). The technique fundamentally evaluates the relative efficiency of DMUs, using the distance function and the efficiency can be decomposed into the mix, scale, pure-technical, allocative cost and profit scores. DEA has received many empirical applications in several industries, including banking (Henriques et al., 2020; Oredegbe, 2020), insurance (Cummins et al., 2010; Kaffash et al., 2020), energy (Mohd Chachuli et al., 2020; Ohene-asare et al., 2017), agriculture (Atici & Podinovski, 2015; Toma et al., 2015), tourism & hospitality (Dobrovič et al., 2021; Nurmatov et al., 2021), healthcare (Dénes et al., 2017; Kohl et al., 2018), aerospace (Dong et al., 2015; Joo et al., 2020), sport (Bhat et al., 2019; Meza et al., 2015), telecommunication (Dehghani Sadrabadi et al., 2023; Valizadeh & Ghiyasi, 2023), education (Camanho et al., 2023; Shero et al., 2022), etc.

DEA has over the years been extended to the slacks-based model (Tone, 2001), Window Analysis (Charnes et al., 1983), Multidirectional Efficiency Analysis (Asmild et al., 2003; Bogetoft & Hougaard, 1999), Malmquist Index (Färe et al., 1992) etc. While efficiency measures performance at a time, the Malmquist Index (MI) measures performance between two time periods (Althin, 2001). The MI has subsequently been extended over the last few decades, to incorporate Scale Decomposition (Ray & Desli, 1997), Sequential Malmquist (Shestalova, 2003), Meta Malmquist (Battese et al., 2004), Global Malmquist Index (Pastor & Lovell, 2005), Pseudo Malmquist (Camanho & Dyson, 2006), Global Frontier Shift Component (GFS) of the Global Malmquist Index (GMI) (Asmild & Tam, 2007), Global Malmquist Index Luenberger (Oh, 2010), Biennial Malmquist Index (Pastor et al., 2011), Global Cost Malmquist (Tohidi et al., 2012), Metafrontier Cost Malmquist (Huang et al., 2015), Overall Malmquist Index (Afsharian & Ahn, 2015), etc.

The GFS component of the GMI by Asmild and Tam (2007) gives an overall measure of the frontier movement or technological change, unlike the classical Mamlquist which computes the frontier shift specifically to each observation before aggregating these local measures into an overall measure. The advantages of the GFS and the global indices are that they provide a better estimation of the true frontier shift because they measure efficiency from the perspective of all firms across all time periods relative to a particular time period. Also, they are easy to compute, can incorporate unbalanced panels without a loss of information, are useful for sparsely populated technology sets, for frontiers that change shape over time, and for comparing group differences (Asmild & Tam, 2007). However, a drawback of the GFS and the global indices is that they were designed for input and output quantities and not for input prices when producers are cost minimisers. In other words, they do not capture allocative elements in the frontier shift estimation. Maniadakis and Thanassoulis (2004), developed a Cost Malmquist Productivity Index which captures allocative elements when producers are cost minimisers. However, the CMPI has one key drawback: it does not compare efficiency between two time periods from a global perspective but rather from a local perspective. In other words, the efficiencies of DMUs in one period are measured relative to another period without considering all other periods which may bias the scores and render them non-generalisable. Such meta-estimation was undertaken by Tohidi et al., (2012) as a global cost Malmquist index, where a single meta frontier is created to estimate meta scores for DMUs of a localised group or time period. The purpose of this study is to estimate an alternative global cost frontier shift of the global Malmquist index of Asmild and Tam (2007) when input prices are known, and firms are cost minimisers. The proposed approach is applied to datasets of banks in Ghana over the period, 2000 - 2022. This will extend the existing productivity literature and help make managerial and industrial policy prescriptions concerning cost minimisation and technical and allocative efficiency changes. Therefore, the study makes a methodological and empirical contribution to academic literature.

1.2 Problem Statement

Several studies have extended and applied the Malmquist Index (Afsharian & Ahn, 2015; Asmild & Tam, 2007; Chen et al., 2023; Kneip et al., 2021; Maniadakis & Thanassoulis, 2004; Pastor et al., 2011, 2020; Pastor & Lovell, 2005; Tohidi et al., 2012; Walheer, 2022) yet, only a few have estimated it in cost terms and from a global perspective. Notable among the gaps identified are the following: first, the GMI by Asmild and Tam, (2007) did not capture allocative efficiency which forms an important part of the overall cost efficiency. Allocative efficiency measures the distance between the actual cost and the minimum cost at which a DMU may obtain an output once technical inefficiencies are eliminated. This is to say that firms will find it difficult to use the GMI scores in managerial and policy implications when these firms are cost minimisers. This study thus fills this gap. Second, the cost Malmquist index propounded by Maniadakis and Thanassoulis, (2004) does not compare efficiency between two time periods from a global perspective but only does so from a local perspective. That is to say that the efficiencies of DMUs in one period are measured relative to another period without considering all other periods, thus, making these scores non-generalisable. This issue is addressed in the current study. Third, empirical banking efficiency studies in Ghana lack a more expansive dataset time frame in their work. Recent papers include Adeabah et al., (2019), Blankson et al., (2022), Ofori-Sasu, et al., (2019a), Ofori-Sasu, et al., (2019b) and Owusu Kwateng et al., (2020). They all considered datasets of time frames below 13 years in their studies. The current study fills this gap.

1.3 Contributions of the Study

This study proposes a Global Cost Frontier Shift (GCFS) and a Global Cost Malmquist Index (GCMI) when input prices are known and firms minimise cost. The proposed approach is applied to datasets of banks in Ghana over the period 2000 - 2022. The proposed index has important implications for managerial practice and policy formulation.

i. First, managers can improve their performance over time by changing their input mix to produce their outputs when allocative efficiency scores are known.

ii. Second, managers will gain the ability to measure price effects over time and take appropriate actions by employing technologies that help reduce costs.

iii. Third, a unique contribution of this study, is the extension of the Global Frontier Shift and the Global Malmquist Indices to the Global Cost Frontier Shift and Global Cost Malmquist indices incorporating allocative efficiency change.

iv. Fourth, this study is a novel application of the proposed Global Cost Malmquist Indices to the Ghanaian banking industry.

v. Fifth, the study adds to the literature by comparing the proposed Global Cost Malmquist Index with the Cost Malmquist Index of Maniadakis and Thanassoulis (2004), the Global Cost Malmquist Index of Tohidi et al (2012) and the Global Malmquist Index of Asmild and Tam (2007).

vi. Sixth, policymakers will gain an in-depth insight into dynamic productivity in the Ghanaian banking industry to help formulate policies as this study considers a more expansive time frame of 23 years to provide more comprehensive technical and cost efficiency changes.

1.4 Research Objectives

The purpose of this study is to propose a Global Cost Frontier Shift (GCFS) of the Global Cost Malmquist Index for firms and apply the proposed estimation to a dataset of banks in Ghana. The objectives of the study are:

i. To model the Global Cost Frontier Shift and formulate the Global Cost Malmquist Indices that are transitive and capture true frontier shift of firms.

ii. To decompose the Global Cost Malmquist Index into a four-factor model.

iii. To use the formulated model to estimate the Global Cost Malmquist Indices of the banking sector in Ghana.

iv. To contrast the proposed model with the existing Cost Malmquist Index of Maniadakis and Thanassoulis (2004), and the Global Cost Malmquist Index of Tohidi et al (2012).

1.5 Research Questions

i. What is the best formulation for the Global Cost Frontier Shift and the Global Cost Malmquist Indices of firms?

ii. To what extent can the Global Cost Malmquist Indices be decomposed into a four-factor model?

iii. Does the banking sector in Ghana experience positive or negative cost productivity change?

iv. Is there a statistically significant difference between the proposed index and the existing Cost Malmquist Index of Maniadakis and Thanassoulis (2004), and the Global Cost Malmquist Index of Tohidi et al (2012)?

1.6 Limitations of the study

Limitations foreseen during the study shall include disparate measurements arising from unbalanced panel estimations of the Malmquist Index and the tendency for non-circularity when comparing three or more technological frontiers.

1.7 Thesis Structure

The thesis is structured as follows: Chapter One provides the background to the study; it defines the purpose of the study and the identified gaps in the literature that led to the conceptualised problem statement. The research objectives and questions are mentioned here, as well as the contributions and limitations of this study. The theoretical framework and empirical review of existing literature in the field of the study are detailed in Chapter Two of the thesis. Chapter Three outlines the methodology used in the research and the variables employed. In Chapter Four, the findings from the research are discussed, and the conclusions, recommendations, and policy suggestions are outlined in Chapter Five of the study.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The chapter is divided into two major sections that span an exposition of some theories that underpin the study and a review of studies that have applied the global Malmquist indices. The review then delves into efficiency and productivity studies in the banking industry.

2.2 Theoretical Review

The theoretical review focuses on the first major section of the literature review by discussing the theories that are key to this study. These theories are the neoclassical growth theory (Solow, 1956), transactions cost theory (Williamson, 1979), and global systems theory (Wallerstein, 1976).

2.2.1 Neoclassical Growth Theory

Productivity is a measure of output per unit of input in an economic context (Emmenegger & Eldin, 2023), in theory, productivity growth is classified under the Classical, Neoclassical, and Endogenous growth models. The Classical growth approach was championed in the nineteenth century by Adam Smith, extended by David Ricardo and Thomas Robert Malthus in terms of production and demography, and further explained by Harrod, (1939) and Domar, (1946), in terms of savings and capital. The Classical Model was then extended in later years to incorporate behaviour, where the organisation is seen as a social system, hence human actions do affect performance (Zhao & Lin, 2019). This extended approach is known as the Neoclassical Model, mainly championed by Solow, (1956) and Swan, (1956).

A Cobb-Douglas production function, which connects output to inputs like capital and labour, is frequently used in neoclassical growth theory.

$$Y_t = F(K_t, L_t, A_t) = AK^{\alpha}L^{1-\alpha} \quad (2.1)$$

where Y_t represents output, K_t denotes capital, L_t implies labour, and A_t represents the level of technology, all at time *t* (Solow, 1956; Swan, 1956). It assumes constant returns to scale (CRS) and thus implies that (2.1) can be expressed in terms of per worker terms by multiplying both sides by $1/L_t$ to obtain:

$$y_t = f(k_t, A_t) = Ak^{\alpha} \quad (2.2)$$

The idea influenced later theories in economics and several other fields, and it has been crucial in laying the groundwork for understanding the factors that contribute to long-term economic growth (Lucas, 2003; Prescott, 1988). In addition to laying the groundwork for future research on the significance of capital accumulation, the drivers of technical innovation, and the implications of human capital for growth, it has also made economic growth possible (Acemoglu, 2012).

2.2.2 Transaction Cost Theory

Cost in an economic term can be said to be what individuals and firms give up to obtain something else, hence, cost theories offer approaches that help understand costs of production that allow individuals and firms to determine the level of output that gives the greatest level of benefit at the lowest cost (Israel, 2018; Mahanty, 1980). For firms, cost is critical in decision-making and provides the basis for pricing. There are varying concepts of cost that firms consider under various circumstances, the fundamental difference in the following cost concepts; accounting cost, economic cost, production cost, actual cost, opportunity cost, agency cost, direct and indirect cost, incremental cost, sunk cost, implicit and explicit cost etc (Mahanty, 1980). define the modalities in the managerial decision-making process.

The transaction cost theory was mainly championed by Williamson, (1979). The premise of the theory is that economic activity assigned to firms is done in such a way as to minimise costs associated with transactions. A world of opportunistic individuals bounded by rationality is associated with high transaction costs. The firm therefore has several advantages as it is more efficient and hence replaces the individual market (Dugger, 1984). The ability of firms to be more efficient leads to a low transaction cost which has a knock-on effect on boosting economic growth (North, 1992). From the transaction cost theory, asset specificity, uncertainty, and production cost are the key attributes between transaction and organisational structures that minimise cost. The transaction cost theory recommends organisational models that minimise fixed and transaction costs, and firms are capable of integrating and forming alliances when these cost minimisations are achieved (Williamson, 1979).

2.2.3 Global System Theory

Global Systems Theory, also known as World-Systems Theory, offers a macro-scale approach to analysing social and economic patterns on a global level. Primarily developed by Immanuel Wallerstein in the 1970s, this theory builds upon dependency theory and Marxist concepts, presenting a holistic view of the world economy as an integrated system rather than a collection of independent nation-states (Wallerstein, 1976).

The origins of Global Systems Theory can be traced to mid-20th-century works in sociology and economics. The Prebisch-Singer hypotheses laid the foundational groundwork by arguing that the terms of trade between primary products and manufactured goods tend to deteriorate over time, disadvantaging primary product exporters (Toye & Toye, 2003).

The theory posits three main structural components of the world system. First, core countries are industrialised, wealthy nations that exploit peripheral countries for labour and raw materials, specialising in high-skill, capital-intensive production. Second, peripheral countries are less developed countries that provide raw materials and cheap labour to core countries, focusing on low-skill, labour-intensive production. Third, semi-peripheral countries act as a buffer between core and peripheral countries, exhibiting characteristics of both and potentially exploiting peripheral countries while being exploited by core countries (Wallerstein, 1976). A key aspect of the theory is the concept of "unequal exchange," where surplus value flows from peripheral to core countries, maintaining and reinforcing the hierarchical structure of the world system (Chase-Dunn & Grimes, 1995).

The theory has been applied to various fields beyond economics and sociology, including environmental studies, where it has been used to analyse global environmental degradation as a consequence of the world system's structure (Goldfrank, 1995). In the context of the insurance and banking industries, Global Systems Theory can provide valuable insights. It can help explain the global distribution of financial markets, with more sophisticated and capital-intensive products concentrated in core countries, while peripheral countries may have less developed sectors focusing on more basic products. The theory could also shed light on the flow of capital from peripheral to core countries, and the role of semi-peripheral countries in regional financial markets (Babones, 2015).

However, Global Systems Theory has been criticized for oversimplifying complex global relationships and fails to adequately account for the agency of individual nations or the impact of technological change (Sanderson, 2012). Others contend that the strict categorization of countries into core, semi-peripheral, and peripheral is too rigid and doesn't capture the nuanced reality of the modern global economy (Arrighi, 2005). Despite these criticisms, Global Systems Theory remains an influential framework for understanding global economic patterns and relationships. Its holistic approach and emphasis on historical context provide a valuable perspective for analysing complex global phenomena, including the evolution and current state of the global financial industry.

2.3 Empirical Review

2.3.1 Literature on Cost Malmquist Productivity Studies

The classical Malmquist productivity index (MPI) is an input index and as such does not take into consideration certain aspects of efficiency such as allocative efficiency. In order to determine how a technically efficient firm can choose an optimal input mix in relation to input costs and still economically meet its output targets, allocative efficiency is required (Ohene-Asare et al., 2019).

In view of this gap inherent in the estimation of the classical MPI, Maniadakis and Thanassoulis, (2004) developed the cost Malmquist productivity change index (CMPI), as an extension of the classical MPI, to assess the productivity change of DMUs that have known input prices and are cost minimisers. The CMPI addresses the lack of input mix effects connected to the classical MPI. We refer to this specific shift in the input mix as an allocative efficiency change. It takes into account the discrepancy between the lowest feasible cost and the actual cost at which a DMU may generate its outputs after accounting for all technological inefficiencies (Maniadakis & Thanassoulis, 2004). The Cost Malmquist Productivity Index (CMPI) has undergone several significant extensions in recent literature, enhancing its applicability and analytical power. Tohidi et al., (2012) introduced a global CMPI, notable for its circularity and provision of a single frontier. Huang et al., (2015) further developed the concept by proposing a meta CMPI under meta production technology, which allows for the analysis of group-specific cost frontier convergence to the meta cost frontier.

Thanassoulis et al., (2015) expanded the CMPI's utility by developing an index for comparing groups of DMUs in cost terms, particularly useful for analysing geographically diverse firms performing similar functions. Walheer, (2018a, 2018b) made additional contributions by extending the CMPI to accommodate multi-output settings with output-specific inputs, without assuming input prices, and enabling simultaneous comparisons of DMU groups and individual DMUs based on specific outputs.

2.3.1 Empirical Review of Cost Efficiency and Productivity Studies in Banking Industry

Cost productivity and efficiency studies in the banking sector have employed diverse methodologies, predominantly focusing on DEA and Malmquist index approaches. These studies can be broadly categorised into those examining developed markets, emerging economies, and those introducing methodological innovations.

The methodological complexity is explored by Nguyen and Pham, (2020), who provides a comparative analysis of cost efficiency in Vietnamese banks using DEA and Stochastic Frontier Analysis (SFA). Their investigation reveals the complementary nature of these analytical approaches, demonstrating that no single methodological framework can comprehensively capture the intricate dynamics of banking performance.

Fukuyama et al., (2020) contribute to this methodological discourse through a Nerlovian cost inefficiency two-stage DEA model, specifically examining the Turkish banking system. Their research highlights the importance of multi-stage analytical approaches that can capture the nuanced interactions between different operational dimensions. Henriques et al., (2020) offer a critical reflection on two-stage DEA methodologies, addressing terminological controversies and charting future research directions. Their work underscores the evolving nature of efficiency measurement techniques, emphasising the need for continual methodological refinement.

The contextual specificity of banking efficiency becomes evident in regional studies. Sultana and Rahman, (2020) investigate the determinants of bank cost efficiency in Bangladesh, revealing how local economic environments significantly influence institutional performance. Similarly, Oredegbe, (2020) examines cost efficiency determinants in the Canadian banking industry, demonstrating the importance of national and regional contexts in performance evaluation. Technological innovation emerges as a critical factor in banking efficiency. Cho and Chen, (2021) explore the impact of financial technology on China's banking industry using a meta frontier cost Malmquist productivity index. Their research illustrates how technological disruption fundamentally reshapes institutional capabilities and performance measurement approaches. Antunes et al., (2024) combines DEA with Machine Learning Perceptron and Simultaneous Specification Robust Procedure (MLP-SSRP) to analyse cost efficiency in Chinese banks, representing a cutting-edge approach that integrates advanced computational techniques with traditional efficiency measurement methodologies.

However, none of these studies employed a global cost Malmquist technique of analysing the performance of all DMUs in all time periods over a study period. It is necessary to assess this because the technological change effect is more global than local (Asmild & Tam, 2007). For research on Ghanaian banks using global cost frontier shift and global cost Malmquist indices, these studies provide a solid foundation. They suggest the importance of adapting methodologies to the specific context of Ghana's banking sector, considering technological advancements.

Furthermore, the findings from these studies indicate that factors such as bank size, operational expenses, market share, and regulatory environment are likely to be significant in determining cost efficiency in the Ghanaian context. The global perspective offered by the proposed global cost frontier and Malmquist index approaches could provide new insights into how Ghana's banking sector efficiency performs over time.

2.3.2 Global Frontier Studies

The field of global frontier studies has seen significant advancements in recent years, particularly with the development and refinement of global Malmquist index (GMI) techniques. These methodologies have proven invaluable in comparing efficiency and productivity across diverse sectors, including banking, manufacturing, and transportation, offering robust frameworks for analysis across different countries, time periods, and operating environments.

The foundation for this study was laid by Asmild and Tam, (2007), who proposed a method for estimating global frontier shifts and global Malmquist indices. Their approach addressed the circularity problem inherent in traditional Malmquist indices, allowing for more consistent comparisons across multiple periods and decision-making units (DMUs). Emrouznejad and Yang, (2016) developed a framework for measuring the global Malmquist–Luenberger productivity index that incorporated CO_2 emissions, initially applying it to Chinese manufacturing industries. This methodology opened new avenues for research, particularly in assessing environmental efficiency alongside traditional productivity measures. The integration of environmental factors into productivity analyses has become increasingly important, as evidenced by several recent studies. Liu et al., (2021) employed a Global Malmquist-Luenberger Index approach to analyse green productivity growth in road transportation at the provincial level in China. Similarly, Cheng et al., (2022) used a global Malmquist index analysis to measure CO_2 emissions performance in China's construction industry. These studies demonstrate the versatility of global Malmquist techniques in addressing contemporary concerns about sustainability and environmental impact across various sectors.

In the realm of economic productivity, Mombini et al., (2020) proposed a new method for calculating the global Malmquist index, offering a more comprehensive view of productivity changes by considering both technical efficiency changes and technological changes on a global scale. This approach has particular relevance for banking studies, as it allows for a nuanced understanding of how banks in different countries adapt to technological advancements and regulatory changes.

2.3.4 Infeasibility Studies in DEA

Infeasibility is a persistent challenge in DEA, particularly when dealing with variable returns to scale (VRS) models or when conducting cross-period efficiency calculations. This issue arises when the linear programming problems underlying DEA models have no feasible solutions, potentially leading to incomplete or biased efficiency analyses (Seiford & Zhu, 1999). The banking industry, characterised by its dynamic nature and diverse operational scales, is particularly susceptible to such infeasibility issues.

Seiford and Zhu, (1999) were among the first to address this problem systematically, proposing super-efficiency models to resolve infeasibility in VRS DEA models. Their approach allowed for the ranking of efficient decision-making units (DMUs) and provided a method to circumvent infeasibility in certain cases.

A significant advancement in addressing infeasibility, particularly relevant to productivity analysis in banking, came with the introduction of the biennial Malmquist index by Pastor et al., (2011). This index effectively mitigates infeasibility issues in cross-period comparisons by constructing a single frontier from two adjacent time periods, thereby ensuring a feasible reference set for all observations. More recently, Aparicio et al., (2017) developed a comprehensive approach to deal with infeasibilities in productivity measurement. Their method, based on the directional distance function, provides a flexible framework that can be adapted to various DEA models and productivity indices.

In the context of banking efficiency studies, recent work has focused on developing robust methods to handle infeasibility while accounting for the sector's unique characteristics. For instance, Wanke et al., (2020) proposed a novel approach combining DEA with dynamic networks to address infeasibility in bank efficiency measurements, particularly in emerging markets where data inconsistencies are more common.

The ongoing development of methods to address infeasibility in DEA is crucial for obtaining reliable and comprehensive efficiency and productivity estimates in the banking industry. As banks continue to evolve in response to technological advancements, regulatory changes, and global economic shifts, the ability to conduct robust cross-period and cross-entity comparisons becomes increasingly important. Future research in this area is likely to focus on developing more flexible and adaptable models that can handle the complex and dynamic nature of modern banking operations while effectively mitigating infeasibility issues.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter delves into the intricacies of the data collection approach and the strategies used to assess the data. The chapter describes the research design, data sources, sampling strategy, and key methods to answer the research question and fulfil the study's goals and objectives.

3.2 Research Design

The philosophy underpinning this study is that of a critical realist and a positivist. The approach to theory is abductive, that is, it tests if the premises that would be identified in the study align with existing theory, to make an assertion and deduction, that is, to test if the existing theory conforms to the premise that shall be identified in the study to conclude. The research is quantitative, and it shall employ an evaluative means to compare the newly estimated model to existing models, it shall also employ an explorative means to gain insight into the performance of Ghanaian banks over the years and finally, it shall employ an explanatory means to gain insight into specific compositions of performance to know which components drive performance. The research strategy is archival and documentary, where data for the study are published data which exist in a secondary form (Saunders et al., 2007).

3.3 Sampling and Data Sources

The study mainly aims to propose a model to globally assess the performance of all homogenous DMUs at all time periods. The proposed model will be applied to the Ghanaian banking industry between the years 2000 and 2022. Out of the existing banks in operation between 2000 and 2022, an entity size of thirty-two (32) is used because datasets existed for all considered entities across all periods. Data is sourced from the published audited financial statements of these banks. A linear interpolation method was employed to fill out some missing values.

There will be three inputs, two outputs and three input prices. The inputs are customer deposits, personnel expenses and fixed assets (Adjei-Frimpong & Gan, 2014; Alhassan & Ohene-Asare, 2016; Jimborean et al., 2010; Novickytė & Droždz, 2018; Titko et al., 2014), the outputs are loans and advances to customers and investments in securities (Adusei, 2016; Amoah et al., 2018; Anagnostopoulos et al., 2022; Faraj & Övenç, 2023; Hassan & Jreisat, 2016) and the input prices are interest expense divided by customer deposit, personnel expense divided by total assets and other operating expense divided by fixed asset (Amin & Ibn Boamah, 2020; Faraj & Övenç, 2023; Jimborean et al., 2010; Sathye & Tel, 2001; Weill, 2004). Researchers who have studied the banking industry have used these variables in their research work.

3.4 Frontier Efficiency and Productivity Change Analysis

Frontier efficiency, or technical efficiency, assesses how well a firm utilises resources to generate goods and services compared to the firms that performed best in the industry or on the efficiency frontier (Koopmans, 1951). The efficiency frontier depicts an industry's production potential, indicating the maximum level of outputs that can be obtained with a given level of inputs or the minimum combination of inputs that can be used to obtain a given level of outputs. The efficiency frontier is formalised using the distance functions introduced by Shephard (1953). Firms operating on the efficiency frontier are technically efficient, whereas those operating below the efficiency frontier are considered technically inefficient. Efficiency analysis is conducted using frontier efficiency techniques to assess the efficiency of DMUs. Efficiency techniques are divided into two main types: parametric and non-parametric.

Parametric efficiency analysis techniques adopt a functional form for the production function, whereas a non-parametric efficiency analysis does not adopt a specific functional form (Fried et al., 2008).

Of the many frontier efficiency performance analysis techniques, DEA and SFA have gained significant interest in productivity change analysis of DMUs (Lampe & Hilgers, 2015). Charnes, Cooper & Rhodes (CCR) (1978), inspired by the works of Farrell (1957) and Debreu (1951), introduced DEA under CRS. In their studies, Debreu (1951) explained the theoretical basis of the efficiency of production in an economy and the important role of price systems in the efficient allocation of resources whereas Farrell (1957) emphasised the need for a better measure of efficiency that considers all inputs yet avoids the index number problem.

DEA is a non-parametric linear programming approach that leverages the single-input-single-output technical efficiency measure to a multiple-inputs-multiple-outputs measure by creating relative efficiency scores of the inputs and outputs for measuring the relative performance of the DMU (Charnes et al., 1978) whereas SFA (Aigner et al., 1977; Meeusen & van den Broeck, 1977) is a parametric frontier methodology that assumes a functional form, and statistically and econometrically estimates the function's parameters through maximum likelihood using data from the DMUs. DEA carries some advantages over other methods such as ratio analysis, accounting valuations and comparison of the performance of firms to engineered standards (Arsad et al., 2022). Unlike these traditional methods of assessing productivity, DEA focuses on 'outcome measures' rather than 'process measures', handles weighting and assesses qualitative inputs better, creates a better functional relationship between inputs and outputs, and evaluates the performance of individual units of a group separately rather than use an average group score as is done in the other performance estimation methods (Gao & Zhang, 2022). However, DEA does not distinguish between random mistakes and inefficiency, hence, counting all departures from the frontier as inefficiency. Thus, a major criticism of DEA is that it is non-statistical in its approach to determining the performance of DMUs. This weakness is addressed using a bootstrapped technique as suggested in some studies (Simar & Wilson, 2000).

3.4.1 Data Envelopment Analysis (DEA)

DEA is a non-parametric mathematical LP methodology for assessing the relative efficiency and dynamic productivity of homogenous DMUs that use multiple incommensurate inputs and outputs based on the minimum extrapolation principle of strong free disposability and convexity. DEA creates a frontier for either an input, output, cost or profit using the best-performing DMUs (Mahmoudi et al., 2020; Rostamzadeh et al., 2021).

A DMU's distance from the created frontier is used to calculate its relative technical efficiency or inefficiency. The frontier DMUs are considered efficient, while the non-frontier DMUs are inefficient. The efficiency score of the DMUs is computed as the ratio of weighted outputs to weighted inputs, where the weights are chosen in a manner to maximise the DMU's efficiency while keeping the efficiency scores of the other DMUs constant (Lampe & Hilgers, 2015). Next, it ranks the DMUs, pinpoints improvement benchmarks, and identifies the sources of inefficiency for the DMUs dominated by the dominant DMUs.

Unlike the approach DEA takes to compute the efficiencies of DMUs, other traditional methods of computing the efficiency of DMUs use return on asset (ROA), return on equity (ROE), and price-earnings (P/E), employing static ratios. Since these methods are easier to calculate and comprehend, they do not consider multiple inputs and outputs in their computation (Arsad et al., 2022). These ratios assume constant returns to scale that do not necessarily hold in real-world settings (Feroz et al., 2003), and also do not set benchmarks for inefficient DMUs to emulate (Giokas, 2008). DEA has been critiqued for not effectively differentiating between random noises and efficiencies, hence, the bootstrap DEA technique of Simar & Wilson (2000) deals with noises in DEA computations using partial frontiers.

3.4.2 Formalising the DEA Model

The DEA model is formulated based on certain assumptions set out in Banker et al., (1984) known as the minimum extrapolation principle are defined below:

Monotonicity (free disposability): DMUs can employ more inputs and produce fewer outputs. This infers that DMUs can be inefficient. If $(x', y') \in \Psi$, then

$$(x, y) = (x' + \alpha, y' - \beta) \in \Psi, \forall \alpha, \beta \geq 0 \quad (3.1)$$

Convexity: Convex combinations of feasible production plans are feasible as well. In other words, unobserved points on the line segment between two observed production points are feasible. FDH relaxes this assumption. If $(x', y') \in \Psi$, and If $(x'', y'') \in \Psi$, then

$$(x, y) = c\,(x', y') + (1 - c)\,(x'', y'') \in \Psi, \forall c \geq 0 \quad (3.2)$$

Additivity: The sum of feasible production plans is also feasible. If $(x', y') \in \Psi$, and $(x'', y'') \in \Psi$, then

$$(x, y) = (x', y') + (x'', y'') \in \Psi \quad (3.3)$$

No free lunch: An output cannot be attained unless an input is employed. Suppose $x' \in X$ and $y' \in Y$, then $(x', y') \in \Psi$ only if $x' \in \Psi$.

Returns to scale: Homogeneity conditions or rescaling is possible. The technology within an industry can either be VRS (when size matters) or CRS (full and equal proportionality between all X's and Y's). CRS implies that If $(x', y') \in \Psi$, then

$$(x, y) = d\,(x', y') \in \Psi, \forall d \geq 0 \quad (3.4)$$

To formalise the basic DEA CCR model, assume there are $j = 1,\ldots,k$ DMUs, in $t = 1,\ldots,T$ periods each of which employs non-negative m inputs (denoted by $x \in \mathfrak{R}_{+}^{m}$) to produce non-negative s outputs (denoted by $y \in \mathfrak{R}_{+}^{s}$). In this case, the production possibility set in period t containing all the observed input-output combinations, is given by: $\psi = \{(x, y) \in \mathfrak{R}_{+}^{m+s} | x \text{ can produce } y\}$, $DMU_j, j = 1, \ldots, k$; $X_{ij} \in \mathfrak{R}_{+}^{m}, i = 1, \ldots, m$; $Y_{rj} \in \mathfrak{R}_{+}^{s}, r = 1, \ldots, s$.

From the above possibility set, the original CCR model (Charnes et al., 1978) is given in ratio form as:

$$\min_{\lambda,\theta} \theta = \frac{\sum_{i=1}^{m} v_i x_{io}}{\sum_{r=1}^{s} u_r y_{ro}} \tag{3.5}$$

Subject to:

$$\frac{\sum_{i=1}^{m} v_i x_{ij}}{\sum_{r=1}^{s} u_r y_{rj}} \geq 1 \text{ ; j=1,…,k}$$

$$v_{i,} u_i \geq 0$$

where v_i and u_r are respective weights attached to the inputs and outputs.

The linear programming dual (Charnes et al., 1978) is given as follows:

$$\min_{\lambda,\theta} \theta = \sum_{i=1}^{m} \omega_i x_{io} \tag{3.6}$$

Subject to:

$$-\sum_{r=1}^{s} \mu_r y_{rj} + \sum_{i=1}^{m} \omega_i x_{ij} \geq 0,$$

$$\sum_{i=1}^{m} \mu_r y_{ro} = 1,$$

$$\mu_{i,} \omega_i \geq 0$$

Assuming the minimum extrapolation principles of monotonicity, convexity, additivity, no free lunch, and returns to scale, the input-oriented DEA model (Banker et al., 1984; Charnes et al., 1978; Färe & Primont, 1995) can be written as:

$$\theta^t(y^t, x^t) = \min_{\lambda,\theta} \theta$$

$$s.t.: \begin{cases} \sum_{j=1}^{k} \lambda_j x_{ij}^t \leq \theta x_{i0}^t; \quad i = 1,2, \dots, m \\ \sum_{j=1}^{k} \lambda_j y_{rj}^t \geq y_{r0}^t; \; r = 1,2, \dots, s \\ \sum_{j=1}^{k} \lambda_j = 1 \text{ (VRS)} \\ \lambda_j \geq 0, \; x_i \geq 0; \quad j = 1,2, \dots, n \\ t = 1, 2, \dots, T \end{cases} \tag{3.7}$$

$$\theta^{t+1}(y^{t+1}, x^{t+1}) = \min_{\lambda,\theta} \theta$$

$$s.t.: \begin{cases} \sum_{j=1}^{k} \lambda_j x_{ij}^{t+1} \leq \theta x_{i0}^{t+1}; \quad i = 1,2, \dots, m \\ \sum_{j=1}^{k} \lambda_j y_{rj}^{t+1} \geq y_{r0}^{t+1}; \; r = 1,2, \dots, s \\ \sum_{j=1}^{k} \lambda_j = 1 \text{ (VRS)} \\ \lambda_j \geq 0, \; x_i \geq 0; \quad j = 1,2, \dots, n \\ t = 1, 2, \dots, T \end{cases} \tag{3.8}$$

$$\theta^{t+1}(y^t, x^t) = \min_{\lambda,\theta} \theta$$

$$s.t.: \begin{cases} \sum_{j=1}^{k} \lambda_j x_{ij}^{t+1} \leq \theta x_{i0}^t; \quad i = 1,2, \dots, m \\ \sum_{j=1}^{k} \lambda_j y_{rj}^{t+1} \geq y_{r0}^t; \; r = 1,2, \dots, s \\ \sum_{j=1}^{k} \lambda_j = 1 \text{ (VRS)} \\ \lambda_j \geq 0, \; x_i \geq 0; \quad j = 1,2, \dots, n \\ t = 1, 2, \dots, T \end{cases} \tag{3.9}$$

$$\theta^t(y^{t+1}, x^{t+1}) = \min_{\lambda,\theta} \theta$$

$$s.t.: \begin{cases} \sum_{j=1}^{k} \lambda_j x_{ij}^t \leq \theta x_{i0}^{t+1}; \quad i = 1,2, \dots, m \\ \sum_{j=1}^{k} \lambda_j y_{rj}^t \geq y_{r0}^{t+1}; \; r = 1,2, \dots, s \\ \sum_{j=1}^{k} \lambda_j = 1 \text{ (VRS)} \\ \lambda_j \geq 0, \; x_i \geq 0; \quad j = 1,2, \dots, n \\ t = 1, 2, \dots, T \end{cases} \tag{3.10}$$

This model minimises θ, representing the input orientation. Banker, Charnes & Cooper (BCC) (1984) proposed the convexity constraint, which is useful when firms do not operate on the same scale due to monopolistic competitive behaviours, non-robotic engineering activities, and other activities that set them apart from others in the same industry. When $\theta = 1$, the DMU is efficient. However, when $\theta < 1$, the DMU is said to be inefficient and when $\theta > 1$, the DMU is super-efficient (Farrell, 1957).

3.4.3 Malmquist Productivity Index (MPI)

Efficiency is a firm's ability to increase outputs or decrease inputs given inputs or outputs respectively at a time, while productivity examines performance over time. Productivity change analysis in DEA determines the performance of DMUs over time. It is a non-parametric approach that combines DEA and index number techniques to assess productivity growth and technological progress. Caves, Christensen, & Diewert (1982) developed the classical MPI, which measures productivity changes between two or more periods, and named it after Stern Malmquist (1953). Researchers desire the use of MPI because it is simple, easy to compute and compare results with prior studies, it adopts a non-parametric approach in assessing productivity change of DMUs and it provides more insight into the drivers of productivity change. Färe, Grosskopf, Lindgren, & Roos (1992), estimated the classical MPI using DEA under CRS and decomposed it to the efficiency change (EC) index, which signifies managerial expertise and the technological change (TC) index, which is changes in the technology underlying the industry. Färe, Grosskopf, Norris and Zhang (1994) with a follow-up study decomposed the classical MPI into three-factor efficiency changes, namely, scale efficiency change (SEC), pure efficiency change (PEC), and technological change (TC)) under VRS. This revealed that the EC index components are PEC and SEC. Ray & Desli (1997) criticised the classical MPI decomposition of Färe et al., (1994) as being internally inconsistent and suggested another three-factor decomposition of the classical MPI to obtain PEC, PTC, and scale change (SCH), which considers both CRS and VRS technologies. The decomposition of Ray & Desli (1997) was criticised for ignoring input mix and output mix effects in later studies by Lovell (2003). Wheelock & Wilson (1999) also decomposed the classical MPI into four-factor decompositions, PEC, SEC, PTC, and scale technological change (STC) to address the weaknesses of the earlier decompositions.

There have been several extensions of the MPI to capture the estimation of various forms of productivity. Some of these extensions are the sequential Malmquist productivity index of Shestalova (2003), the cost Malmquist productivity index of Maniadakis & Thanassoulis (2004), global Malmquist productivity index of Pastor & Lovell (2005), sequential Malmquist Luenberger productivity index of Oh & Heshmati (2010), metafrontier Malmquist index by Oh & Lee (2010), biennial Malmquist index of Pastor, Asmild and Lovell (2011), global cost Malmquist productivity index of Tohidi, Razavyan & Tohidnia (2012), biennial Malmquist for negative data by Mohammadi & Yousefpour (2014), metafrontier cost Malmquist index of Huang, Juo & Fu (2015), overall Malmquist index of Afsharian & Ahn (2015), and the green total factor productivity measure of Chen et al., (2023).

The interest of this study is the global cost Malmquist productivity index which considers not only inputs and outputs but also, input prices of all DMUs in all periods in the computation.

3.4.4 Formalising the MPI

In formulating the Malmquist index estimation by Färe et al. (1992), we require efficiency in the current period, efficiency in the next period, efficiency of DMU in the next period relative to the frontier of DMU in the current period, and efficiency of DMU in the current period relative to the frontier of DMU in the next period. These are provided in equations *3.7* to *3.10* above.

$$M_i(x^t, y^t, x^{t+1}, y^{t+1}) = \left[\frac{\theta_c^t(x^{t+1}, y^{t+1})}{\theta_c^t(x^t, y^t)} \times \frac{\theta_c^{t+1}(x^{t+1}, y^{t+1})}{\theta_c^{t+1}(x^t, y^t)}\right]^{1/2} \tag{3.11}$$

This composite index is multiplicatively decomposed into EC and TC by Färe et al. (1992) as:

$$M_i(x^t, y^t, x^{t+1}, y^{t+1}) = \underbrace{\left[\frac{\theta_c^{t+1}(x^{t+1}, y^{t+1})}{\theta_c^t(x^t, y^t)}\right]}_{EC} \underbrace{\left[\frac{\theta_c^t(x^{t+1}, y^{t+1})}{\theta_c^{t+1}(x^{t+1}, y^{t+1})} \times \frac{\theta_c^t(x^t, y^t)}{\theta_c^{t+1}(x^t, y^t)}\right]^{1/2}}_{TC} \quad (3.12)$$

This composite index is further decomposed into PEC, SEC and TC by Färe et al. (1992) and PEC, PTC and SCH by Ray & Desli (1997) respectively in equations *3.13* and *3.14* as:

$$M_i(x^t, y^t, x^{t+1}, y^{t+1})$$

$$= \underbrace{\left[\frac{\theta_v^{t+1}(x^{t+1}, y^{t+1})}{\theta_v^t(x^t, y^t)}\right]}_{PEC} \times \underbrace{\left[\frac{\theta_c^{t+1}(x^{t+1}, y^{t+1})/\theta_v^{t+1}(x^{t+1}, y^{t+1})}{\theta_c^t(x^t, y^t)/\theta_v^t(x^t, y^t)}\right]}_{SEC}$$

$$\times \underbrace{\left[\frac{\theta_c^t(x^{t+1}, y^{t+1})}{\theta_c^{t+1}(x^{t+1}, y^{t+1})} \times \frac{\theta_c^t(x^t, y^t)}{\theta_c^{t+1}(x^t, y^t)}\right]^{1/2}}_{PTC} \quad (3.13)$$

$$M_i(x^t, y^t, x^{t+1}, y^{t+1})$$

$$= \underbrace{\left[\frac{\theta_v^{t+1}(x^{t+1}, y^{t+1})}{\theta_v^t(x^t, y^t)}\right]}_{PEC} \times \underbrace{\left[\frac{\theta_v^t(x^{t+1}, y^{t+1})}{\theta_v^t(x^t, y^t)} \times \frac{\theta_v^{t+1}(x^{t+1}, y^{t+1})}{\theta_v^{t+1}(x^t, y^t)}\right]^{1/2}}_{PTC}$$

$$\times \underbrace{\left[\frac{\theta_c^t(x^{t+1}, y^{t+1})/\theta_v^t(x^{t+1}, y^{t+1})}{\theta_c^t(x^t, y^t)/\theta_v^t(x^t, y^t)} \times \frac{\theta_c^{t+1}(x^{t+1}, y^{t+1})/\theta_v^{t+1}(x^{t+1}, y^{t+1})}{\theta_c^{t+1}(x^t, y^t)/\theta_v^{t+1}(x^t, y^t)}\right]^{\frac{1}{2}}}_{SCH} \quad (3.14)$$

This composite index is multiplicatively decomposed into PEC, PTC, SEC and STC by Wheelock & Wilson (1999) as:

$$M_i(x^t, y^t, x^{t+1}, y^{t+1})$$

$$= \underbrace{\left[\frac{\theta_v^{t+1}(x^{t+1}, y^{t+1})}{\theta_v^t(x^t, y^t)}\right]}_{PEC} \times \underbrace{\left[\frac{\theta_v^t(x^{t+1}, y^{t+1})}{\theta_v^{t+1}(x^{t+1}, y^{t+1})} \times \frac{\theta_v^t(x^t, y^t)}{\theta_v^{t+1}(x^t, y^t)}\right]^{1/2}}_{PTC}$$

$$\times \underbrace{\left[\frac{\theta_c^{t+1}(x^{t+1}, y^{t+1})/\theta_v^{t+1}(x^{t+1}, y^{t+1})}{\theta_c^t(x^t, y^t)/\theta_v^t(x^t, y^t)}\right]}_{SEC}$$

$$\times \underbrace{\left[\frac{\theta_c^t(x^{t+1}, y^{t+1})/\theta_v^t(x^{t+1}, y^{t+1})}{\theta_c^{t+1}(x^{t+1}, y^{t+1})\,/\theta_v^{t+1}(x^{t+1}, y^{t+1})} \times \frac{\theta_c^t(x^t, y^t)/\theta_v^t(x^t, y^t)}{\theta_c^{t+1}(x^t, y^t)/\theta_v^{t+1}(x^t, y^t)}\right]^{\frac{1}{2}}}_{STC} \qquad (3.15)$$

Färe et al. (1992) provided the first major decomposition of the Malmquist Index, breaking productivity change into two fundamental components. The first component, technical efficiency change, captures whether firms are moving closer to or further from their maximum potential given the technology available. The second component, technical change, measures shifts in the production frontier itself, capturing whether the maximum possible productivity has increased or decreased over time. However, Ray and Desli's (1997) key contribution was to introduce scale efficiency change as a separate component in the decomposition. This measures whether firms are operating at their optimal size. Building on these insights, Wheelock and Wilson (1999) further refined our understanding by introducing the concept of scale bias in technical change. This important addition recognises that technological improvements might not benefit all operational scales equally.

3.5 Global Malmquist Index (GMI)

The Malmquist index generally measures the productivity change of a DMU within two periods at a local level, but the global Malmquist index measures the productivity of a DMU at a global level over multiple periods either by way of creating a single frontier encompassing all DMUs in all period as estimated by Pastor & Lovell (2005) or by estimating all DMUs in all periods with each period frontier as estimated by Asmild & Tam (2007). Asmild & Tam (2007) argued, that technological change is a phenomenon that can be considered to be a global occurrence, that is caused by factors such as changes in economic conditions or improved technology becoming available to all DMUs in an industry. These factors can reasonably be assumed to be equal for all DMUs, so individual or local measures of technological changes are combined into an overall measure, generally using geometric means. They showed in their study a way to calculate global Malmquist indices and global frontier shift indices, offering a better valuation of the actual frontier shift. They showed how this approach betters the conventional aggregation approaches, especially for sparsely populated production possibility sets and frontiers that change shape over time. Furthermore, the global indices can be used for unbalanced panels without disregarding any information.

Building on thier work, Öttl et al., (2023) work, demonstrates the most direct methodological lineage to Asmild and Tam, (2007) original framework. This connection is not surprising given Asmild's involvement, but the paper significantly extends the original methodology through the integration of hyperbolic efficiency measures. This extension represents a natural evolution of the original concepts, maintaining the core principles of temporal analysis while introducing more sophisticated measurement techniques. The authors have effectively built upon the foundational treatment of inter-temporal dependencies while introducing novel approaches to between-group comparisons and enhanced statistical inference methods.

Walheer's, (2022) contribution represents an interesting bridge between Asmild and Tam, (2007) framework and modern group comparison methodologies. The paper's development of global Malmquist and cost Malmquist indexes for group comparison shows a sophisticated evolution of productivity measurement techniques. While maintaining some conceptual links to Asmild and Tam, (2007) treatment of technological change, Walheer, (2022) introduces innovative approaches to handling group heterogeneity and cost efficiency considerations. The methodology addresses the challenges of comparing groups operating under different technological conditions, an aspect not fully explored in the original Asmild and Tam, (2007) framework. This work demonstrates how foundational concepts can be adapted and extended to address increasingly complex analytical challenges in productivity measurement.

Aparicio and Santín, (2024) research shows substantial methodological ties to Asmild and Tam, (2007) work, particularly in their treatment of sequential technological change. However, they introduce significant innovations through their "virtual units" concept and more complex intermediate technology sets. This represents a thoughtful evolution of the original methodology, where the fundamental principles are respected but enhanced through new analytical tools. Their approach to decomposing technical change, while different from Asmild and Tam's original framework, builds upon the same underlying concerns about accurate measurement of productivity changes over time.

The evolution of methodological approaches since Asmild and Tam, (2007) work reflects the dynamic nature of the field. Rather than seeing a linear progression or consistent application of their methods, we observe a diversification of approaches tailored to specific research contexts and questions.

3.5.1 Formalising the Global Malmquist Index, Global Frontier Shift (GFS) and Global Efficiency Change (GEC)

In formulating the Global Malmquist index estimation of Asmild and Tam, (2007), we use the adjacent Malmquist index estimated in equation *3.11,* which is decomposed in equation *3.12*, with the first part being the efficiency change and the second part being the technological change or frontier shift. The frontier shift in equation *3.12* is the geometric mean of the frontier shifts observed by the DMU at time t and $t+i$. For each period, we define a technology index TI of Asmild and Tam, (2007) as:

$$\mathrm{TI}^t(\mathrm{X},\mathrm{Y}) = \left(\prod_{\substack{k=1,\dots,K \\ \tau=1,\dots T}} \theta^t(x_k^\tau, y_k^\tau) \right)^{\frac{1}{K\times T}} \tag{3.16}$$

Let the global frontier shift of Asmild and Tam, (2007) between period t and period $t+i$ be given by:

$$GFS(t,t+i;X,Y) = \frac{TI^t(X,Y)}{TI^{t+i}(X,Y)} = \left(\frac{\prod_{\substack{k=1,\dots,K \\ \tau=1,\dots T}} \theta^t(x_k^\tau, y_k^\tau)}{\prod_{\substack{k=1,\dots,K \\ \tau=1,\dots T}} \theta^{t+i}(x_k^\tau, y_k^\tau)} \right)^{\frac{1}{K\times T}} \tag{3.17}$$

The global productivity change between periods t and $t+i$ is made up of the global frontier shift GFS(t, $t+i$; X, Y) as well as the global efficiency change Asmild and Tam, (2007) given as:

$$GEC\big(t,t+i;(x^t,y^t),(x^{t+i},y^{t+i})\big) = \prod_{k=1,\dots,K} \left[\frac{\theta_c^{t+i}(x_k^{t+i}, y_k^{t+i})}{\theta_c^t(x_k^t, y_k^t)} \right]^{\frac{1}{\mathrm{K}}} \tag{3.18}$$

The global version of the adjacent productivity change index of Asmild and Tam, (2007) is defined as:

$$\mathrm{GMI}(t,t+i;(X,Y)) = GFS(t,t+i;X,Y) \times \mathrm{GEC}(t,t+i;(x^t,y^t),(x^{t+1},y^{t+1}))$$

$$= \underbrace{\prod_{k=1,\dots,K} \left[\frac{\theta_c^{t+i}(x_k^{t+i}, y_k^{t+i})}{\theta_c^t(x_k^t, y_k^t)} \right]^{\frac{1}{\mathrm{K}}}}_{GEC} \times \underbrace{\left(\frac{\prod_{\substack{k=1,\dots,K \\ \tau=1,\dots T}} \theta^t(x_k^\tau, y_k^\tau)}{\prod_{\substack{k=1,\dots,K \\ \tau=1,\dots T}} \theta^{t+i}(x_k^\tau, y_k^\tau)} \right)^{\frac{1}{K\times T}}}_{GFS} \tag{3.19}$$

This study proposes a four-part decomposition of the two-parts done by Asmild and Tam (2007), by considering the effect of the size of the firm and the industry. The individual parts are pure global efficiency change (PGEC), scale global efficiency change (SGEC), pure global frontier shift (PGFS), and scale global frontier shift (SGFS).

$$GMI = \underbrace{\prod_{k=1,\dots,K}\left[\frac{\theta_v^{t+i}(x_k^{t+i},y_k^{t+i})}{\theta_v^t(x_k^t,y_k^t)}\right]^{\frac{1}{K}}}_{PGEC} \times \underbrace{\prod_{k=1,\dots,K}\left[\frac{\theta_c^{t+i}(x_k^{t+i},y_k^{t+i})/\theta_v^{t+i}(x_k^{t+i},y_k^{t+i})}{\theta_c^t(x_k^t,y_k^t)/\theta_v^t(x_k^t,y_k^t)}\right]^{\frac{1}{K}}}_{SGEC} \times \underbrace{\left(\frac{\prod_{\substack{k=1,\dots,K\\ \tau=1,\dots T}}\theta_v^t(x_k^\tau,y_k^\tau)}{\prod_{\substack{k=1,\dots,K\\ \tau=1,\dots T}}\theta_v^{t+i}(x_k^\tau,y_k^\tau)}\right)^{\frac{1}{K\times T}}}_{PGFS}$$

$$\times \underbrace{\left(\frac{\prod_{\substack{k=1,\dots,K\\ \tau=1,\dots T}}\theta_c^t(x_k^\tau,y_k^\tau)/\prod_{\substack{k=1,\dots,K\\ \tau=1,\dots T}}\theta_v^t(x_k^\tau,y_k^\tau)}{\prod_{\substack{k=1,\dots,K\\ \tau=1,\dots T}}\theta_c^{t+i}(x_k^\tau,y_k^\tau)/\prod_{\substack{k=1,\dots,K\\ \tau=1,\dots T}}\theta_v^{t+i}(x_k^\tau,y_k^\tau)}\right)^{\frac{1}{K\times T}}}_{SGFS} \quad (3.20)$$

The Global Malmquist Index (GMI), introduced by Asmild and Tam in 2007, represents an innovative refinement in productivity measurement that addresses key limitations of the traditional Malmquist Index approach. The fundamental insight behind the GMI lies in its treatment of technological change across time periods, offering a more comprehensive view of productivity evolution (Asmild & Tam, 2007). Another key feature of the GMI is its ability to identify genuine technological regress. Under traditional approaches, apparent technological regression might simply reflect the limitations of bilateral comparisons. The GMI's global technology frontier provides a more reliable reference point for determining whether true technological regression has occurred (Asmild & Tam, 2007).

The framework's global perspective also makes it especially suitable for cross-country or cross-industry comparisons, where understanding relative performance against all observed best practices is more informative than year-to-year changes (Walheer, 2022).

3.6 Cost Efficiency

Consider that $L^t(y^t)$ is non-empty, closed, convex, bounded and satisfies strong disposability of inputs and outputs. $L^t(y^t)$ is bounded from below by the input isoquant, (Maniadakis & Thanassoulis, 2004) that is:

$$\text{Isoq } L^t(y^t) = \{x^t : x^t \in L^t(y^t),\ \lambda x^t \notin L^t(y^t) \quad \text{for } \lambda < 1\} \tag{3.21}$$

Isoq $L^t(y^t)$ defines a boundary or frontier to the input requirement set in the sense that any radial contraction of input vectors that lie on the frontier is not possible within $L^t(y^t)$ (Maniadakis & Thanassoulis, 2004). Alternatively, regarding the input requirement set, define the technology of production in terms of the input distance function (Shephard, 1953) as;

$$D_i^t(x^t, y^t) = \sup_{\theta}\{\theta : (x^t/\theta) \in L^t(y^t), \theta > 0\} \tag{3.22}$$

where the subscript i denotes input orientation. $D_i^t(x^t, y^t)$ in *3.21* is the largest factor by which the input levels in x^t can be divided, while x^t remains in $L^t(y^t)$. $D_i^t(x^t, y^t)$ characterises the technology of production completely in the sense that $D_i^t(x^t, y^t) \geq 1$ is sufficient for $x^t \in L^t(y^t)$ and if $D_i^t(x^t, y^t) = 1$, $x^t \in \text{Isoq}L^t(y^t)$. $D_i^t(x^t, y^t)$ is reciprocal to Farrell's input-oriented measure (Farrell, 1957) of technical efficiency as;

$$TE_i^t(x^t, y^t) = \min_{\emptyset}\{\emptyset : (\emptyset x^t) \in L^t(y^t), \emptyset > 0\} \tag{3.23}$$

When input prices, $w^t \in \Re_+^m, i$, are available one may define technology in terms of the cost function as;

$$C^t(w^t, y^t) = \min_{x^t}\{w^t x^t : x^t \in L^t(y^t), w^t > 0\} \tag{3.24}$$

$C^t(w^t, y^t)$ defines the minimum cost of producing a given output vector y^t given the input prices w^t and the technology of period t. The set of input vectors x^t which correspond to the scalar $C^t(w^t, y^t)$ lie on an isocost line which defines a cost boundary (Maniadakis & Thanassoulis, 2004) given as;

$\text{Iso}C^t(w^t, y^t) = \{x^t: w^t x^t = C^t(w^t, y^t)\}$ (3.25)

This boundary contains the input vectors that, given the technology and input prices, are capable of securing output y^t at the cost of $C^t(w^t, y^t)$ (Maniadakis & Thanassoulis, 2004).

The Cost Efficiency for (y^t, x^t) under input prices w^t is defined for the input orientation measure (Färe & Primont, 1995; Maniadakis & Thanassoulis, 2004) as;

$$\text{CE}_i^t(x^t, y^t, w^t) = \frac{C^t(w^t, y^t)}{w^t x^t} \quad (3.26)$$

This measure compares the minimum feasible production cost to the observed cost.

3.6.1 Cost Malmquist Productivity Index (CMPI)

The CMPI is more useful as managers tend to minimise cost more than minimise input quantity (Maniadakis & Thanassoulis, 2004). Debreu (1951) and Farrell (1957) first proposed the concept of cost efficiency, which measures a DMU's capacity to produce its present production at the lowest possible cost given its current price levels. The most cost-effective entities in the production possibility set make up the cost frontier, whereas the best production processes make up the production frontier (Afsharian & Ahn, 2015). Tone (2002) identified some flaws with Farrell's (1957) model as the latter made assumptions that there was a perfect market with known and fixed input prices. Tone, (2002) proposed a new cost efficiency model that evaluates DMUs when prices are unequal, and inputs are heterogeneous in an imperfect market system.

3.6.2 Formalising the Cost Malmquist Index

Just as MPI is formulated using four efficiency scores, the CMPI is also computed using these four cost efficiency formulations (Banker et al., 1984; Färe & Primont, 1995):

$$C^t(y^t, w^t) = \min_{\lambda_j, x_i} \; C = \sum_{i=1}^{m} w_{i0}^t \, x_{i0}^t$$

$$s.t.: \begin{cases} \sum_{j=1}^{k} \lambda_j x_{ij}^{t} \le x_{i0}^{t}; \quad i = 1,2,\dots,m \\ \sum_{j=1}^{k} \lambda_j y_{rj}^{t} \ge y_{r0}^{t}; \; r = 1,2,\dots,s \\ \sum_{j=1}^{k} \lambda_j = 1 \text{ (VRS)} \\ \lambda_j \ge 0, \; x_i \ge 0; \quad j = 1,2,\dots,n \\ t = 1, 2, \dots, T \end{cases} \tag{3.27}$$

$$C^t(y^{t+1}, w^t) = \min_{\lambda_j, x_i} \; C = \sum_{i=1}^{m} w_{i0}^{t} x_{i0}^{t+1}$$

$$s.t.: \begin{cases} \sum_{j=1}^{k} \lambda_j x_{ij}^{t} \le x_{i0}^{t+1}; \quad i = 1,2,\dots,m \\ \sum_{j=1}^{k} \lambda_j y_{rj}^{t} \ge y_{r0}^{t+1}; \; r = 1,2,\dots,s \\ \sum_{j=1}^{k} \lambda_j = 1 \text{ (VRS)} \\ \lambda_j \ge 0, \; x_i \ge 0; \quad j = 1,2,\dots,n \\ t = 1, 2, \dots, T \end{cases} \tag{3.28}$$

$$C^{t+1}(y^{t+1}, w^{t+1}) = \min_{\lambda_j, x_i} \; C = \sum_{i=1}^{m} w_{i0}^{t+1} x_{i0}^{t+1}$$

$$s.t.: \begin{cases} \sum_{j=1}^{k} \lambda_j x_{ij}^{t+1} \le x_{i0}^{t+1}; \quad i = 1,2,\dots,m \\ \sum_{j=1}^{k} \lambda_j y_{rj}^{t+1} \ge y_{r0}^{t+1}; \; r = 1,2,\dots,s \\ \sum_{j=1}^{k} \lambda_j = 1 \text{ (VRS)} \\ \lambda_j \ge 0, \; x_i \ge 0; \quad j = 1,2,\dots,n \\ t = 1, 2, \dots, T \end{cases} \tag{3.29}$$

$$C^{t+1}(y^{t}, w^{t+1}) = \min_{\lambda_j, x_i} \; C = \sum_{i=1}^{m} w_{i0}^{t+1} x_{i0}^{t}$$

$$s.t.: \begin{cases} \sum_{j=1}^{k} \lambda_j x_{ij}^{t+1} \le x_{i0}^{t}; \quad i = 1,2,\dots,m \\ \sum_{j=1}^{k} \lambda_j y_{rj}^{t+1} \ge y_{r0}^{t}; \; r = 1,2,\dots,s \\ \sum_{j=1}^{k} \lambda_j = 1 \text{ (VRS)} \\ \lambda_j \ge 0, \; x_i \ge 0; \quad j = 1,2,\dots,n \\ t = 1, 2, \dots, T \end{cases} \tag{3.30}$$

In reference to the cost Malmquist productivity index (CM) expressed by Maniadakis & Thanassoulis, (2004), we present the CM in efficiency functions as follows:

The CM of a DMU in period t is stated as:

$$CM^t = \left[\frac{C^t(w^t, y^{t+1}) / w^t x^{t+1}}{C^t(w^t, y^t) / w^t x^t} \right] \tag{3.31}$$

The CM of a DMU in period $t+1$ is also stated as:

$$CM^{t+1} = \left[\frac{C^{t+1}(w^{t+1}, y^{t+1})/w^{t+1}x^{t+1}}{C^{t+1}(w^{t+1}, y^{t})/w^{t+1}x^{t}}\right] \tag{3.32}$$

The above-stated CMs combine as a geometric average to make up the CM between periods *t* and *t+1* as:

$$CM_c = \left[\frac{C_c^t(y^{t+1}, w_c^t)/w_c^t x^{t+1}}{C_c^t(y^t, w_c^t)/w_c^t x^t} \times \frac{C_c^{t+1}(y^{t+1}, w_c^{t+1})/w_c^{t+1}x^{t+1}}{C_c^{t+1}(y^t, w_c^{t+1})/w_c^{t+1}x^t}\right]^{1/2} \tag{3.33}$$

3.6.3 Decomposition of the Cost Malmquist Index

The composite CM in *3.33* can be decomposed into several parts that give further insight into the drivers of cost productivity. Stated below are the two and four-factor decompositions of the CM.

The CM can be decomposed into a two-factor Cost Efficiency Change (CEC) and Cost Technological Change (CTC) as follows:

$$CM = \underbrace{\left[\frac{C^{t+1}(w^{t+1}, y^{t+1})/w^{t+1}x^{t+1}}{C^{t}(w^{t}, y^{t})/w^{t}x^{t}}\right]}_{CEC} \times \underbrace{\left[\frac{C^{t}(w^{t}, y^{t+1})/w^{t}x^{t+1}}{C^{t+1}(w^{t+1}, y^{t+1})/w^{t+1}x^{t+1}} \times \frac{C^{t}(w^{t}, y^{t})/w^{t}x^{t}}{C^{t+1}(w^{t+1}, y^{t})/w^{t+1}x^{t}}\right]^{\frac{1}{2}}}_{CTC} \tag{3.34}$$

CEC estimates how managers cheaply run their business between periods *t* and *t+1*, by utilising available inputs of production, input prices, and technology whereas, CTC estimates the changes in production technology over the period. Graphically, CEC is a measure of the gap between a DMU and the efficient cost frontier modelled by the best cost efficient firms whereas CTC is a measure of shifts in the cost frontier due to input mixes Maniadakis & Thanassoulis, (2004).

From the two-factor decomposition, both CEC and CTC can further be decomposed into two parts each considering the impact of the input mix, thus forming a four-part decomposition of the CM as follows efficiency change (EC), allocative efficiency change (AEC), technical change (TC) and price effect (PE) Maniadakis & Thanassoulis, (2004):

$$CEC = \underbrace{\frac{\theta^{t+1}(x^{t+1},y^{t+1})}{\theta^{t}(x^{t},y^{t})}}_{EC} \times \underbrace{\frac{C^{t+1}(w^{t+1},y^{t+1})/(w^{t+1}x^{t+1} \times \theta^{t+1}(x^{t+1},y^{t+1}))}{C^{t}(w^{t},y^{t})/(w^{t}x^{t} \times \theta^{t}(x^{t},y^{t}))}}_{AEC} \quad (3.35)$$

$$CTC = \underbrace{\left[\frac{\theta^{t}(x^{t+1},y^{t+1})}{\theta^{t+1}(x^{t+1},y^{t+1})} \times \frac{\theta^{t}(x^{t},y^{t})}{\theta^{t+1}(x^{t},y^{t})}\right]^{\frac{1}{2}}}_{TC} \times \underbrace{\left[\left(\frac{C^{t}(w^{t},y^{t+1})/(w^{t}x^{t+1} \times \theta^{t}(x^{t+1},y^{t+1}))}{C^{t+1}(w^{t+1},y^{t+1})/(w^{t+1}x^{t+1} \times \theta^{t+1}(x^{t+1},y^{t+1}))}\right) \times \left(\frac{C^{t}(w^{t},y^{t})/(w^{t}x^{t} \times \theta^{t}(x^{t},y^{t}))}{C^{t+1}(w^{t+1},y^{t})/(w^{t+1}x^{t} \times \theta^{t+1}(x^{t},y^{t}))}\right)\right]^{\frac{1}{2}}}_{PE} \quad (3.36)$$

3.7 Proposed Global Cost Frontier Shift (GCFS), Global Cost Efficiency Change (GCEC) and Global Cost Malmquist Index (GCMI)

The cost frontier shift in *3.34* is specific to the observations under consideration as it is the geometric mean of the frontier shifts observed by the DMU at time *t* and *t+1*. Inferring from the arguments of Asmild & Tam (2007), a proposed new way of estimating the global version using the adjacent index is defined as follows;

For each period *t*, define a cost technology index number CTI as;

$$\mathrm{CTI}^{t}(X,Y,W) = \left(\prod_{\substack{k=1,\dots,K \\ \tau=1,\dots T}} CE^{t}(x_k^{\tau},y_k^{\tau},w_k^{\tau})\right)^{\frac{1}{K\times T}} \quad (3.37)$$

The global cost frontier shift or global cost technical change between period *t* and period *t+i* can be expressed as;

$$GCFS(t, t+i; X, Y, W) = \left(\frac{\prod_{\substack{k=1,\ldots,K \\ \tau=1,\ldots T}} CE^{t}(x_k^{\tau}, y_k^{\tau}, w_k^{\tau})}{\prod_{\substack{k=1,\ldots,K \\ \tau=1,\ldots T}} CE^{t+i}(x_k^{\tau}, y_k^{\tau}, w_k^{\tau})} \right)^{\frac{1}{K \times T}} \tag{3.38}$$

This is similar to the index in Asmild and Tam, (2007). The global cost efficiency change is the geometric mean of the individual efficiency changes between *t* and *t+i* for the K observations in the sample. This is given as;

$$GCEC\left(t, t+i; (X^t, Y^t, W^t), (X^{t+i}, Y^{t+i}, W^{t+i})\right) = \prod_{k=1,\ldots,K} \left[\frac{CE^{t+i}(x_k^{t+i}, y_k^{t+i}, w_k^{t+i})}{CE^{t}(x_k^{t}, y_k^{t}, w_k^{t})} \right]^{\frac{1}{K}} \tag{3.39}$$

The global cost productivity change between periods *t* and *t+i* is made up of the global cost frontier shift in *3.38* as well as the global cost efficiency change in *3.39,* the Global Cost Malmquist Index can now be defined as;

$$\mathrm{GCMI}(t, t+i; X, Y, W) = \underbrace{\prod_{k=1,\ldots,K} \left[\frac{CE^{t+i}(x_k^{t+i}, y_k^{t+i}, w_k^{t+i})}{CE^{t}(x_k^{t}, y_k^{t}, w_k^{t})} \right]^{\frac{1}{\mathrm{K}}}}_{GCEC} \times \underbrace{\left[\frac{\prod_{\substack{k=1,\ldots,K \\ \tau=1,\ldots T}} CE^{t}(x_k^{\tau}, y_k^{\tau}, w_k^{\tau})}{\prod_{\substack{k=1,\ldots,K \\ \tau=1,\ldots T}} CE^{t+i}(x_k^{\tau}, y_k^{\tau}, w_k^{\tau})} \right]^{\frac{1}{\mathrm{K \times T}}}}_{GCFS} \tag{3.40}$$

The components of the GCMI, both GCEC and GCFS can further be decomposed into two parts each considering the impact of the input mix, thus forming a four-part decomposition of the GCMI as follows global efficiency change (GEC), global allocative efficiency change (GAEC), global frontier shift (GFS) and global price effect (GPE):

$$\text{GCMI}(t, t+i; X, Y, W)$$

$$= \underbrace{\prod_{k=1,\dots,K} \left[\frac{\theta_c^{t+i}(x_k^{t+i}, y_k^{t+i})}{\theta_c^t(x_k^t, y_k^t)}\right]^{\frac{1}{K}}}_{GEC} \times \underbrace{\prod_{k=1,\dots,K} \left[\frac{CE^{t+i}(x_k^{t+i}, y_k^{t+i}, w_k^{t+i}) \times \theta_c^t(x_k^t, y_k^t)}{CE^t(x_k^t, y_k^t, w_k^t) \times \theta_c^{t+i}(x_k^{t+i}, y_k^{t+i})}\right]^{\frac{1}{K}}}_{GAEC}$$

$$\times \underbrace{\left(\frac{\prod_{\substack{k=1,\dots,K \\ \tau=1,\dots T}} \theta^t(x_k^\tau, y_k^\tau)}{\prod_{\substack{k=1,\dots,K \\ \tau=1,\dots T}} \theta^{t+i}(x_k^\tau, y_k^\tau)}\right)^{\frac{1}{K\times T}}}_{GFS}$$

$$\times \underbrace{\left[\frac{\prod_{\substack{k=1,\dots,K \\ \tau=1,\dots T}} CE^t(x_k^\tau, y_k^\tau, w_k^\tau) \times \prod_{\substack{k=1,\dots,K \\ \tau=1,\dots T}} \theta^{t+i}(x_k^\tau, y_k^\tau)}{\prod_{\substack{k=1,\dots,K \\ \tau=1,\dots T}} CE^{t+i}(x_k^\tau, y_k^\tau, w_k^\tau) \times \prod_{\substack{k=1,\dots,K \\ \tau=1,\dots T}} \theta^t(x_k^\tau, y_k^\tau)}\right]^{\frac{1}{K\times T}}}_{GPE} \qquad (3.41)$$

The proposed Global Cost Malmquist Index (GCMI) represent a synthesis of both the Cost Malmquist Index Maniadakis and Thanassoulis, (2004), and the Global Malmquist Index Asmild and Tam, (2007), frameworks, offering a more comprehensive approach to measuring cost productivity changes across extended time periods. This proposed framework integrates price information and economic behaviour while establishing a global benchmark technology that spans the entire observation period. The fundamental innovation of the GCMI lies in its ability to evaluate cost efficiency changes from a global perspective, incorporating both the best technical practices and the most efficient input allocations observed across all firms in all time periods (Asmild & Tam, 2007; Maniadakis & Thanassoulis, 2004). The framework captures the global cost frontier shift, which measures how technological changes interact with price structures to affect cost efficiency (Maniadakis & Thanassoulis, 2004).

3.8 Hypothetical Example

We consider a calculation of the proposed model and its associated decomposition with a hypothetical example as below. Consider four-year data with different numbers of DMUs in each year, with two inputs x1 and x2, a single output of y and input prices of w1 and w2 as shown in Table 1.

Table 1: Four-Year Hypothetical Data of DMUs

year	dmu	x1	x2	y	w1	w2
1	GCB	2	7	11	1	2
1	BCB	2	5	8	3	2
1	UNI	5	6	9	2	1
1	SCB	8	4	12	4	2
1	ZEN	5	3	10	3	5
2	GCB	1.5	5	10	2	3
2	BCB	2	6	11	3	3
2	UNI	4.5	6.5	12	4	2
2	SCB	1	7	9	4	3
2	ZEN	5	4	9	2	5
2	UTB	7	6	7	3	3
2	GTB	4	4	10	5	4
2	GNB	4	8	10	5	3
3	GCB	1.5	6	12	1	2
3	BCB	3	3	13	3	2
3	SCB	6	2	12	2	1
3	ZEN	3	5	13	4	2
3	GTB	7	7	13	3	5
3	GNB	3	10	11	2	4
3	EXB	10	3	12	2	3
4	GCB	10	1	12	1	2
4	BCB	1.2	8	15	3	2
4	SCB	3	2	14	2	1
4	ZEN	7	3	15	4	2
4	GTB	1.5	10	13	3	5
4	EXB	6	7	15	2	4

Source: Author's Compilation, 2024.

We show results for the calculation for each component in each adjacent period in Table 2.

Table 2: Results of Hypothetical Data for GCMI and Component

Period	GEC	GFS	GCEC	GCFS	GAEC	GPE	GCMI
yr1-yr2	0.908	1.042	0.916	1.129	1.009	1.083	1.034
yr2-yr3	0.918	1.500	0.837	1.387	0.912	0.924	1.161
yr3-yr4	1.046	1.288	0.922	1.292	0.881	1.004	1.191
Average	**0.957**	**1.277**	**0.892**	**1.269**	**0.934**	**1.004**	**1.129**

Source: Author's Compilation, 2024.

From Table 2, the GCMI can be calculated using the two-factor components of GCEC and GCFS as in equation *3.40* and using the four-factor components of GEC, GFS, GAEC and GPE as in equation *3.41*. Thus, for equation *3.40* for periods 1-2, we have 0.916×1.129 = 1.034 and for the same period for equation *3.41*, we have 0.908×1.009×1.042×1.083 =1.034.

3.9 Non-parametric Test of Return to Scale

The bootstrapped test approach of Simar & Wilson (2002) is used to estimate the returns to scale of the underlying technology, as different returns to scale axioms can lead to different conclusions (Dyson et al., 2001; Ray & Desli, 1997). Earlier, Färe & Grosskopf (1985) proposed an approach for determining the nature of returns to scale but it lacked statistical foundation. Later, Banker (1996) proposed a semi-parametric returns to scale test that uses the Kolmogorov-Smirnov test.

This is based on the hypothesis that:

H_0: The PPS is globally CRS

H_A: The PPS is globally VRS

$$\hat{S}_1 = n^{-1} \sum_{j=1}^{n} \left[\frac{\hat{\theta}_j^{CRS}(x,y)}{\hat{\theta}_j^{VRS}(x,y)} \right] \tag{3.42}$$

mean of ratios

$$\hat{S}_2 = \frac{\sum_{j=1}^{n} \hat{\theta}_j^{CRS}(x,y)}{\sum_{j=1}^{n} \hat{\theta}_j^{VRS}(x,y)} \tag{3.43}$$

ratio of means

$$\hat{S}_3 = n^{-1} \sum_{j=1}^{n} \left[\frac{\hat{\theta}_j^{CRS}(x,y)}{\hat{\theta}_j^{VRS}(x,y)} - 1 \right] \tag{3.44}$$

mean of ratios minus one

3.10 Modelling of Input and Output Variables

The variables used in the study are those that have been extensively used in studies to compute the efficiency and productivity of firms in the banking industry. Below is a table outlining the variables to be employed in this study.

Table 3: Description of Variables

Variables	Description	Empirical Applications
Inputs:		
Customer Deposit (X1)	Total amount customers deposited with the firm	(Novickytė & Droždz, 2018; Titko et al., 2014)
Personnel Expense (X2)	The total amount expended on personnel	(Amin & Ibn Boamah, 2020; Camanho & Dyson, 2005)
Fixed Asset (X3)	The total amount of physical property and equipment	(Adjei-Frimpong & Gan, 2014; Alhassan & Ohene-Asare, 2016)
Input Prices:		
Interest Expense (W1)	Total amount of Interest Expense divided by total Customer Deposit	(Alhassan & Ohene-Asare, 2016; Weill, 2004)
Personnel Expense (W2)	Total Personnel Expense divided by Total Asset	(Alhassan & Ohene-Asare, 2016; Weill, 2004)
Other Operating Expense (W3)	Other Operating expenses divided by total Fixed Asset	(Adjei-Frimpong & Gan, 2014; Faraj & Övenç, 2023)
Output:		
Loans and Advances to Customers (Y1)	Total Loans given out to customers	(Amoah et al., 2018; Anagnostopoulos et al., 2022; Hassan & Jreisat, 2016)
Investments (Y2)	Total Investments made in Securities	(Adusei, 2016; Alhassan & Ohene-Asare, 2016)

Source: Author's Compilation, 2024.

3.11 Instruments of the Data Analysis

The statistical results are generated with R software version 4.4.1. The packages within R which were mainly used are deaR version 1.4.1 by Bolós et al., (2022) and Benchmarking version 0.32 by Bogetoft & Otto, (2010).

With collated Annual Reports, data on the banks in Ghana were collected and organised in Microsoft Excel for analysis. Interpolation was done to obtain data for a few banks in years that there is evidence that they existed, but data was not included in the collated files.

3.12 Summary of Chapter

The Chapter provided explanations of the research design, the sources of data, modalities used in the sampling, and other techniques employed to accomplish the objectives of the study. The cost efficiency and productivity models outlined were employed to achieve all the research objectives.

CHAPTER FOUR

DATA ANALYSIS AND DISCUSSION OF FINDINGS

4.1 Introduction

This Chapter presents the results of the data analysis and discusses the findings in relation to the research objectives. The analysis aims to apply the proposed Global Cost Frontier Shift (GCFS) and Global Cost Malmquist Index (GCMI) methodologies developed in Chapter 3 to the Ghanaian banking sector for the period 2000-2022. The Chapter begins by presenting descriptive statistics of the input and output variables used in the analysis. It then computes the correlation of variables and applies the Simar and Wilson's (2002) non-parametric test of returns to scale to determine the appropriate technology assumption for the Ghanaian banking industry. The core of the analysis involves computing the proposed GCMI and GCFS for Ghanaian banks over the study period.

The results are compared with those obtained from Cost Malmquist approaches to highlight the advantages of the global perspective. The Chapter also examines trends in productivity change and its components over time, identifying key drivers of efficiency and technological change in the Ghanaian banking sector. Finally, the findings are discussed in the context of the broader Ghanaian financial industry and economy, drawing implications for bank management and policymakers.

Through this analysis, the chapter aims to demonstrate the practical application and value of the proposed GCFS and GCMI methodologies, while also providing novel insights into the productivity dynamics of the Ghanaian banking industry over the past two decades.

4.2 Description of Data

The data for this study were sourced from the published audited financial statements of Ghanaian banks for the period 2000 to 2022. The dataset comprises 32 banks, which satisfies the requirement proposed by Dyson et al., (2001) that the number of decision-making units (DMUs) should be at least three times the total number of inputs and outputs. In this study, we have 32 banks, which is 6 times more than the total of three inputs and two outputs.

Table 4 presents the descriptive statistics of the pooled data for the Ghanaian banking sector. These statistics provide insights into the characteristics and dynamics of the Ghanaian banking industry over the study period.

On average in cedis, Ghanaian banks employ approximately 1.65 billion in customer deposits, 72.6 million in fixed assets, and 67.8 million in personnel expense to produce 782 million in loans and advances to customers and 820 million in investments in securities. These figures vary across banks and over time, with standard deviations of 2.55 billion, 125 million, 99.9 million, 1.01 billion, and 1.49 billion respectively. These huge variations in the figures project the possibility of differences in the scale of production within the banking industry of Ghana.

It is also observed that all the inputs banks use and the output they produce varies significantly over the study period. With the wide ranges observed through the differences between the maximum and minimum figures of the inputs and outputs, the variations in the scale of production in the banking industry are more pronounced.

This descriptive analysis sets the stage for the subsequent efficiency and productivity analysis using the proposed Global Cost Frontier Shift (GCFS) and Global Cost Malmquist Index (GCMI) methodologies.

Table 4: Summary Statistics of Variables Used (2000-2022)

		Customer Deposit (GHS)	Fixed Assets (GHS)	Personnel Expense (GHS)	Loans and Advances (GHS)	Investment (GHS)
Pooled	mean	1650000000	72565724	67836597	782245470	820771097
	sd	2540000000	125000000	99900000	1010000000	1490000000
	min	532192	124941	49094	154708	407576
	max	19590400000	1253410000	796993000	8802239000	9707420000
	n	495	495	495	495	495
Time	F-stat	332.4***	231.6***	279.5***	301.9***	224.1***

sd=standard deviation, min=minimum value, max=maximum value,

n=number of observations

*** p<0.001, ** p<0.01, * p<0.05, . p<0.1

Source: Author's Construct, 2024.

An isotonicity test was conducted to ensure the validity of the DEA calculations by examining the inter-correlations between inputs and outputs (K. Chen & Zhu, 2019; Yen & Li, 2022). This test verifies whether increasing input quantities results in larger outputs, which is a fundamental assumption in DEA. To satisfy the isotonicity condition, each input must be significantly and positively correlated with each output (Cooper et al., 2011).

Table 5 presents the correlation matrix for all inputs and the output at a significance level of 0.1%. The results show that all three inputs (customer deposits, fixed assets, and personnel expenses) exhibit significant and positive correlations with the outputs (loans and advances to customers, and investment). Specifically, the correlations are as follows: 98% for Customer deposits and Loans and Advances, 95% for Fixed Assets and Loans and Advances, 98% for Personnel Expenses and Loans and Advances, 97% for Customer deposits and Investment, 86% for Fixed Assets and Investment, 96% for Personnel Expenses and Investment.

These strong positive correlations demonstrate the relevance of the chosen inputs in the production process of Ghanaian banks. The results confirm that the isotonicity property is satisfied, as an increase in any of the inputs is associated with an increase in the output.

This verification of the isotonicity condition provides confidence in the appropriateness of the selected variables for the DEA-based Global Cost Malmquist Index (GCMI) analysis, ensuring that the fundamental assumptions of the methodology are met in the context of the Ghanaian banking sector.

Table 5: Correlation matrix of inputs and outputs (Isotonicity Test)

	Customer Deposit	Fixed Assets	Personnel Expense	Loans and Advances	Investment
Customer Deposit (X1)	1				
Fixed Assets (X2)	0.93***	1			
Personnel Expense (X3)	0.99***	0.90***	1		
Loans and Advances (Y1)	0.98***	0.95***	0.98***	1	
Investment (Y2)	0.97***	0.86**	0.96***	0.91***	1

Source: Author's Construct, 2024. *** p<0.001, ** p<0.01, * p<0.05, . p<0.1

Three statistical tests were conducted to assess the significance of differences among banks across time. The parametric one-way ANOVA test (Fisher, 1919) was used to evaluate differences in each variable across the study period as evidenced from Table 2.

The F-statistic from the ANOVA tests indicate that differences in each variable across the years of study are statistically significant at the 0.1% alpha level, confirming that time is a significant factor in the dataset. These findings suggest that variable returns to scale (VRS) may be present in the Ghanaian banking industry. However, as emphasised by Dyson et al., (2001) and Simar and Wilson, (2002), it is crucial to formally test the actual returns to scale (RTS) technology underlying an industry before assessing performance to avoid misspecification.

Therefore, this study conducts three tests of returns to scale as proposed by Simar and Wilson, (2002, 2011) to determine the appropriate RTS underlying the Ghanaian banking industry. These tests are mean of ratios ($\hat{S}1$), ratio of means ($\hat{S}2$), and mean of ratios minus one ($\hat{S}3$)

The results of these tests are presented in Table 6. The results of all three tests suggest the rejection of the null hypothesis that the underlying technology within the Ghanaian banking industry is CRS. Therefore, VRS technology is present in the industry.

This rigorous approach to testing for differences and determining the appropriate returns to scale ensures that the subsequent Global Cost Malmquist Index (GCMI) analysis is based on a solid understanding of the underlying characteristics of the Ghanaian banking industry.

Table 6: Tests of returns to scale

H_0: Ψ is CRS	Level of significance	$\hat{S}1$	$\hat{S}2$	$\hat{S}3$	Conclusion
Test Statistic		0.4187395**	0.5073329	-0.5812605*	Reject H_0:CRS
Critical Value	5%	0.7060041	0.2018313	0.7105185	
Critical Value	1%	0.4759592	0.1084886	0.4693028	

Source: Author's Construct, 2024. *** p<0.001, ** p<0.01, * p<0.05, . p<0.1

4.3 Estimating Global Cost Malmquist Indices and its Components for Ghanaian Banks

To address the third objective of this study, we applied the formulated model to estimate the Global Cost Malmquist Index (GCMI) and its components for the Ghanaian banking sector from 2000 to 2022. The GCMI provides a comprehensive measure of productivity change, considering all banks with each time period simultaneously.

Table 7 presents the annual GCMI values and its components for the Ghanaian banking sector from 2000 to 2022. It is observed that the average GCMI over the entire period was 0.945, indicating an overall decline in productivity of 5.5% per annum. This decline can be explained by the significant banking reforms that the sector underwent during this period (2000 to 2022). While these changes were intended to strengthen the sector, they initially led to increased costs and operational challenges for the banks (Ref Table 7).

Additionally, Ghana experienced periods of economic instability, including high inflation rates and currency depreciation. These macroeconomic factors negatively impacted bank productivity by increasing operational costs and reducing the value of assets, as investigated in Sultana and Rahman (2020) in Bangladesh banks that the economic environment significantly influence institutional performance. Notably, the 2008-2009 global financial crisis likely contributed to decreased productivity, especially in the years immediately following the crisis. The Ghanaian banking sector was found to have had increased productivity in three separate periods, that is, 2010-2011, 2012-2013 and 2017-2018 out of the thirteen periods after the financial crises. The GCMI saw its highest performance (27.9% growth) in the 2010-2011 period, which can be attributed to regulatory reform in increasing minimum capital requirement, the commencement of commercial oil production in the country, the consolidation of the amended Banking Act (2007), and technological transformations. Also, the financial sector clean-up which occurred within the 2018-2019 period, contributed to the poorest performance (27.7% decline in productivity) of the banking industry over the study period. In addition, the COVID-19 pandemic and its associated lockdowns in the country in 2020 also contributed to the poor performance in the subsequent years that followed.

Finally, the sector experienced significant challenges related to technological adaptation and digital infrastructure. While global banking has rapidly evolved toward digital transformation, many Ghanaian banks continued to operate with legacy systems that impede operational efficiency. This affected the performance of the industry as Cho and Chen (2021) illustrated in their research that technological disruption fundamentally reshapes institutional capabilities and performance. Also, the financial sector clean-up and regulatory reforms such as the capital adequacy requirements, created ongoing operational adjustments that were resource-intensive. This regulatory compliance, while important for system stability and potentially beneficial in the long run, led to short-term productivity declines as banks navigated integration challenges.

Table 7: Summary of GCMI and its Components

Period	Global Cost Malmquist (Proposed Model)	Global Cost Efficiency Change (Proposed Component)	Global Cost Frontier Shift (Proposed Component)
2000-01	0.932	1.334	0.699
2001-02	1.020	0.790	1.291
2002-03	1.026	1.064	0.964
2003-04	0.952	1.064	0.895
2004-05	0.972	1.141	0.852
2005-06	0.937	0.888	1.055
2006-07	0.927	1.037	0.894
2007-08	0.967	0.651	1.486
2008-09	0.963	1.310	0.735
2009-10	0.895	1.173	0.763
2010-11	1.279	1.061	1.205
2011-12	0.855	0.918	0.931
2012-13	1.077	0.867	1.242
2013-14	0.903	1.087	0.831
2014-15	0.804	0.838	0.959
2015-16	0.919	0.976	0.942
2016-17	0.984	1.219	0.807
2017-18	1.043	1.065	0.979
2018-19	0.723	1.058	0.683
2019-20	0.880	1.089	0.808
2020-21	0.863	0.960	0.899
2021-22	0.867	0.967	0.897
Year Average	**0.945**	**1.025**	**0.946**

Source: Author's Construct, 2024

The violin plots presented in Figure 1 offer a detailed visualisation of the decomposition of the Global Cost Malmquist Index (GCMI) into its two main components: Global Cost Efficiency Change (GCEC) and Global Cost Frontier Shift (GCFS) for the Ghanaian banking sector.

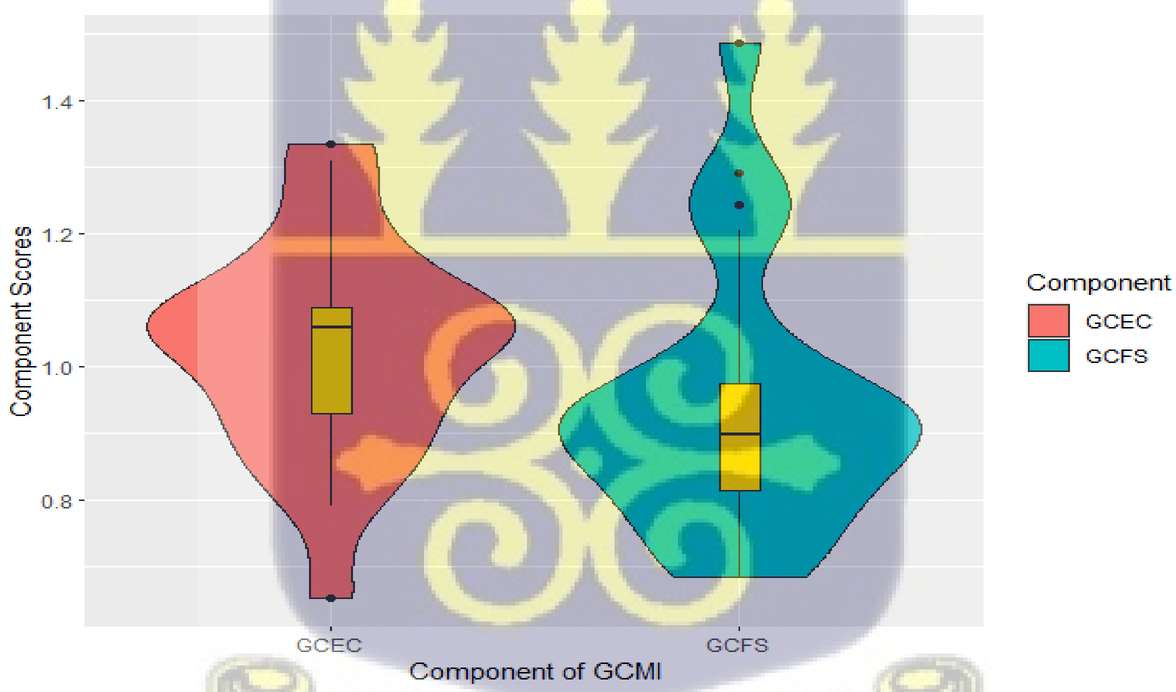
The plot for GCEC shows a relatively symmetrical distribution centred around a median slightly above 1. This suggests that, on average, there has been a marginal improvement in cost efficiency across the Ghanaian banking sector over the study period. The width of the GCEC plot indicates a moderate spread of efficiency changes, with most periods experiencing small to moderate improvements or declines in efficiency. The presence of a few outliers at both the upper and lower ends of the distribution suggests that while the banks saw incremental changes over the period, a small number of years showed the banks experienced more dramatic shifts in efficiency, both positive and negative.

In contrast, the GCFS plot displays a more asymmetrical distribution with a longer upper tail. The median for GCFS appears to be below 1, indicating that the overall technological frontier of the banking sector has experienced a slight regression. However, the extended upper tail and the presence of high-value outliers suggest that the banks made significant technological advancements, pushing the cost frontier forward. This could indicate the adoption of innovative technologies or industrial reforms by most banks in the sector within the periods. The wider spread of the GCFS distribution compared to GCEC implies that there's greater variability in technological progress across banks than in efficiency changes. This could reflect disparities in banks' abilities or willingness to invest in new technologies or innovative practices. The presence of outliers at both extremes of the GCFS distribution further emphasises the heterogeneity in technological advancement within the sector.

Comparing the two plots, it appears that changes in how well bank managers produce while considering prices of inputs (GCEC) have been more consistent across banks in the sector, while technological progress (GCFS) has been more varied and potentially more impactful for certain periods. This suggests that while overall efficiency improvements have been modest but widespread, technological advancements have been more concentrated around certain periods.

These findings have important implications for the Ghanaian banking sector. They suggest a need for policies that can help disseminate technological advancements more evenly across the sector, potentially through investments, knowledge sharing or incentives for innovation. Additionally, the relatively stable efficiency levels indicate that there might be room for initiatives aimed at improving operational efficiency in the industry.

Fig. 1: Distribution of the components of GCMI



Source: Author's Construct, 2024.

Moreover, an observation of the trends of GCMI and its components over the study period (2000 to 2022), as illustrated in Figure 2 shows that productivity growth was not uniform across the years.

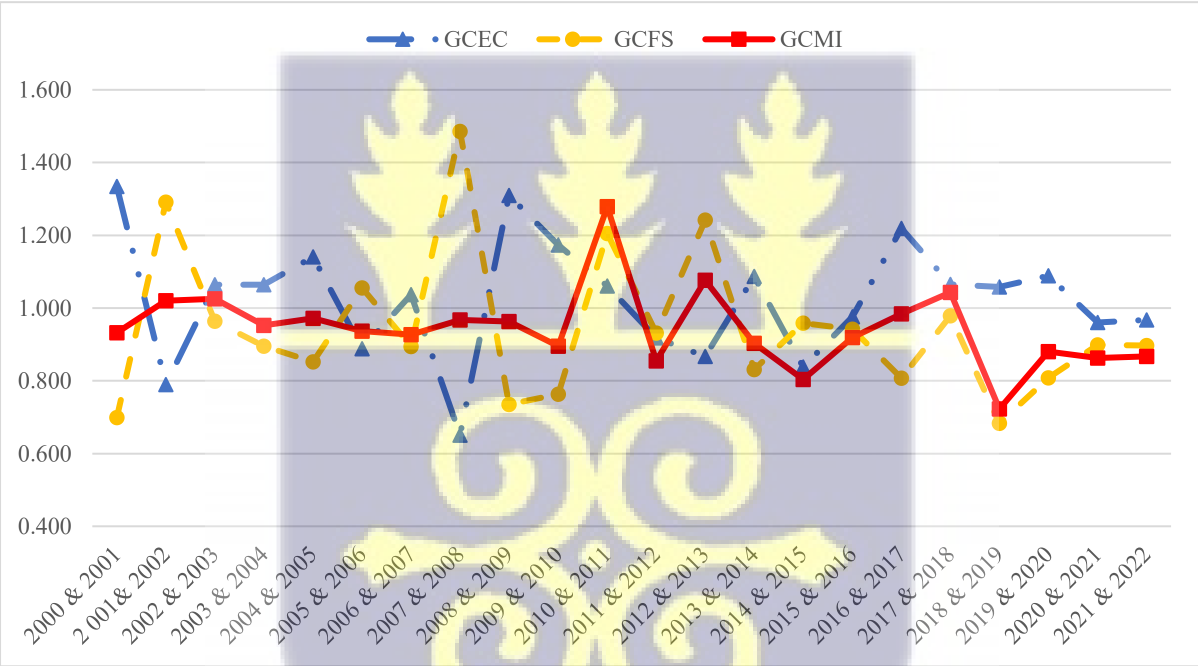
The early years show fluctuations in the GCFS and GCEC while the GCMI shows fair stability. There was a spike in GCFS in 2001-02, indicating a significant technological advancement in the banking sector during this time. This period saw a change in government after almost twenty years under the same leadership and the introduction of drastic economic reforms, such as the debt reduction under the Highly Indebted Poor Countries (HPIC) initiative, and a move to adopt the Financial Sector Strategic Plan (FINSSP) which aimed at broadening and deepening the financial sector of Ghana. However, this was accompanied by a drop in GCEC, suggesting that banks may have struggled to adapt to these new technological changes.

The period that followed till 2020 is characterised by alternating peaks and troughs between GCEC and GCFS. In 2008-09, there was a sharp rise in GCEC, possibly indicating improved managerial acumen, where competition for customers became fierce, hence, managers devised innovative ways to pull in more customers across the industry. The most dramatic change occurred in 2007-08, with a massive spike in GCFS and a corresponding dip in GCMI, which could be related to technological adaptations such as the proliferation of debit cards and the beginning of Internet banking. Interestingly, this is followed by a sharp decline in GCFS in 2008-09, suggesting that banks may have struggled to maintain efficiency in the face of these rapid changes and the global financial crises.

Finally, the latter part of the graph shows a period of relative stability, with all three measures showing less dramatic fluctuations. There's a slight upward trend in GCEC from 2014 to 2017, indicating gradual improvements in operational efficiency. The GCFS and GCMI remain relatively stable during this period, suggesting a consolidation phase where banks are optimizing their use of existing technologies.

Throughout the entire period, the GCMI has been relatively stable in the early periods but later, largely follows the pattern of GCFS, indicating that technological changes have been the primary driver of overall productivity changes in the Ghanaian banking sector. The GCEC shows more frequent but less extreme fluctuations, suggesting that efficiency changes, while important, have had a more moderate impact on overall productivity. This analysis reveals a dynamic Ghanaian banking sector that has undergone significant technological changes, particularly after 2007. The sector has faced challenges in maintaining consistent efficiency improvements, especially in the face of major technological shifts. The recent stability suggests a maturing industry that is focusing on optimizing existing technologies and improving operational efficiencies.

Fig. 2: Trend of GCMI, GCEC and GCFS scores across years (2000-2022)



Source: Author's Construct, 2024.

4.4 Comparing the Global Cost Malmquist Index to other productivity models

To address the fourth objective of this study, we conducted a comparative analysis of various productivity measures for the Ghanaian banking sector from 2000 to 2022. These measures include the classical Cost Malmquist Productivity Index (CMPI) by Maniadakis and

Thanassoulis (2004), Global Cost Malmquist Index (GCMI(T)) by Tohidi et al. (2012) and (GMI(A&T)) by Asmild and Tam (2007) – and our formulated Global Cost Malmquist Index (GCMI). Henriques et al (2020) emphasises the need for continual methodological refinement, hence, this comprehensive comparison allows for a nuanced understanding of productivity changes in the sector over time.

Table 8 presents the annual values of all productivity measures for the Ghanaian banking sector from 2000 to 2022. The newly proposed GCMI, which is the focus of our analysis, demonstrates considerable fluctuation over the study period, with an average value of 0.945, indicating an overall productivity decline of 5.5% per annum. The GMI(A&T) and the GCMI exhibited higher volatility than the other measures, particularly the GCMI(T), which shows relatively stable values closer to 1 throughout the period. This heightened sensitivity of GCMI to productivity changes can be seen as both a strength and a potential limitation. On one hand, it allows for detecting short-term shifts in productivity that might be missed by more stable measures. For instance, the GCMI captures a significant productivity increase in 2010-2011 (27.9% increase) and a significant decline in 2018-2019 (27.7% decrease), which are less pronounced in the other cost measures. On the other hand, this volatility may make long-term trend analysis more challenging by possibly obscuring the underlying direction of productivity changes over time. It can disproportionately influence trend lines, potentially skewing perceptions of long-term patterns. Despite these challenges, the GCMI's sensitivity can offer unique insights into both short-term changes and long-term trends in banking sector productivity.

Interestingly, while the GCMI often moves in the same direction as its variant GMI(A&T)), there are periods of significant divergence. For example, in 2007-2008, our GCMI showed a modest decline, while GMI(A&T) showed a significant increase (34.4%), and CMPI indicated an increase (28.6%) than our proposed GCMI.

The CMPI and GCMI(T) offer yet another perspective on productivity changes. The CMPI generally shows less volatility than the GCMI except in 2007-2008 but more than the GCMI(T), potentially offering a middle ground in terms of sensitivity to productivity changes. The GCMI(T), while sometimes aligning with the GCMI, often provides a different perspective, particularly in years of extreme GCMI values. This varying perspective can be explained by the GCMI's unique advantage of accounting for industry-wide shifts in the computation of productivity.

The comparative analysis reveals that each measure captures different aspects of productivity change in the Ghanaian banking sector. This is shown in Nguyen and Pham (2020) study, which demonstrated that no single methodological framework can comprehensively capture the intricate dynamics of banking performance. The GCMI's high sensitivity allows it to reflect short-term productivity shifts that might be crucial for policymakers and bank managers to address promptly. For instance, the sharp productivity decline captured by GCMI in 2018-2019 (27.7% decrease) could be attributed to the impact of the financial clean-up. The inability of the GCMI to go beyond a productivity of one (1) from 2017 to 2022 could also be attributed to the COVID-19 pandemic that had a huge impact on businesses, a significant event whose ripple effect may protract. However, a more stable measure like CMPI provides valuable context for long-term trends. It suggests that, while there have been fluctuations, the overall productivity changes in the Ghanaian banking sector have been less dramatic than the GCMI alone might indicate.

A further test was conducted to corroborate these visible differences in the productivity indices with results from the ANOVA test of differences and the Kruskal Wallis test. The F-statistic of the ANOVA test shows that the differences in cost productivity scores across the different Malmquist productivity measures are statistically significant at a 10% alpha level, but not at the conventional 5% alpha level. The non-parametric equivalent of the ANOVA test, the

Kruskal Wallis test, also reported statistically non-significant differences in the productivity measures at an alpha level of 5%. The alignment of results from both parametric and non-parametric approaches at the 5% alpha level strengthens the conclusion that there is no strong statistical evidence for systematic differences in the cost productivity measures. However, the statistical significance of the ANOVA at 10% alpha level might suggest some subtle patterns that could merit further investigation with larger sample sizes or more refined measurement approaches. A paired t-test was also conducted to measure the differences in the GCMI and the CMPI and the GCMI and the GCMI(T). The comparison of CMPI and GCMI measurements showed a statistically significant difference. This finding suggests these methods are not interchangeable, and researchers should carefully consider which method to use based on their specific requirements. While, the comparison, between GCMI and GCMI(T) measurements, showed no statistically significant difference, suggesting that these two methods produce statistically similar results.

In conclusion, this comparative analysis not only underscores the importance of considering multiple productivity measures as shown by Nguyen and Pham (2020), but also demonstrates the superior attributes of our formulated Global Cost Malmquist Index (GCMI) in assessing the cost performance of the Ghanaian banking sector. The approach by which the GCMI is estimated has an advantage over the other cost measures, as the GCMI measures the scores of individual DMUs from both a local and global perspective, whereas the CMPI measures scores at only the local level and the GCMI(T) measures scores at a single meta level. This approach allows the presence of super-efficiency scores which may contribute to the GCMI's high volatility observed. The GCMI stands out for its heightened sensitivity to short-term productivity changes, offering unique and timely insights that other cost measures may not capture. This responsiveness is particularly valuable in the dynamic banking environment, where rapid detection of productivity shifts can be crucial for effective management and policymaking.

The GCMI's ability to capture extreme values, both positive and negative, provides a more nuanced picture of the sector's performance. For instance, it effectively highlighted the significant productivity increase in 2010-2011 and the sharp decline during the financial clean-up in 2018-2019, offering a level of detail not as apparent in other measures. This granularity allows for more targeted and timely interventions, a key advantage in a sector subject to frequent regulatory changes and economic pressures. Furthermore, the GCMI's comprehensive nature, considering all banks with each time periods simultaneously, provides a more holistic view of productivity changes. This approach allows for a better understanding of sector-wide trends and the impact of broad economic or regulatory shifts, surpassing the capabilities of more traditional productivity measures.

Table 8: Summary of Malmquist Indices

Period	Classical Malmquist Productivity Index (MPI)	Classical Cost Malmquist Index (CMPI)	Global Malmquist Index (GMI(P&L))	Global Cost Malmquist Index (GCMI(T))	Global Malmquist Index (GMI(A&T))	Global Cost Malmquist Index (GCMI) (Proposed Model)
2000-01	0.954	1.104	1.113	1.116	0.974	0.932
2001-02	1.049	1.097	0.938	1.075	0.967	1.020
2002-03	1.075	1.160	0.930	0.886	1.030	1.026
2003-04	0.841	0.869	1.225	1.113	0.888	0.952
2004-05	0.985	1.029	0.994	1.079	0.951	0.972
2005-06	0.907	0.875	1.130	1.075	0.916	0.937
2006-07	0.817	0.939	0.941	1.007	0.864	0.927
2007-08	1.229	1.286	0.760	0.756	1.344	0.967
2008-09	0.992	0.993	0.958	0.993	0.837	0.963
2009-10	0.908	0.955	0.990	1.014	0.862	0.895
2010-11	1.035	1.105	0.987	0.926	1.080	1.279
2011-12	1.039	1.038	0.883	0.916	0.953	0.855
2012-13	1.147	1.048	0.905	0.901	1.300	1.077
2013-14	1.069	1.108	0.940	0.948	0.866	0.903
2014-15	0.903	0.924	1.193	1.096	0.843	0.804
2015-16	1.113	0.929	0.975	0.965	0.947	0.919

2016-17	0.978	1.015	1.097	1.152	0.879	0.984
2017-18	1.261	1.084	0.716	0.794	1.141	1.043
2018-19	0.900	0.982	1.037	0.932	0.645	0.723
2019-20	0.924	0.951	1.025	0.949	0.805	0.880
2020-21	1.118	1.025	0.881	0.852	0.950	0.863
2021-22	0.874	0.899	1.064	1.035	0.827	0.867
Year Average	**1.005**	**1.019**	**0.986**	**0.981**	**0.949**	**0.945**

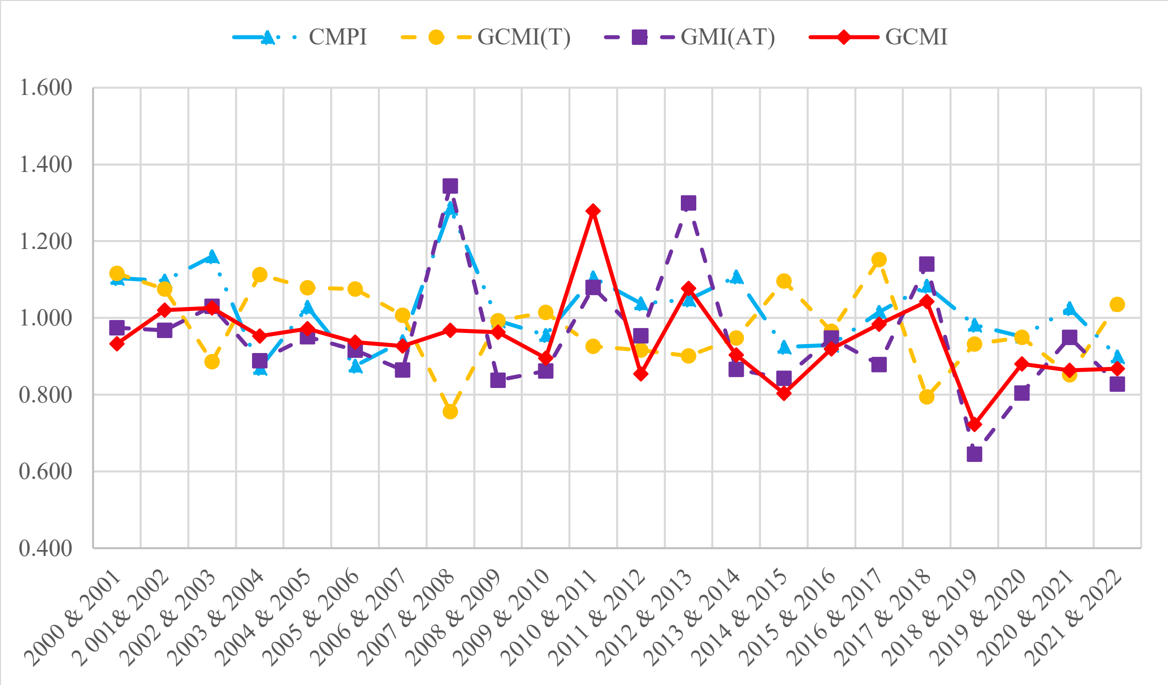
Source: Author's Construct, 2024.

The trend of the Malmquist indices is also displayed in Figure 3 to graphically show the relationship between the various indices being compared.

The global cost Malmquist index (GCMI) exhibits notable fluctuations throughout the years. It reached a significant peak in 2010-11, with values of 1.279 and, while experiencing its lowest points in 2018-19 (0.723). This high degree of volatility sets GCMI apart from other measures, particularly the GCMI(T), which demonstrates a more stable pattern, generally hovering close to 1. The pronounced volatility of GCMI suggests a heightened sensitivity to changes in underlying productivity factors as earlier mentioned.

When comparing GCMI to other productivity measures, we observe interesting relationships. GCMI often moves in tandem with GMI(A&T), suggesting these measures capture similar aspects of productivity. However, there are instances where GCMI diverges significantly from this related measure, most notably in 2007-08. This divergence indicates that GCMI may be capturing unique aspects of productivity that are not reflected in the other measures, most apparently the cost component.

Fig. 3: Trend of GCMI and Comparative Indexes scores across years (2000-2022)



Source: Author's Construct, 2024.

4.5 Conclusion

In conclusion, GCMI offers a unique and valuable perspective on cost productivity measurement. Its high sensitivity to changes and potential to capture aspects of productivity not reflected in other measures make it a powerful tool in the productivity measurement toolkit. While its volatility presents some challenges, this same characteristic allows GCMI to potentially detect rapid changes in productivity that might be missed by more stable measures. To maximise its effectiveness, GCMI might be best utilized in combination with other, more stable measures like CMPI or GCMI(T) This approach would provide both sensitivity to short-term changes and context for long-term trends, offering a comprehensive and nuanced view of productivity dynamics over time.

Ultimately, the superiority of the GCMI lies in its ability to offer a more complete and responsive picture of banking sector productivity. Its unique insights into short-term changes and potential areas for immediate intervention, combined with its sector-wide perspective, make it an invaluable tool for developing effective policies and strategies. As the Ghanaian banking sector continues to face ongoing economic challenges and regulatory changes, the GCMI's superior sensitivity and comprehensive approach provide the nuanced understanding necessary for enhancing cost productivity and overall performance. While other cost measures retain their value, the GCMI emerges as a leading indicator for proactive and informed decision-making in the dynamic landscape of Ghana's banking industry.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Introduction

This Chapter concludes the research on estimating the Global Cost Frontier Shift (GCFS) and Global Cost Malmquist Index (GCMI) and applying it to the Ghanaian banking sector from 2000 to 2022. It is structured into three main sections: a summary of key findings, conclusions drawn from these findings, and recommendations for practice, policy, and future research. This structure allows for a comprehensive review of the study's contributions and implications.

5.2 Summary of Study

The primary aim of this study was to propose and apply a novel approach for assessing the productivity of decision-making units using a global cost perspective. The proposed approach was applied to assess the performance of Ghanaian banks.

This study successfully achieved its objectives. First, it modelled the Global Cost Frontier Shift (GCFS) of firms, extending existing global frontier methodologies to incorporate cost considerations. Second, it formulated the Global Cost Malmquist Index (GCMI) and its components, providing a comprehensive framework for assessing productivity changes from a cost perspective. Third, the formulated model was applied to estimate GCMI and its components for Ghanaian banks over the period 2000-2022, revealing an average productivity decline of 5.5% per annum and capturing significant short-term productivity shifts. Finally, the study compared the proposed GCMI with existing models, demonstrating its superior sensitivity to cost-related factors and short-term changes in the banking environment. This comparison highlighted the GCMI's ability to provide unique insights not captured by traditional productivity measures, particularly in detecting and quantifying the impacts of regulatory changes, economic instability, and global events on bank productivity.

Methodologically, this study extended the Global Malmquist Index of Asmild and Tam (2007) and the Cost Malmquist Index of Maniadakis and Thanassoulis (2004) to develop a Global Cost Malmquist Index. This new approach was then applied to a dataset of 32 Ghanaian banks over the period 2000-2022.

The main findings of the research are as follows:

a) The descriptive statistics revealed that Ghanaian banks, on average, accumulate approximately 1.65 billion in customer deposits, 72.6 million in fixed assets, and 67.8 million in personnel expenses to produce 782 million in loans and advances to customers and 820 million in investments in securities. Significant variations were observed across banks and over time, indicating differences in the scale of operations within the Ghanaian banking industry.
b) Statistical tests confirmed that the Ghanaian banking industry operates under variable returns to scale (VRS) technology, aligning with findings from previous studies on banking efficiency (Adjei-Frimpong & Gan, 2014; Alhassan & Ohene-Asare, 2016).
c) The average GCMI over the entire period was 0.945, indicating an overall productivity decline of 5.5% per annum in the Ghanaian banking sector. This decline can be attributed to significant regulatory reforms, periods of economic instability, the collapse of banks, and the impacts of global events such as the global financial crisis and the COVID-19 pandemic.
d) The GCMI exhibited higher volatility compared to traditional measures like the Cost-Malmquist Productivity Index (CMPI), allowing for the detection of short-term

productivity shifts. For instance, significant productivity changes were captured in 2010-2011 (27.9% increase) and 2018-2019 (27.7% decrease).

e) The comparative analysis revealed that the GCMI offers unique insights not captured by other productivity measures. It showed a stronger sensitivity to cost-related factors and short-term changes in the banking environment.

5.3 Conclusions of the Study

The objectives of the study have been achieved, and the results of this study have significant implications for the analysis of dynamic cost productivity and efficiency in the banking industry:

First, the objective to model the Global Cost Frontier Shift and formulate the Global Cost Malmquist Indices that are transitive and capture the true frontier shift of firms was found to be 0.946 for the Global Cost Frontier Shift, and the Global Cost Malmquist Indices was found to be 0.945. This indicates the Global Frontier Shift decreased by 5.4%, while the Global Cost Malmquist Indices decreased by 5.5%.

Second, the objective to decompose the Global Cost Malmquist Indices into a four-factor model was carried out to obtain the Global Efficiency Change (GEC), Global Allocative Efficiency Change (GAEC), Global Frontier Shift (GFS) and Global Price Effect (GPE).

Third, the objective to use the formulated model to estimate the Global Cost Malmquist Indices of the banking sector in Ghana was found to be 0.945 which indicates a 5.5% decline in the banking industry of Ghana.

Fourth, the objective to contrast the proposed model with the existing Cost Malmquist Index of Maniadakis and Thanassoulis (2004), and the Global Cost Malmquist Index of Tohidi et al (2012) was carried out and found to be 1.019 for the Cost Malmquist Index of Maniadakis and

Thanassoulis (2004) and found to be 0.981 for the Global Cost Mamquist Index of Tohidi et al (2021). This indicates the Cost Malmquist showed growth in the banking industry of 1.9% while the Global Cost Mamlquist showed a decline of 1.9% in contrast to the much more decline showed by the proposed model of 5.5%.

Fifth, the evidence of variable returns to scale in the Ghanaian banking industry suggests that banks are not operating at their optimal scales. This aligns with similar findings of variable return to scale by Ohene-Asare et al., (2019) on the comparison of the return to scale in the insurance industry, indicating that financial institutions in Ghana may be experiencing either economies or diseconomies of scale. Banks can potentially improve their performance by adjusting their operational scales to achieve long-term targets at appropriate levels.

Sixth, the overall productivity decline of 5.5% per annum, as indicated by the GCMI, highlights the challenges faced by the Ghanaian banking sector during the study period. This decline can be attributed to various factors, including regulatory changes, economic instability, liquidation, financial sector clean-up, and global events. The finding underscores the importance of considering both internal and external factors when assessing bank productivity, as emphasised by Fethi and Pasiouras (2010) in their review of bank efficiency studies.

Seventh, the higher volatility of the GCMI compared to the other cost measures like the CMPI and GCMI(T) demonstrates its ability to capture short-term productivity shifts. This sensitivity is particularly valuable in the dynamic banking environment, where rapid detection of productivity changes can be crucial for effective management and policymaking. This aligns with the arguments of Asmild and Tam (2007) regarding the benefits of global productivity measures.

Eighth, the comparative analysis revealed that the GCMI provides a more comprehensive view of productivity changes by incorporating cost considerations. This supports the assertion of

Maniadakis and Thanassoulis (2004) that cost-based productivity measures offer insights not captured by quantity-based measures alone.

Nineth, the study demonstrates the value of applying advanced productivity measurement techniques to the banking sector in developing economies. As highlighted by Adjei-Frimpong et al. (2014), such analysis can provide crucial insights for improving the efficiency and competitiveness of the banking sector in countries like Ghana.

Finally, the challenge of unbalanced panel data emerges as a significant consideration in this study of Ghanaian banks from 2000 to 2022. This limitation manifests primarily through missing observations for certain banks in specific periods. The global cost Malmquist index's inherent ability to handle unbalanced panels provided an initial advantage in addressing the issue. Another crucial limitation is the non-circularity challenge in comparing technological frontiers across time. The global cost frontier shift component of the study specifically addresses this limitation by providing a unified framework for technological change measurement as shown by Asmild and Tam (2007).

5.4 Contributions to Academic Research

i. The proposed Global Cost Frontier Shift (GCFS) and Global Cost Malmquist Index (GCMI) contribute to the academic papers by extending the Global Frontier Shift and the Global Malmquist Indices of Asmild and Tam (2007) to the Global Cost Frontier Shift and Global Cost Malmquist indices incorporating allocative efficiency change.

ii. The study is a novel application of the proposed Global Cost Malmquist Index, adding to the academic studies on productivity in the Ghanaian banking industry.

iii. The study adds a new approach to estimating cost productivity to the existing cost productivity models in the academic literature.

iv. The study adds a more expansive time frame on productivity in the Ghanaian banking industry to the literature.

5.5 Recommendations

Based on the study's findings and conclusions, the following recommendations are proposed for practice, policy, and future research:

5.5.1 For Policy

- Regulatory bodies, such as the Bank of Ghana, should consider the implications of variable returns to scale when formulating policies. Measures that encourage banks to operate at optimal scales could potentially enhance sector-wide productivity.
- The high sensitivity of the GCMI to short-term changes suggests that regulators should develop more responsive monitoring systems to detect and address productivity shifts in real time.
- The GCMI framework offers valuable tools for analysing regional financial integration initiatives. In the context of economic communities like ECOWAS, the methodology could help assess the efficiency implications of cross-border banking activities and regulatory harmonisation efforts.
- The GCMI framework could be used to identify whether newer technologies and business models adopted by firms in emerging markets represent genuine advances in cost productivity or simply match efficiency levels previously achieved in developed markets through different means. This would be particularly valuable for understanding whether digital-first strategies in emerging markets deliver sustainable cost advantages.

5.5.2 For Practice

- Bank managers should focus on optimising their input mix and cost structures, as the GCMI results indicate that cost efficiency is a key driver of overall productivity. This may involve investing in cost-effective technologies through the adoption of digital banking platforms, automation tools, and AI-driven customer service to reduce transaction costs and improve service delivery speed, and streamlining operations through lean management techniques to reduce process redundancies and operational bottlenecks, or standardize routine tasks and optimize branch workflows to reduce overheads.
- The variations in productivity in the industry suggest that there are, opportunities for knowledge sharing within the industry. Best practices from high-performing banks should be identified and disseminated.
- Given the impact of global events on productivity, banks should incorporate risk-adjusted performance indicators into the proposed model to evaluate how risk exposure affects productivity outcomes to help mitigate the effects of external shocks on their operations.
- The GCMI model can be applied across various industries, groups, or blocs because of its ability to provide a comprehensive, long-term view of cost productivity evolution while maintaining the crucial economic insights provided by price information.

5.5.3 For Further Research

- Future studies may extend the decomposed GCMI to an eight-factor decomposition to capture variable returns to scale and apply the decomposed GCMI to ascertain those scale and pure technical factors that affect productivity.
- A cross-country comparison using the GCMI may offer valuable insights into the relative performance of Ghana's banking sector compared to other African countries. This would

extend the work of researchers like Hassan and Jreisat (2016) who have conducted cross-country banking efficiency studies in Africa.

- Future research may explore the incorporation of non-radial slacks into the GCMI analysis.
- The development of a fuzzy GCMI may address situations where input-output data and corresponding prices are ambiguous or incomplete, building on the work of fuzzy DEA researchers in the banking sector.

In conclusion, this study has demonstrated the value of the Global Cost Malmquist Index in providing a nuanced understanding of productivity changes in the Ghanaian banking sector. By offering a more sensitive and comprehensive measure of productivity, the GCMI can inform better decision-making at both the policy and managerial levels, potentially contributing to the enhanced efficiency and competitiveness of the banking industrie.

REFERENCES

Acemoglu, D. (2012). Introduction to economic growth. *Journal of Economic Theory*, *147*(2), 545–550. https://doi.org/10.1016/J.JET.2012.01.023

Adeabah, D., Gyeke-Dako, A., & Andoh, C. (2019). Board gender diversity, corporate governance and bank efficiency in Ghana: a two stage data envelope analysis (DEA) approach. *Corporate Governance (Bingley)*, *19*(2), 299–320. https://doi.org/10.1108/CG-08-2017-0171

Adjei-Frimpong, K., & Gan, C. (2014). COST EFFICIENCY OF GHANA'S BANKING INDUSTRY: A PANEL DATA ANALYSIS. In *The International Journal of Business and Finance Research* ♦ (Vol. 8). http://ssrn.com/abstract=2322961

Adusei, M. (2016). Determinants of bank technical efficiency: Evidence from rural and community banks in Ghana. *Cogent Business and Management*, *3*(1). https://doi.org/10.1080/23311975.2016.1199519

Afsharian, M., & Ahn, H. (2015). The overall Malmquist index: a new approach for measuring productivity changes over time. *Annals of Operations Research*, *226*(1), 1–27. https://doi.org/10.1007/s10479-014-1668-5

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

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

Althin, R. (2001). Measurement of Productivity Changes: Two Malmquist Index Approaches. In *»£L Journal of Productivity Analysis* (Vol. 16). Pi. http://about.jstor.org/terms

Amin, G. R., & Ibn Boamah, M. (2020). A new inverse DEA cost efficiency model for estimating potential merger gains: a case of Canadian banks. *Annals of Operations Research*, *295*(1), 21–36. https://doi.org/10.1007/s10479-020-03667-9

Amoah, B., Ohene-Asare, K., Bokpin, G. A., & Aboagye, A. Q. Q. (2018). Technical efficiency: the pathway to credit union cost efficiency in Ghana. *Managerial Finance*, *44*(11), 1292–1310. https://doi.org/10.1108/MF-10-2017-0431

Anagnostopoulos, Y., Husa, K. A., & Noikokyris, E. (2022). A three-phase comparative efficiency analysis of US and EU banks. *International Review of Economics and Finance*, *81*, 113–127. https://doi.org/10.1016/j.iref.2022.04.009

Antunes, J., Hadi-Vencheh, A., Jamshidi, A., Tan, Y., & Wanke, P. (2024). Cost efficiency of Chinese banks: Evidence from DEA and MLP-SSRP analysis. *Expert Systems with Applications*, *237*, 121432. https://doi.org/10.1016/J.ESWA.2023.121432

Aparicio, J., Barbero, J., Kapelko, M., Pastor, J. T., & Zofío, J. L. (2017). Testing the consistency and feasibility of the standard Malmquist-Luenberger index: Environmental productivity in world air emissions. *Journal of Environmental Management*, *196*, 148–160. https://doi.org/10.1016/J.JENVMAN.2017.03.007

Aparicio, J., & Santín, D. (2024). Global and local technical changes: A new decomposition of the Malmquist productivity index using virtual units. *Economic Modelling*, *134*, 106674. https://doi.org/10.1016/J.ECONMOD.2024.106674

Arsad, R., Isa, Z., Abidin, N. H. Z., & Mohd Shaari, S. N. (2022). Stock Selection using the Data Envelopment Analysis Models and DuPont Analysis. *International Journal of Academic Research in Business and Social Sciences*, *12*(8). https://doi.org/10.6007/IJARBSS/V12-I8/14448

Asmild, M., Hougaard, J. L., Kronborg, D., & Kvist, H. K. (2003). Measuring Inefficiency via Potential Improvements. *Journal of Productivity Analysis*, *19*(1), 59–76. https://doi.org/10.1023/A:1021822103696/METRICS

Asmild, M., & Tam, F. (2007). Estimating global frontier shifts and global Malmquist indices. *Special Issue on Productivity Measurement in Complex Services Industries*, *27*(2), 137–148. https://doi.org/10.1007/sl

Atici, K. B., & Podinovski, V. V. (2015). Using data envelopment analysis for the assessment of technical efficiency of units with different specialisations: An application to agriculture. *Omega*, *54*, 72–83. https://doi.org/10.1016/J.OMEGA.2015.01.015

Babones, S. (2015). What is world-systems analysis? Distinguishing theory from perspective. *Http://Dx.Doi.Org/10.1177/0725513615575324*, *127*(1), 3–20. https://doi.org/10.1177/0725513615575324

Banker, R. D. (1996). Hypothesis tests using data envelopment analysis. *Journal of Productivity Analysis*, *7*(2–3), 139–159. https://doi.org/10.1007/BF00157038/METRICS

Banker, R. D., Charnes, A., & Cooper, W. W. (1984). Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis. In *Source: Management Science* (Vol. 30, Issue 9).

Battese, G. E., Rao, D. S. P., & O'donnell, C. J. (2004). A Metafrontier Production Function for Estimation of Technical Efficiencies and Technology Gaps for Firms Operating Under Different Technologies. In *Source: Journal of Productivity Analysis* (Vol. 21, Issue 1).

Bhat, Z. U. H., Sultana, D., Dar, Q. F. ; Z. U. H., & Dar, Q. F. (2019). A comprehensive review of data envelopment analysis (DEA) in sports. In *Journal of Sports Economics & Management* (Vol. 9, Issue 2). http://creativecommons.org/licenses/by/3.0

Blankson, N., Anarfo, E. B., Amewu, G., & Doabil, L. (2022). Examining the determinants of bank efficiency in transition: empirical evidence from Ghana. *Heliyon*, *8*(8), e10156. https://doi.org/10.1016/j.heliyon.2022.e10156

Bogetoft, P., & Hougaard, J. L. (1999). Efficiency Evaluations Based on Potential (Non-Proportional) Improvements. *Journal of Productivity Analysis*, *12*(3), 233–247. https://doi.org/10.1023/A:1007848222681/METRICS

Bogetoft, P., & Otto, L. (2010). Benchmarking with DEA, SFA, and R. In *International Series in Operations Research & Management Science* (Vol. 139).

Bolós, V., Benıtez, R., & Coll-Serrano, V. (2022). *Conventional and Fuzzy Data Envelopment Analysis with deaR*. https://www.uv.es/vbolos/investigacion/pdf/deaR_manual.pdf

Camanho, A. S., & D'Inverno, G. (2023). Data Envelopment Analysis: A Review and

Synthesis. *Lecture Notes in Economics and Mathematical Systems*, *692*, 33–54. https://doi.org/10.1007/978-3-031-29583-6_3

Camanho, A. S., & Dyson, R. G. (2005). Cost efficiency measurement with price uncertainty: A DEA application to bank branch assessments. *European Journal of Operational Research*, *161*(2), 432–446. https://doi.org/10.1016/j.ejor.2003.07.018

Camanho, A. S., & Dyson, R. G. (2006). Data envelopment analysis and Malmquist indices for measuring group performance. *Journal of Productivity Analysis*, *26*(1), 35–49. https://doi.org/10.1007/S11123-006-0004-8/METRICS

Camanho, A. S., Stumbriene, D., Barbosa, F., & Jakaitiene, A. (2023). The assessment of performance trends and convergence in education and training systems of European countries. *European Journal of Operational Research*, *305*(1), 356–372. https://doi.org/10.1016/j.ejor.2022.05.048

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*, *50*(6), 1393. https://doi.org/10.2307/1913388

Charnes, A., Clark, C. T., Cooper, W. W., & Golany, B. (1983). *CENTER FOR CYBERNETIC STUDIES*.

Charnes, A., Cooper, W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. In *Company European Journal of Operational Research* (Vol. 2).

Chase-Dunn, C., & Grimes, P. (1995). WORLD-SYSTEMS ANALYSIS. *Annual Review of Sociology*, 387–417.

Chen, K., & Zhu, J. (2019). Computational tractability of chance constrained data envelopment analysis. *European Journal of Operational Research*, *274*(3), 1037–1046. https://doi.org/10.1016/j.ejor.2018.10.039

Chen, X., Chen, Y., Huang, W., & Zhang, X. (2023). A new Malmquist-type green total factor productivity measure: An application to China. *Energy Economics*, *117*, 106408. https://doi.org/10.1016/J.ENECO.2022.106408

Cheng, M., Lu, Y., Zhu, H., & Xiao, J. (2022). Measuring CO2 emissions performance of China's construction industry: A global Malmquist index analysis. *Environmental Impact Assessment Review*, *92*, 106673. https://doi.org/10.1016/J.EIAR.2021.106673

Cho, T. Y., & Chen, Y. S. (2021). The impact of financial technology on China's banking industry: An application of the metafrontier cost Malmquist productivity index. *The North American Journal of Economics and Finance*, *57*, 101414. https://doi.org/10.1016/J.NAJEF.2021.101414

Cooper, W. W., Seiford, L. M., & Zhu, J. (2011). Data envelopment analysis: History, models, and interpretations. *International Series in Operations Research and Management Science*, *164*, 1–39. https://doi.org/10.1007/978-1-4419-6151-8_1

Cova-Alonso, D. J., Díaz-Hernández, J. J., & Martínez-Budría, E. (2021). A strong efficiency measure for CCR/BCC models. *European Journal of Operational Research*, *291*(1), 284–295. https://doi.org/10.1016/J.EJOR.2020.09.006

Cummins, J. D., Weiss, M. A., Xie, X., & Zi, H. (2010). Economies of scope in financial services: A DEA efficiency analysis of the US insurance industry. *Journal of Banking* *and Finance*, *34*(7), 1525–1539. https://doi.org/10.1016/j.jbankfin.2010.02.025

Daraio, C., Simar, L., & Wilson, P. W. (2020). Fast and efficient computation of directional distance estimators. *Annals of Operations Research*, *288*(2), 805–835. https://doi.org/10.1007/S10479-019-03163-9/METRICS

Debreu, G. (1951). The Coefficient of Resource Utilization. *Econometrica*, *19*(3), 273. https://doi.org/10.2307/1906814

Dehghani Sadrabadi, M. H., Sabouhi, F., Bozorgi-Amiri, A., & Sheikhalishahi, M. (2023). A robust-stochastic data envelopment analysis model for supplier performance evaluation of the telecommunication industry under uncertainty. *RAIRO - Operations Research*, *57*(1), 263–290. https://doi.org/10.1051/RO/2023008

Dénes, R. V., Kecskés, J., Koltai, T., & Dénes, Z. (2017). The Application of Data Envelopment Analysis in Healthcare Performance Evaluation of Rehabilitation Departments in Hungary. *Quality Innovation Prosperity*, *21*(3), 127–142. https://doi.org/10.12776/QIP.V21I3.920

Dobrovič, J., Čabinová, V., Gallo, P., Partlová, P., Váchal, J., Balogova, B., & Orgonáš, J. (2021). Application of the DEA Model in Tourism SMEs: An Empirical Study from Slovakia in the Context of Business Sustainability. *Sustainability 2021, Vol. 13, Page 7422*, *13*(13), 7422. https://doi.org/10.3390/SU13137422

Domar, E. D. (1946). CAPITAL EXPANSION, RATE OF GROWTH, AND EMPLOYMENT'. In *Source: Econometrica* (Vol. 14, Issue 2).

Dong, P., Qiao, K., & Yang, M. (2015). Operational efficiency across the Chinese aerospace industry: a DEA and Malmquist analysis. *Chinese Management Studies*, *9*(4), 553–570. https://doi.org/10.1108/CMS-07-2015-0142/FULL/XML

Dugger, W. M. (1984). The Nature of Capital Accumulation and Technological Progress in the Modern Economy. *Journal of Economic Issues*, *18*(3), 799–823. https://doi.org/10.1080/00213624.1984.11504275

Dyson, R. G., Allen, R., Camanho, A. S., Podinovski, V. V., Sarrico, C. S., & Shale, E. A. (2001). Pitfalls and protocols in DEA. *European Journal of Operational Research*, *132*(2), 245–259. https://doi.org/10.1016/S0377-2217(00)00149-1

Emmenegger, J.-F., & Eldin, H. A. N. (2023). Measuring I/O-Production in Digital Economy. *Chinese Business Review*, *22*(1). https://doi.org/10.17265/1537-1506/2023.01.002

Emrouznejad, A., & Yang, G. liang. (2016). A framework for measuring global Malmquist–Luenberger productivity index with CO2 emissions on Chinese manufacturing industries. *Energy*, *115*, 840–856. https://doi.org/10.1016/J.ENERGY.2016.09.032

Faraj, B. A. A., & Övenç, G. (2023). Estimating Cost Efficiency Function and Market Power Indicators of Commercial Banks: An Empirical Study of Iraq. *Audit and Accounting Review*, *3*(2), 69–94. https://doi.org/10.32350/aar.32.04

Färe, R., & Grosskopf, S. (1985). A Nonparametric Cost Approach to Scale Efficiency. *The Scandinavian Journal of Economics*, *87*(4), 594. https://doi.org/10.2307/3439974

Färe, R., Grosskopf, S., Lindgren, B., & Roos, P. (1992). Productivity changes in Swedish pharamacies 1980-1989: A non-parametric Malmquist approach. *Journal of Productivity Analysis*, *3*(1–2), 85–101. https://doi.org/10.1007/BF00158770/METRICS

Färe, R., Grosskopf, S., Norris, M., & Zhang, Z. (1994). American Economic Association Productivity Growth, Technical Progress, and Efficiency Change in Industrialized Countries. In *Source: The American Economic Review* (Vol. 84, Issue 1).

Färe, R., & Primont, D. (1995). Multi-Output Production and Duality: Theory and Applications. *Multi-Output Production and Duality: Theory and Applications*. https://doi.org/10.1007/978-94-011-0651-1

Farrell, M. J. (1957). The Measurement of Productive Efficiency. In *Source: Journal of the Royal Statistical Society. Series A (General)* (Vol. 120, Issue 3). https://www.jstor.org/stable/2343100

Feroz, E. H., Kim, S., & Raab, R. L. (2003). Financial statement analysis: A data envelopment analysis approach. *Journal of the Operational Research Society*, *54*(1), 48–58. https://doi.org/10.1057/PALGRAVE.JORS.2601475

Fisher, R. A. (1919). The causes of human variability. *The Eugenics Review*, *10*(4), 213. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2942138/

Fried, H. O., Knox Lovell, C. A., & Schmidt, S. S. (2008). The Measurement of Productive Efficiency and Productivity Change. *The Measurement of Productive Efficiency and Productivity Change*, 1–641. https://doi.org/10.1093/ACPROF:OSO/9780195183528.001.0001

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. https://doi.org/10.1016/J.OMEGA.2020.102198

Gao, B., & Zhang, X. (2022). Analysis of an Enterprise Human Resource Management Performance Evaluation Model Based on the DEA Method. *Journal of Sensors*, *2022*(1), 4203768. https://doi.org/10.1155/2022/4203768

Giokas, D. I. (2008). Assessing the efficiency in operations of a large Greek bank branch network adopting different economic behaviors. *Economic Modelling*, *25*(3), 559–574. https://doi.org/10.1016/J.ECONMOD.2007.10.007

Goldfrank, W. L. (1995). Beyond Cycles of Hegemony: Economic, Social, and Military Factors. *Journal of World-Systems Research*, *1*(8), 34–48. https://doi.org/10.5195/JWSR.1995.37

Harrod, F. R. (1939). *An Essay in Dynamic Theory*.

Hassan, H. I., & Jreisat, A. (2016). International Journal of Economics and Financial Issues Cost Efficiency of the Egyptian Banking Sector: A Panel Data Analysis. *International Journal of Economics and Financial Issues*, *6*(3), 861–871. http:www.econjournals.com

Henriques, I. C., Sobreiro, V. A., Kimura, H., & Mariano, E. B. (2020). Two-stage DEA in banks: Terminological controversies and future directions. *Expert Systems with Applications*, *161*. https://doi.org/10.1016/J.ESWA.2020.113632

Huang, M. Y., Juo, J. C., & Fu, T. tan. (2015). Metafrontier cost Malmquist productivity index: an application to Taiwanese and Chinese commercial banks. *Journal of Productivity Analysis*, *44*(3), 321–335. https://doi.org/10.1007/s11123-014-0411-1

Israel, K.-F. (2018). Review Essay: The Economic Theory of Costs. *The Quarterly Journal of Austrian Economics*, *21*(3), 287–306. https://doi.org/10.2139/SSRN.3338419

Jimborean, Brack, R., & Estelle. (2010). *The cost-efficiency of French banks*.

Joo, S. J., Boehmke, B. C., Min, H., & Bayazit, O. (2020). Sourcing analytics for evaluating and selecting suppliers using DEA and AHP: A case of the aerospace company. *International Journal of Services and Operations Management*, *35*(4), 440–460. https://doi.org/10.1504/IJSOM.2020.105910

Kaffash, S., Azizi, R., Huang, Y., & Zhu, J. (2020). A survey of data envelopment analysis applications in the insurance industry 1993–2018. In *European Journal of Operational Research* (Vol. 284, Issue 3, pp. 801–813). Elsevier B.V. https://doi.org/10.1016/j.ejor.2019.07.034

Kneip, A., Simar, L., & Wilson, P. W. (2021). INFERENCE IN DYNAMIC, NONPARAMETRIC MODELS OF PRODUCTION: CENTRAL LIMIT THEOREMS FOR MALMQUIST INDICES. *Econometric Theory*, *37*(3), 537–572. https://doi.org/10.1017/S0266466620000237

Kohl, S., Schoenfelder, J., Fügener, A., & Brunner, J. O. (2018). The use of Data Envelopment Analysis (DEA) in healthcare with a focus on hospitals. *Health Care Management Science 2018 22:2*, *22*(2), 245–286. https://doi.org/10.1007/S10729-018-9436-8

Koopmans, T. (1951). Efficient Allocation of Resources. *Econometrica*, *19*(4), 455–465. https://doi.org/10.7249/p116

Lampe, H. W., & Hilgers, D. (2015). Trajectories of efficiency measurement: A bibliometric analysis of DEA and SFA. In *European Journal of Operational Research* (Vol. 240, Issue 1, pp. 1–21). Elsevier. https://doi.org/10.1016/j.ejor.2014.04.041

Liu, H., Yang, R., Wu, D., & Zhou, Z. (2021). Green productivity growth and competition analysis of road transportation at the provincial level employing Global Malmquist-Luenberger Index approach. *Journal of Cleaner Production*, *279*, 123677. https://doi.org/10.1016/J.JCLEPRO.2020.123677

Lovell, C. A. K. (2003). The Decomposition of Malmquist Productivity Indexes. In *Source: Journal of Productivity Analysis* (Vol. 20, Issue 3).

Lucas, M. R. (2003). Pricing decisions and the neoclassical theory of the firm. *Management Accounting Research*, *14*(3), 201–217. https://doi.org/10.1016/S1044-5005(03)00044-1

Mahanty, A. K. (1980). THEORY OF COSTS. *Intermediate Microeconomics with Applications*, 211–239. https://doi.org/10.1016/B978-0-12-465150-0.50014-9

Mahmoudi, R., Emrouznejad, A., Shetab-Boushehri, S. N., & Hejazi, S. R. (2020). The origins, development and future directions of data envelopment analysis approach in transportation systems. In *Socio-Economic Planning Sciences* (Vol. 69). Elsevier Ltd. https://doi.org/10.1016/j.seps.2018.11.009

Malmquist, S. (1953). Index numbers and indifference surfaces. *Trabajos de Estadistica*, *4*(2), 209–242. https://doi.org/10.1007/BF03006863/METRICS

Maniadakis, N., & Thanassoulis, E. (2004). *A cost Malmquist productivity index*. *154*, 396–409. https://doi.org/10.1016/S0377-2217(03)00177-2

Meeusen, W., & van den Broeck, J. (1977). Technical efficiency and dimension of the firm: Some results on the use of frontier production functions. *Empirical Economics*, *2*(2), 109–122. https://doi.org/10.1007/BF01767476/METRICS

Meza, L. A., Valério, R. P., & De Mello, J. C. C. B. S. (2015). Assessing the Efficiency of Sports in Using Financial Resources with DEA Models. *Procedia Computer Science*, *55*, 1151–1159. https://doi.org/10.1016/J.PROCS.2015.07.086

Mohammadi, N., & Yousefpour, A. (2014). The Biennial Malmquist Index in the of Negative Data. In *Journal of mathematics and computer Science* (Vol. 12).

Mohd Chachuli, F. S., Ahmad Ludin, N., Mat, S., & Sopian, K. (2020). Renewable energy performance evaluation studies using the data envelopment analysis (DEA): A systematic review. *Journal of Renewable and Sustainable Energy*, *12*(6). https://doi.org/10.1063/5.0024750/823992

Mombini, E., Rostamy-Malkhalifeh, M., Saraj, M., Zahraei, M., & Tayebi Khorami, R. (2020). Global malmquist index for measuring the economic productivity changes. *Https://Doi.Org/10.1177/0020294020923096*, *53*(7–8), 1278–1285. https://doi.org/10.1177/0020294020923096

Nguyen, P. H., & Pham, D. T. B. (2020). The cost efficiency of Vietnamese banks – the difference between DEA and SFA. *Journal of Economics and Development*, *22*(2), 209–227. https://doi.org/10.1108/JED-12-2019-0075

North, D. C. . (1992). *Transaction costs, institutions, and economic performance*. 32. https://search.worldcat.org/title/611921863

Novickytė, L., & Droždz, J. (2018). Measuring the efficiency in the lithuanian banking sector: The dea application. *International Journal of Financial Studies*, *6*(2). https://doi.org/10.3390/ijfs6020037

Nurmatov, R., Fernandez Lopez, X. L., & Coto Millan, P. P. (2021). Tourism, hospitality, and DEA: Where do we come from and where do we go? *International Journal of Hospitality Management*, *95*, 102883. https://doi.org/10.1016/j.ijhm.2021.102883

Ofori-Sasu, D., Abor, J. Y., & Mensah, Lord. (2019). Funding structure and technical efficiency: A data envelopment analysis (DEA) approach for banks in Ghana. *International Journal of Managerial Finance*, *15*(4), 425–443. https://doi.org/10.1108/IJMF-01-2018-0003

Ofori-Sasu, D., Mensah, Lord, Akuma, J. K., & Doku, I. (2019). Banking efficiency in emerging economies: Does foreign banks entry matter in the Ghanaian context? *International Journal of Finance and Economics*, *24*(3), 1091–1108. https://doi.org/10.1002/ijfe.1707

Oh, D. H., & Heshmati, A. (2010). A sequential Malmquist–Luenberger productivity index: Environmentally sensitive productivity growth considering the progressive nature of technology. *Energy Economics*, *32*(6), 1345–1355. https://doi.org/10.1016/J.ENECO.2010.09.003

Oh, D. hyun. (2010). A global Malmquist-Luenberger productivity index. *Journal of Productivity Analysis*, *34*(3), 183–197. https://doi.org/10.1007/s11123-010-0178-y

Oh, D. hyun, & Lee, J. dong. (2010). A metafrontier approach for measuring Malmquist productivity index. *Empirical Economics*, *38*(1), 47–64. https://doi.org/10.1007/S00181-009-0255-0/METRICS

Ohene-Asare, K., Asare, J. K. A., & Turkson, C. (2019). Dynamic cost productivity and economies of scale of Ghanaian insurers. *Geneva Papers on Risk and Insurance: Issues and Practice*, *44*(1), 148–177. https://doi.org/10.1057/S41288-018-0111-6/METRICS

Ohene-asare, K., Turkson, C., & Afful-dadzie, A. (2017). Multinational operation , ownership and ef fi ciency differences in the international oil industry. *Energy Economics*, *68*, 303–312. https://doi.org/10.1016/j.eneco.2017.10.006

Oredegbe, A. (2020). Cost Efficiency Determinants: Evidence from the Canadian Banking Industry. *International Journal of Business and Management*, *15*(1). https://doi.org/10.5539/ijbm.v15n1p86

Öttl, A., Asmild, M., & Gulde, D. (2023). Data Envelopment Analysis and hyperbolic efficiency measures: Extending applications and possibilities for between-group comparisons. *Decision Analytics Journal*, *9*, 100343. https://doi.org/10.1016/J.DAJOUR.2023.100343

Owusu Kwateng, K., Osei-Wusu, E. E., & Amanor, K. (2020). Exploring the effect of online banking on bank performance using data envelopment analysis. *Benchmarking*, *27*(1), 137–165. https://doi.org/10.1108/BIJ-06-2018-0154

Pastor, J. T., Asmild, M., & Lovell, C. A. K. (2011). The biennial Malmquist productivity change index. *Socio-Economic Planning Sciences*, *45*(1), 10–15. https://doi.org/10.1016/j.seps.2010.09.001

Pastor, J. T., & Lovell, C. A. K. (2005). A global Malmquist productivity index. *Economics Letters*, *88*(2), 266–271. https://doi.org/10.1016/j.econlet.2005.02.013

Pastor, J. T., Lovell, C. A. K., & Aparicio, J. (2020). Defining a new graph inefficiency measure for the proportional directional distance function and introducing a new Malmquist productivity index. *European Journal of Operational Research*, *281*(1), 222–230. https://doi.org/10.1016/J.EJOR.2019.08.021

Prescott, E. C. (1988). Robert M. Solow's Neoclassical Growth Model: An Influential Contribution to Economics. *The Scandinavian Journal of Economics*, *90*(1), 7. https://doi.org/10.2307/3440145

Purba, H. H., Nindiani, A., Trimarjoko, A., Jaqin, C., Hasibuan, S., & Tampubolon, S. (2021). Increasing Sigma levels in productivity improvement and industrial sustainability with Six Sigma methods in manufacturing industry: A systematic literature review. *Advances in Production Engineering And Management*, *16*(3), 307–325. https://doi.org/10.14743/APEM2021.3.402

Ray, S. C., & Desli, E. (1997). American Economic Association Productivity Growth, Technical Progress, and Efficiency Change in Industrialized Countries. In *Source: The American Economic Review* (Vol. 87, Issue 5).

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. https://doi.org/10.3846/TEDE.2021.13406

Sanderson, M. R. (2012). International Migration in the World-System. *Routledge Handbook of World-Systems Analysis*, 1–535. https://doi.org/10.4324/9780203863428

Sathye, M., & Tel, *. (2001). X-e□ciency in Australian banking: An empirical investigation.

In *Journal of Banking & Finance* (Vol. 25). www.elsevier.com/locate/econbase

Saunders, M., Lewis, P., & Thornhill, A. (2007). Research Methods for Business Students. In *Pearson*.

Seiford, L. M., & Zhu, J. (1999). Infeasibility Of Super-Efficiency Data Envelopment Analysis Models. *INFOR: Information Systems and Operational Research*, *37*(2), 174–187. https://doi.org/10.1080/03155986.1999.11732379

Shephard, G. C. (1953). *UNITARY GROUPS GENERATED BY REFLECTIONS*. https://doi.org/10.4153/CJM-1953-042-7

Shero, J. A., Al Otaiba, S., Schatschneider, C., & Hart, S. A. (2022). Data envelopment analysis (DEA) in the educational sciences. *The Journal of Experimental Education*, *90*(4), 1021–1040. https://doi.org/10.1080/00220973.2021.1906198

Shestalova, V. (2003). Sequential Malmquist Indices of Productivity Growth: An Application to OECD Industrial. In *Source: Journal of Productivity Analysis* (Vol. 19, Issue 2).

Simar, L., & Wilson, P. W. (2000). A general methodology for bootstrapping in non-parametric frontier models. *Journal of Applied Statistics*, *27*(6), 779–802. https://doi.org/10.1080/02664760050081951

Simar, L., & Wilson, P. W. (2002). Non-parametric tests of returns to scale. *European Journal of Operational Research*, *139*(1), 115–132. https://doi.org/10.1016/S0377-2217(01)00167-9

Simar, L., & Wilson, P. W. (2011). *PERFORMANCE OF THE BOOTSTRAP FOR DEA ESTIMATORS AND ITERATING THE*. *98*.

Solow, R. M. (1956). A Contribution to the Theory of Economic Growth. In *Source: The Quarterly Journal of Economics* (Vol. 70, Issue 1).

Sultana, I., & Rahman, M. M. (2020). DETERMINANTS OF BANK COST EFFICIENCY: EMPIRICAL EVIDENCE FROM BANGLADESH. *International Journal of Banking and Finance*, *15*(1), 39–71. https://doi.org/10.32890/IJBF2020.15.1.9931

Swan, T. W. (1956). ECONOMIC GROWTH and CAPITAL ACCUMULATION. *Economic Record*, *32*(2), 334–361. https://doi.org/10.1111/J.1475-4932.1956.TB00434.X

Tangen, S. (2005). Demystifying productivity and performance. *International Journal of Productivity and Performance Management*, *54*(1), 34–46. https://doi.org/10.1108/17410400510571437/FULL/XML

Thanassoulis, E., Shiraz, R. K., & Maniadakis, N. (2015). A cost Malmquist productivity index capturing group performance. *European Journal of Operational Research*, *241*(3), 796–805. https://doi.org/10.1016/j.ejor.2014.09.002

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

Tohidi, G., Razavyan, S., & Tohidnia, S. (2012). A global cost Malmquist productivity index using data envelopment analysis. *Journal of the Operational Research Society*, *63*(1), 72–78. https://doi.org/10.1057/jors.2011.23

Toma, E., Dobre, C., Dona, I., & Cofas, E. (2015). DEA Applicability in Assessment of

Agriculture Efficiency on Areas with Similar Geographically Patterns. *Agriculture and Agricultural Science Procedia*, *6*, 704–711. https://doi.org/10.1016/J.AASPRO.2015.08.127

Tone, K. (2001). *Theory and Methodology A slacks-based measure of efficiency in data envelopment analysis*. www.elsevier.com/locate/dsw

Tone, K. (2002). A slacks-based measure of super-efficiency in data envelopment analysis. *European Journal of Operational Research*, *143*(1), 32–41. https://doi.org/10.1016/S0377-2217(01)00324-1

Toye, J., & Toye, R. (2003). The Origins and Interpretation of the Prebisch-Singer Thesis. *History of Political Economy*, *35*(3), 437–467. https://doi.org/10.1215/00182702-35-3-437

Valizadeh, O., & Ghiyasi, M. (2023). Assessing telecommunication contractor firms using a hybrid DEA-BWM method. *Operations Research and Decisions*, *33*(4), 189–200. https://doi.org/10.37190/ORD230411

Walheer, B. (2018a). Cost Malmquist productivity index: an output-specific approach for group comparison. *Journal of Productivity Analysis*, *49*(1), 79–94. https://doi.org/10.1007/s11123-017-0523-5

Walheer, B. (2018b). Disaggregation of the cost Malmquist productivity index with joint and output-specific inputs. *Omega (United Kingdom)*, *75*, 1339–1351. https://doi.org/10.1016/j.omega.2017.01.012

Walheer, B. (2022). Global Malmquist and cost Malmquist indexes for group comparison. *Journal of Productivity Analysis*, *58*(1), 75–93. https://doi.org/10.1007/s11123-022-00640-5

Wallerstein, I. (1976). A world-system perspective on the social sciences. *The British Journal of Sociology*, *27*(3), 343–352.

Wanke, P., Tsionas, M. G., Chen, Z., Junio, J., & Antunes, M. (2020). *Dynamic network DEA and SFA models for accounting and financial indicators with an analysis of super-efficiency in stochastic frontiers: An efficiency comparison in OECD banking*. https://doi.org/10.1016/j.iref.2020.06.002

Weill, L. (2004). Measuring Cost Efficiency in European Banking: A Comparison of Frontier Techniques. In *Source: Journal of Productivity Analysis* (Vol. 21, Issue 2).

Wheelock, D. C., & Wilson, P. W. (1999). Technical Progress, Inefficiency, and Productivity Change in U.S. Banking, 1984-1993. *Journal of Money, Credit and Banking*, *31*(2), 212. https://doi.org/10.2307/2601230

Williamson, O. E. (1979). Transaction-Cost Economics: The Governance of Contractual Relations. *Source: Journal of Law and Economics*, *22*(2), 233–261.

Yen, B. T. H., & Li, J. S. (2022). Route-based performance evaluation for airlines – A metafrontier data envelopment analysis approach. *Transportation Research Part E: Logistics and Transportation Review*, *162*, 102748. https://doi.org/10.1016/J.TRE.2022.102748

Yeşilyurt, M. E., Şahin, E., Elbi, M. D., Kızılkaya, A., Koyuncuoğlu, M. U., & Akbaş-Yeşilyurt, F. (2021). A novel method for computing single output for DEA with application in hospital efficiency. *Socio-Economic Planning Sciences*, *76*, 100995. https://doi.org/10.1016/J.SEPS.2020.100995

Zhao, H., & Lin, B. (2019). Assessing the energy productivity of China's textile industry under carbon emission constraints. *Journal of Cleaner Production*, *228*, 197–207. https://doi.org/10.1016/j.jclepro.2019.03.327

Zhu, Q., Aparicio, J., Li, F., Wu, J., & Kou, G. (2022). Determining closest targets on the extended facet production possibility set in data envelopment analysis: Modeling and computational aspects. *European Journal of Operational Research*, *296*(3), 927–939. https://doi.org/10.1016/J.EJOR.2021.04.019

APPENDIX

Appendix 1: Pooled Input and Output Data for 32 Banks in Ghana

BANK	DMU	YEAR	CUSTOMER DEPOSITS	FIXED ASSETS	PERSONNEL EXPENSE	LOANS AND ADVANCES TO CUSTOMERS	INVESTMENTS	INTEREST EXPENSE DIVIDED BY DEPOSIT	OTHER OP. EXPENSE BY FIXED ASSET DIVIDED	PERSONNEL EXPENSE DIVIDED BY TOTAL ASSET
Agricultural Development Bank Limited	ADB	2000	53333117.10	1871703.10	3943435.00	54029356.60	31469215.00	0.103621275	2.889637518	32.60286889
Amalgamated Bank	AMA	2000	532192.10	142846.30	49094.00	154708.00	878290.40	0.064769282	1.111174738	18.006457
Barclays Bank of Ghana Limited	BBG	2000	134434100.00	2604900.00	3549800.00	47955100.00	59378200.00	0.059482676	2.279703635	48.89092343
CAL Bank Limited	CAL	2000	13263400.00	1293900.00	844200.00	6961400.00	5392900.00	0.131399189	0.676945668	27.87834636
Ecobank Ghana Limited	ECO	2000	66714683.40	2937827.00	1658128.00	28098701.70	15276800.00	0.059356528	0.795777798	50.73000944
First Atlantic Bank Limited	FAB	2000	12725429.20	340725.40	284481.20	3456347.80	3478891.30	0.144205415	2.230993932	60.56128665
Ghana Commercial Bank Limited	GCB	2000	169328300.00	5454000.00	9881200.00	102016900.00	69281600.00	0.076072931	0.825925926	22.83396753
Inter Continental Bank	ICB	2000	2927891.90	156736.00	189747.70	364467.90	2097901.00	0.109298468	1.351959346	28.10343314
National Investment Bank Limited	NIB	2000	12878800.00	930700.00	1211800.00	12263900.00	6758300.00	0.158842439	1.135381971	23.21463938
Prudential Bank Limited	PBL	2000	8011199.80	385242.10	345122.40	3434532.80	3626895.00	0.155165597	1.813994109	32.5589898
Societe General (Ghana) Limited	SGG	2000	70248200.00	3927000.00	3399700.00	48436300.00	30059900.00	0.105318001	1.473109244	35.80383563
Stanbic Bank Ghana Limited	SBG	2000	2682508.00	533671.50	271267.60	822702.70	1139510.00	0.094718375	1.142236751	20.75753868
Standard Chartered Bank (Ghana) Limited	SCB	2000	149938900.00	9732800.00	4297000.00	128695800.00	54913700.00	0.127120447	0.765802236	73.296835
The Trust Bank	TTB	2000	18530195.60	436279.60	722317.60	6146292.90	7212777.00	0.12057985	1.922336043	36.66366568
Universal Merchant Bank Limited	UMB	2000	39915800.00	4623000.00	52090100.00	19521500.00	8071000.00	0.144892499	0.568894657	1.036219934
Agricultural Development Bank Limited	ADB	2001	64351161.50	3158092.90	5436853.50	54220868.60	40488719.00	0.119106724	1.236284943	26.77526422
Amalgamated Bank	AMA	2001	2806604.60	124941.40	71530.00	953303.20	1038483.30	0.100492531	2.143244753	58.57033413
Barclays Bank of Ghana Limited	BBG	2001	132527119.00	4040000.00	5186000.00	68688300.00	68086800.00	0.080573698	2.67730198	44.28638642

CAL Bank Limited	CAL	2001	20814100.00	1146600.00	1025500.00	10993400.00	9069200.00	0.156826382	1.075091575	30.05265724
Ecobank Ghana Limited	ECO	2001	77960500.00	3753700.00	2187100.00	26792700.00	15983900.00	0.061889034	1.080427312	44.68506241
First Atlantic Bank Limited	FAB	2001	14536349.40	1340498.80	433584.00	4974877.50	4953579.00	0.20761939	0.71123622	43.34450303
Ghana Commercial Bank Limited	GCB	2001	192441900.00	6728800.00	13744100.00	182619800.00	34910300.00	0.075179054	1.091353585	27.70985368
Inter Continental Bank	ICB	2001	5097663.30	198503.80	327660.80	982647.10	3809882.10	0.112066111	1.933539811	23.92749209
National Investment Bank Limited	NIB	2001	15219700.00	897800.00	1933000.00	13998300.00	7390200.00	0.156501114	3.767877033	15.37909984
Prudential Bank Limited	PBL	2001	14242230.30	553578.80	556681.50	6562070.00	6949090.70	0.156714107	1.904546923	38.14959739
Societe General (Ghana) Limited	SGG	2001	76545300.00	6544000.00	4995300.00	40420100.00	40942300.00	0.114904508	0.450947433	27.338298
Stanbic Bank Ghana Limited	SBG	2001	6258886.50	658452.30	552046.40	1324975.70	2957133.20	0.115414938	1.161190112	17.61684163
Standard Chartered Bank (Ghana) Limited	SCB	2001	163614300.00	15981700.00	6060300.00	89444500.00	41688300.00	0.11012546	0.773465902	37.70338102
The Trust Bank	TTB	2001	21607300.00	701688.00	1119581.20	7301478.20	9535570.00	0.152226377	1.987145284	28.36693935
UniBank Ghana Limited	UBG	2001	2172653.00	309440.00	153359.00	646602.00	407576.00	0.059807065	1.42883273	17.68581564
Universal Merchant Bank Limited	UMB	2001	44226700.00	4455300.00	1780200.00	20636200.00	8902000.00	0.147017526	0.81554553	32.48078868
Agricultural Development Bank Limited	ADB	2002	96871298.30	4925927.70	7859893.00	63515497.00	47721414.00	0.063669447	1.101446739	23.50488817
Amalgamated Bank	AMA	2002	8251793.30	181583.50	122659.40	2476568.60	2738820.30	0.072189944	3.046735524	84.80501943
Barclays Bank of Ghana Limited	BBG	2002	195662600.00	4038500.00	5734700.00	102606200.00	66842900.00	0.036014547	2.649052866	47.26085061
CAL Bank Limited	CAL	2002	22925500.00	1051700.00	1232200.00	15513500.00	9619800.00	0.127495584	1.499572121	33.20848888
Ecobank Ghana Limited	ECO	2002	71103200.00	4627200.00	3057700.00	46248500.00	14761300.00	0.072804037	0.854274723	43.32367466
First Atlantic Bank Limited	FAB	2002	22983600.00	1312900.00	575800.00	8760700.00	5891130.00	0.10019875	0.848274811	49.75234456
Ghana Commercial Bank Limited	GCB	2002	240860900.00	10362500.00	17773200.00	95531000.00	247857600.00	0.049287369	0.411387214	26.01603538
Inter Continental Bank	ICB	2002	9199823.90	191701.40	469907.00	1754394.00	6970535.00	0.081039269	0.503950415	25.55402665
National Investment Bank Limited	NIB	2002	23344600.00	1759100.00	2718200.00	21372800.00	13267300.00	0.068632575	1.055596612	19.79074387
Prudential Bank Limited	PBL	2002	23406200.00	608900.00	694000.00	21372800.00	13267300.00	0.132819509	2.363934965	50.77334294
Societe General (Ghana) Limited	SGG	2002	102158400.00	8115100.00	4919200.00	57784300.00	45956900.00	0.059226652	1.131569543	34.81450236

Stanbic Bank Ghana Limited	SBG	2002	13954521.00	855165.00	770348.00	2545902.00	4812276.00	0.053351168	1.450054083	29.92039182
Standard Chartered Bank (Ghana) Limited	SCB	2002	217476900.00	18417800.00	10387900.00	92177500.00	90927600.00	0.044842924	0.029107711	28.98690784
The Trust Bank	TTB	2002	30012935.60	725188.30	1489183.00	11701226.00	11311459.00	0.082015136	2.47409397	31.54267608
UniBank Ghana Limited	UBG	2002	3584259.00	300870.00	190313.00	1721615.00	1010145.00	0.09586305	0.422853724	25.85902697
Universal Merchant Bank Limited	UMB	2002	62521100.00	4428200.00	2506700.00	27303500.00	10676000.00	0.099309353	1.080120591	24.63333666
Agricultural Development Bank Limited	ADB	2003	151819520.20	4502322.10	9054849.40	86534781.80	90974725.30	0.063155273	1.56916672	33.06232588
Amalgamated Bank	AMA	2003	13944051.30	232341.30	306230.00	4385457.30	9596126.30	0.211818713	4.775177723	98.27536492
Barclays Bank of Ghana Limited	BBG	2003	277141500.00	5280200.00	8938100.00	159382500.00	118959300.00	0.025667394	2.893867657	42.33755496
CAL Bank Limited	CAL	2003	33594500.00	1163300.00	1454100.00	21790300.00	17444500.00	0.128181696	1.860826958	39.73750086
Ecobank Ghana Limited	ECO	2003	135272000.00	5585500.00	5294000.00	62396900.00	32845900.00	0.038318351	0.961292633	31.77659615
First Atlantic Bank Limited	FAB	2003	25310998.10	1443909.00	771418.20	16063923.40	8948681.00	1.501437867	0.564135274	53.51658802
Ghana Commercial Bank Limited	GCB	2003	318383000.00	10120100.00	29715800.00	175429700.00	191417700.00	0.056984512	1.359867985	17.0681523
HFC/Republic Bank (Ghana) Limited	RBG	2003	10783187.70	2329457.70	615775.10	21375292.50	20639543.20	0.404843644	0.619155093	83.13082406
Inter Continental Bank	ICB	2003	16644198.30	517875.70	781161.70	3461252.20	11291581.70	0.10432616	1.20461493	27.94794317
National Investment Bank Limited	NIB	2003	34510800.00	3587600.00	3050600.00	37333000.00	46888000.00	0.112295281	0.949325454	34.16983544
Prudential Bank Limited	PBL	2003	30591400.00	1071900.00	1203900.00	13855100.00	17328500.00	0.161623855	2.603227913	51.10200183
Societe General (Ghana) Limited	SGG	2003	126321000.00	7809800.00	7291100.00	74627700.00	60785600.00	0.068301391	1.467617609	28.66165599
Stanbic Bank Ghana Limited	SBG	2003	30869041.80	816875.00	1170832.00	10243277.20	12570405.30	0.04037077	2.248112624	35.67978583
Standard Chartered Bank (Ghana) Limited	SCB	2003	281794500.00	16696200.00	10867300.00	141075900.00	66094000.00	0.048941338	0.985912962	35.94062923
The Trust Bank	TTB	2003	39174608.00	829211.00	2285800.00	17842123.00	20894675.00	0.102841565	2.556109362	27.31149969
UniBank Ghana Limited	UBG	2003	7355846.00	264844.00	287498.00	3005457.00	2109435.00	0.099989179	3.054308574	33.47612853
Universal Merchant Bank Limited	UMB	2003	79754900.00	3966200.00	3215300.00	36718300.00	14644300.00	0.074933327	1.540085977	30.89105216
Agricultural Development Bank Limited	ADB	2004	160370500.00	4806600.00	13654260.00	84536500.00	15426905.90	0.079827026	4.303208089	22.66391588
Amalgamated Bank	AMA	2004	32001976.90	2122149.70	574005.40	8129514.10	16949449.60	0.126285011	1.07599478	63.80231963

Barclays Bank of Ghana Limited	BBG	2004	316393000.00	9041400.00	11100100.00	206505600.00	241060200.00	0.025494243	3.107616077	43.14456627
CAL Bank Limited	CAL	2004	53543800.00	3839200.00	1871600.00	30131700.00	25147800.00	0.086947508	1.271384663	44.10851678
Ecobank Ghana Limited	ECO	2004	193867500.00	6972900.00	6243300.00	87009000.00	59542800.00	0.03743433	1.958826313	38.56152996
First Atlantic Bank Limited	FAB	2004	25573565.60	1747331.10	1631543.10	21721913.50	1398857.80	0.159922596	0.172150544	26.49661048
Ghana Commercial Bank Limited	GCB	2004	426573300.00	11875800.00	32348200.00	209506100.00	196879000.00	0.11830417	6.721324037	17.23663759
HFC/Republic Bank (Ghana) Limited	RBG	2004	17289130.00	2794280.00	1162833.50	23052898.00	26913479.00	0.280019527	0.843809497	51.00083374
Inter Continental Bank	ICB	2004	17478921.00	784300.00	926459.00	3950231.00	12892079.00	0.147595095	0.398571975	22.86926459
National Investment Bank Limited	NIB	2004	44670300.00	6599700.00	5165700.00	77929700.00	22245300.00	0.129611845	1.625346607	30.27416071
Prudential Bank Limited	PBL	2004	50395000.00	1445200.00	1825000.00	29462000.00	36599600.00	0.106570096	4.092305563	47.8070137
Societe General (Ghana) Limited	SGG	2004	157992300.00	10422600.00	10430800.00	15109400.00	14945800.00	0.045202203	2.089708902	23.38426583
Stanbic Bank Ghana Limited	SBG	2004	53628586.80	1170943.20	2336271.80	19954921.50	19035663.50	0.035905906	4.298555216	31.7948237
Standard Chartered Bank (Ghana) Limited	SCB	2004	307664500.00	14160300.00	11601400.00	163674400.00	153125400.00	0.041250453	2.051856246	37.90814902
The Trust Bank	TTB	2004	50895634.50	1044438.10	3118602.90	22265921.40	36810561.70	0.088531817	5.833602776	28.79317434
UniBank Ghana Limited	UBG	2004	11120603.00	1661891.00	485332.00	4530507.00	7496315.00	0.075261746	9.181827809	35.32577699
Universal Merchant Bank Limited	UMB	2004	120560900.00	5902000.00	4728200.00	87263000.00	15890300.00	0.041004173	1.318773297	29.47098261
Agricultural Development Bank Limited	ADB	2005	181456100.00	5194500.00	15109304.00	126266200.00	80830200.00	0.058140784	3.465203581	22.71267426
Amalgamated Bank	AMA	2005	35326852.00	2048549.00	937234.00	10345298.00	15426906.00	0.090756006	2.067365731	42.63606421
Barclays Bank of Ghana Limited	BBG	2005	349596400.00	10814900.00	14052200.00	274552700.00	192340000.00	0.02800887	2.947877465	35.07423037
CAL Bank Limited	CAL	2005	60781200.00	5169600.00	2751600.00	39792000.00	22737000.00	0.085302692	0.408716342	35.29895334
Ecobank Ghana Limited	ECO	2005	251069300.00	8691500.00	8888200.00	117525100.00	85810000.00	0.040121592	0.371765518	35.95411894
First Atlantic Bank Limited	FAB	2005	35572047.00	4434230.00	2094366.00	39415459.60	27532127.50	0.187560334	0.303957395	39.9530932
Ghana Commercial Bank Limited	GCB	2005	472994000.00	16155300.00	43519700.00	256157400.00	257999100.00	0.153802162	0.608982811	13.47599593
HFC/Republic Bank (Ghana) Limited	RBG	2005	28026232.00	3290359.00	2169021.00	29768399.00	29679023.00	0.167443165	1.506906693	32.48251077
Inter Continental Bank	ICB	2005	15600524.00	1790000.00	1230859.00	5739120.00	15902900.00	0.2147258	0.124101676	16.93583912

National Investment Bank Limited	NIB	2005	125452700.00	8266900.00	8008000.00	90163300.00	42288600.00	0.061431121	0.406428044	23.73881119
Prudential Bank Limited	PBL	2005	72356100.00	2870900.00	2218000.00	48449700.00	36992300.00	0.087723081	0.255076805	45.96293959
Societe General (Ghana) Limited	SGG	2005	178725000.00	11744200.00	13802600.00	124100300.00	98563500.00	0.044061547	2.397924082	21.11577529
Stanbic Bank Ghana Limited	SBG	2005	64235799.00	1435364.00	3023106.20	26183145.00	32614808.50	0.05268022	4.322741827	29.16743613
Standard Chartered Bank (Ghana) Limited	SCB	2005	325470800.00	12145300.00	13447300.00	216060300.00	181672100.00	0.043208177	0.140482326	38.24155035
The Trust Bank	TTB	2005	57089961.00	1313801.00	4171690.00	44889731.00	34247228.40	0.086275274	5.699317477	235.484373
UniBank Ghana Limited	UBG	2005	15773273.00	2430274.00	772009.00	9368863.00	7517276.00	0.06445143	7.123188579	28.38753823
Universal Merchant Bank Limited	UMB	2005	141970300.00	8258300.00	6720700.00	141425810.00	16094300.00	0.052207398	1.433769662	28.48590177
Agricultural Development Bank Limited	ADB	2006	234414300.00	7096500.00	20715804.00	150923300.00	109237300.00	0.060853369	3.614457831	19.80705166
Amalgamated Bank	AMA	2006	55639734.30	2583187.40	2080123.80	18377045.70	13630229.30	0.056058104	1.842738549	31.89696642
Barclays Bank of Ghana Limited	BBG	2006	489738000.00	12301000.00	20765000.00	444105000.00	171965000.00	0.028041524	33.47630274	31.43761137
CAL Bank Limited	CAL	2006	87915000.00	7218800.00	3764600.00	85680000.00	31012000.00	0.077602229	1.225065108	41.72182968
Ecobank Ghana Limited	ECO	2006	304273000.00	10709000.00	10900000.00	45044000.00	8565000.00	0.045889711	2.213932207	39.62027523
Fidelity Bank Ghana Limited	FBG	2006	121368706.00	2719050.00	3179380.00	34347918.00	57171181.00	0.049843293	0.381132381	24.99595676
First Atlantic Bank Limited	FAB	2006	57607933.80	4573179.20	3263544.50	55036761.50	30940474.40	0.154918748	1.579398857	42.18774311
Ghana Commercial Bank Limited	GCB	2006	775992315.00	23182200.00	47425300.00	364538500.00	293136600.00	0.105159031	0.565114614	16.36241236
Guaranty Trust Bank (Ghana) Limited	GTB	2006	12542271.00	5052770.00	837639.00	3515503.00	4428706.00	0.03957808	0.574227602	25.34398948
HFC/Republic Bank (Ghana) Limited	RBG	2006	55476168.00	3430567.00	2274809.00	65934161.00	34857671.00	0.110850537	1.710136254	47.13868505
Inter Continental Bank	ICB	2006	11860300.00	5343600.00	4651797.00	6454700.00	17911000.00	0.246115191	0.404837001	4.213898414
National Investment Bank Limited	NIB	2006	169753900.00	24066000.00	10549100.00	137736600.00	48327000.00	0.065500704	0.184505111	26.5234001
Prudential Bank Limited	PBL	2006	104359900.00	4006800.00	3692800.00	89228000.00	31066200.00	0.066967293	2.843416192	41.86831131
Societe General (Ghana) Limited	SGG	2006	236604626.00	19120751.00	16266100.00	141648623.00	102413082.00	0.035409392	1.762644626	22.50756715
Stanbic Bank Ghana Limited	SBG	2006	103402578.60	1941323.70	4015887.60	72212513.80	16841678.70	0.033737166	0.496576125	33.66249643
Standard Chartered Bank (Ghana) Limited	SCB	2006	445544000.00	11912000.00	18645000.00	239918000.00	335270000.00	0.041183362	3.309889187	38.13413784

The Trust Bank	TTB	2006	70825193.00	2667503.00	5609895.80	69532539.60	20524264.50	0.059287985	3.764863245	21.93305872
UniBank Ghana Limited	UBG	2006	25099621.00	3666094.00	1275030.00	15760561.00	11631455.00	0.048140328	0.999330895	29.14279429
United Bank for Africa (Ghana) Limited	UBA	2006	43590750.00	4132117.00	2366883.00	24555530.00	7246195.00	0.040738436	1.83949801	22.87585825
Universal Merchant Bank Limited	UMB	2006	222850000.00	3353790.00	9694000.00	218482000.00	16300000.00	0.048252188	10.93747671	34.59655457
Zenith Bank (Ghana) Limited	ZBG	2006	56023700.00	5150000.00	1274400.00	13983700.00	9022600.00	0.107979587	0.636413204	62.36004787
Agricultural Development Bank Limited	ADB	2007	271024641.00	21484240.00	27335512.00	222933509.00	88143426.00	0.065344582	1.875290352	16.98124001
Amalgamated Bank	AMA	2007	125694858.00	3670962.00	4696798.00	68706196.00	24412535.00	0.065099998	2.477135421	31.80532099
Barclays Bank of Ghana Limited	BBG	2007	720040000.00	42913000.00	37171000.00	722192000.00	357322000.00	0.035066107	1.555589215	32.18710823
CAL Bank Limited	CAL	2007	124326000.00	11824000.00	5287000.00	113953000.00	35695000.00	0.099544745	1.179465494	44.08246643
Ecobank Ghana Limited	ECO	2007	407053000.00	16932000.00	15691000.00	127039000.00	5642000.00	0.039451865	1.900011812	42.35141164
Fidelity Bank Ghana Limited	FBG	2007	121368706.00	2264874.00	3255132.00	34293379.00	65868946.00	0.084054517	0.855153532	44.95394534
First Atlantic Bank Limited	FAB	2007	92355749.00	4558723.00	3665802.00	68524813.00	33462712.00	0.111425061	0.204095094	45.86449323
Ghana Commercial Bank Limited	GCB	2007	1142116567.00	29948050.00	57884160.00	742696325.00	323308360.00	0.08705538	0.490109005	19.73107266
Guaranty Trust Bank (Ghana) Limited	GTB	2007	33652173.00	5765040.00	1466174.00	12689450.00	5973484.00	0.041692107	0.636791072	28.1127847
HFC/Republic Bank (Ghana) Limited	RBG	2007	63795343.00	4066265.00	3739039.00	102763626.00	29643694.00	0.171766833	2.172380059	43.1800575
Inter Continental Bank	ICB	2007	82507141.00	6718891.00	4651797.00	36188274.00	11486744.00	0.02757937	1.203577793	21.23443327
National Investment Bank Limited	NIB	2007	244583000.00	25358000.00	12806000.00	194933000.00	59603000.00	0.060543864	0.147685149	26.88232079
Prudential Bank Limited	PBL	2007	177922970.00	6142470.00	3843100.00	114454430.00	50610390.00	0.067236007	2.200100285	63.07149957
Societe General (Ghana) Limited	SGG	2007	279740749.00	18422727.00	19640880.00	212444163.00	83255647.00	0.027668808	1.997438924	21.2748526
Stanbic Bank Ghana Limited	SBG	2007	241399000.00	5166000.00	7231000.00	195120000.00	14282000.00	0.034275204	1.393921796	48.55040797
Standard Chartered Bank (Ghana) Limited	SCB	2007	534840000.00	11656000.00	22923000.00	287069000.00	353772000.00	0.057450826	0.409831846	35.28019893
The Trust Bank	TTB	2007	109774564.00	3414029.00	7828722.00	107380027.00	20960691.00	0.006220102	0.390559365	35.72436855
UniBank Ghana Limited	UBG	2007	56338760.00	6670506.00	2356275.00	39075021.00	14063780.00	0.048726774	1.030361115	29.38523644
United Bank for Africa (Ghana) Limited	UBA	2007	72708290.00	4861150.00	4058941.00	30296550.00	30116781.00	0.076260809	2.160885387	23.12752021

Universal Merchant Bank Limited	UMB	2007	321213000.00	9910000.00	12898000.00	294260000.00	16300000.00	0.093386631	2.409889001	36.59156458
Zenith Bank (Ghana) Limited	ZBG	2007	143621767.00	6195697.00	3360675.00	66345108.00	34689771.00	0.071030932	1.082654139	43.35099377
Agricultural Development Bank Limited	ADB	2008	319499930.00	22328817.00	38054673.00	370606658.00	158735532.00	0.064084086	2.565837411	16.40456819
Amalgamated Bank	AMA	2008	260148178.00	7434256.00	7823558.00	119231699.00	39059499.00	0.062892245	0.469465943	38.47166379
Barclays Bank of Ghana Limited	BBG	2008	923858000.00	57412000.00	63454000.00	850024000.00	413914000.00	0.059898816	2.188288163	21.80836511
CAL Bank Limited	CAL	2008	176660000.00	14335000.00	11449000.00	190938000.00	75310000.00	0.122874448	1.444157656	29.31688357
Ecobank Ghana Limited	ECO	2008	682705000.00	24381000.00	22737000.00	118631000.00	35182000.00	0.03896998	2.358598909	40.44926771
Fidelity Bank Ghana Limited	FBG	2008	157785366.00	3292431.00	5835420.00	86424961.00	78306275.00	0.094914886	1.111694976	37.57485425
First Atlantic Bank Limited	FAB	2008	99725681.00	5263781.00	5107372.00	73982667.00	37276812.00	0.127731682	0.235380423	43.24079664
Ghana Commercial Bank Limited	GCB	2008	1030106198.00	41085138.00	67714010.00	1087118928.00	345636676.00	0.048160475	1.05280491	24.30511788
Guaranty Trust Bank (Ghana) Limited	GTB	2008	91235280.00	8562597.00	2571799.00	41158887.00	60201998.00	0.061776716	0.566235337	67.67718784
HFC/Republic Bank (Ghana) Limited	RBG	2008	85205083.00	6198639.00	6190719.00	142817851.00	67238067.00	0.209423644	2.261969281	60.81052637
National Investment Bank Limited	NIB	2008	297781000.00	26783000.00	15209000.00	268396000.00	75302000.00	0.079857345	0.148334391	33.68975363
Prudential Bank Limited	PBL	2008	195287000.00	10963000.00	5833667.00	156896000.00	46370000.00	0.088275205	1.795621819	48.16524495
Sahel Shara Bank (Ghana)	SAH	2008	5061311.00	731065.00	650752.00	2247845.00	9212538.00	0.0240821	1.714859828	23.17469174
Societe General (Ghana) Limited	SGG	2008	298858563.00	20519035.00	22736917.00	287120110.00	42339395.00	0.023429099	0.875936661	19.20951381
Stanbic Bank Ghana Limited	SBG	2008	296120000.00	13437000.00	1369000.00	241234000.00	52433000.00	0.066702688	1.064597752	335.3630387
Standard Chartered Bank (Ghana) Limited	SCB	2008	742290000.00	12988000.00	33836000.00	460338000.00	300619000.00	0.045984723	5.510317216	29.10935099
UniBank Ghana Limited	UBG	2008	89908666.00	16657564.00	4907349.00	65188137.00	20438024.00	0.075714959	0.795952037	23.7677897
United Bank for Africa (Ghana) Limited	UBA	2008	150244184.00	8659318.00	6575484.42	36765023.00	140790220.00	0.067417492	1.091766026	29.64364791
Universal Merchant Bank Limited	UMB	2008	354213000.00	3268000.00	15477600.00	301560000.00	20100000.00	0.101623599	7.673225214	32.56341733
Zenith Bank (Ghana) Limited	ZBG	2008	339992666.00	9811602.00	6389823.00	137642614.00	75506464.00	0.05636278	1.109533387	60.71452527
Access Bank (Ghana) Plc	ABL	2009	6978000.00	4283000.00	4013000.00	12933000.00	73991000.00	0.246488965	0.787065141	23.2020932
Agricultural Development Bank Limited	ADB	2009	425144815.00	25058866.00	39790772.00	372864956.00	262895859.00	0.093152153	2.472088921	18.46069275

Amalgamated Bank	AMA	2009	300980131.00	7510950.00	11391427.00	162655235.00	73716629.00	0.135380734	2.65453438	30.44911915
Barclays Bank of Ghana Limited	BBG	2009	933888000.00	51918000.00	69434000.00	624432000.00	661227000.00	0.059633489	2.925671251	20.81409684
CAL Bank Limited	CAL	2009	277602000.00	14991000.00	12932000.00	214715000.00	110065000.00	0.150265488	1.697685278	34.83374575
Ecobank Ghana Limited	ECO	2009	922077000.00	44015000.00	33150000.00	496403000.00	24363000.00	0.053056307	1.764875611	41.8761086
Fidelity Bank Ghana Limited	FBG	2009	295148657.00	5168681.00	9066724.00	176523797.00	133503588.00	0.122616689	1.436363552	39.93599474
First Atlantic Bank Limited	FAB	2009	105672865.00	9677357.00	6432872.00	91826782.00	44715826.00	0.14960572	0.24669432	58.07103219
Ghana Commercial Bank Limited	GCB	2009	1259470137.00	49654822.00	84988696.00	1265516727.00	371247449.00	0.027242952	0.95474792	22.55691982
Guaranty Trust Bank (Ghana) Limited	GTB	2009	179980817.00	14594726.00	8710059.00	107280935.00	36914191.00	0.081644229	0.588745757	32.81534901
HFC/Republic Bank (Ghana) Limited	RBG	2009	122705215.00	8253717.00	9554661.00	160236863.00	51588990.00	0.223754736	2.383127989	27.03239968
National Investment Bank Limited	NIB	2009	386290000.00	26173000.00	18900200.00	354837200.00	92308000.00	0.080253178	0.163909372	33.47340758
Prudential Bank Limited	PBL	2009	251276000.00	14864000.00	5938699.00	185561000.00	70340000.00	0.11951798	1.644196851	57.22751734
Sahel Shara Bank (Ghana)	SAH	2009	19173121.00	5426854.00	2441390.00	7923377.00	6141389.00	0.058477595	0.404272807	10.33516071
Societe General (Ghana) Limited	SGG	2009	388646975.00	29338605.00	28243941.00	296218660.00	44666907.00	0.0278413	0.782799523	20.41833985
Stanbic Bank Ghana Limited	SBG	2009	499493000.00	11401000.00	3738000.00	261374000.00	79066000.00	0.072689707	1.944478555	191.0098983
Standard Chartered Bank (Ghana) Limited	SCB	2009	833084000.00	15590000.00	39527000.00	408538000.00	762122000.00	0.043300556	5.369595895	35.52541301
UniBank Ghana Limited	UBG	2009	184843596.00	20385098.00	10224316.00	110772545.00	54362009.00	0.111009899	1.074962014	21.51536983
United Bank for Africa (Ghana) Limited	UBA	2009	199790681.00	9465067.00	8022090.99	37979690.00	390190200.00	0.064804269	0.898942847	33.60734692
Universal Merchant Bank Limited	UMB	2009	386451000.00	5420000.00	18573120.00	309400000.00	31900200.00	0.111775309	4.857916052	28.97870482
Zenith Bank (Ghana) Limited	ZBG	2009	468513097.00	13102839.00	9635192.00	187856728.00	189264123.00	0.094019828	2.328944513	57.5662786
Access Bank (Ghana) Plc	ABL	2010	91845000.00	6338000.00	4139000.00	18211000.00	169851000.00	0.061473134	0.703376459	47.54385117
Agricultural Development Bank Limited	ADB	2010	536079338.00	24644011.00	71365281.00	576986904.00	329193766.00	0.069787372	1.708163497	14.09504737
Bank of Africa Ghana Limited	BOA	2010	370733174.00	8518044.00	13003189.00	187888510.00	147205089.00	0.123401757	3.253786433	31.88477903
Barclays Bank of Ghana Limited	BBG	2010	1093655000.00	46486000.00	73123090.00	602230000.00	927252000.00	0.023560446	2.464742073	22.25257439
CAL Bank Limited	CAL	2010	296625000.00	27379000.00	12269000.00	256634000.00	156541000.00	0.110577328	1.034661602	40.73282256

Ecobank Ghana Limited	ECO	2010	1116332000.00	40451000.00	41834000.00	849893000.00	14826000.00	0.029080059	2.0702084	36.36346034
Fidelity Bank Ghana Limited	FBG	2010	548029272.00	10063080.00	13122863.00	212046833.00	261846539.00	0.082534079	1.275506406	49.55612407
First Atlantic Bank Limited	FAB	2010	125973822.00	12788399.00	8096735.00	112093560.00	58167927.00	0.132394888	0.25822646	64.99906456
Ghana Commercial Bank Limited	GCB	2010	1575281050.00	54001812.00	107422804.00	1003682422.00	806726000.00	0.065508772	0.26473395	19.40608439
Guaranty Trust Bank (Ghana) Limited	GTB	2010	286891866.00	21997769.00	10876682.00	137160748.00	57014671.00	0.064219768	0.578740508	38.14581359
HFC/Republic Bank (Ghana) Limited	RBG	2010	156874543.00	13981735.00	13859918.00	180290246.00	113382315.00	0.137534393	1.831701001	26.07600456
National Investment Bank Limited	NIB	2010	498803000.00	27625900.00	21400000.00	447593000.00	126433000.00	0.078588741	0.177455938	33.69799065
Prudential Bank Limited	PBL	2010	339302552.00	19546470.00	7278690.00	225514896.00	82844000.00	0.088038041	0.195511159	55.84686255
Sahel Shara Bank (Ghana)	SAH	2010	41388736.00	6254857.00	4222089.00	24165490.00	29157003.00	0.071156172	0.403369561	16.25824941
Societe General (Ghana) Limited	SGG	2010	495397719.00	25417515.00	33064230.00	298750342.00	104483701.00	0.020571035	0.973965748	20.74485488
Stanbic Bank Ghana Limited	SBG	2010	623350000.00	10833000.00	29184000.00	343646000.00	71605000.00	0.047730809	2.677466999	13.48319271
Standard Chartered Bank (Ghana) Limited	SCB	2010	1092442000.00	19414000.00	55156000.00	467152000.00	707851000.00	0.056014873	5.302153085	30.23935746
UniBank Ghana Limited	UBG	2010	307870599.00	29816705.00	12180789.00	220557783.00	88129055.00	0.090733253	0.4790911	32.30443414
Unique Trust Bank Ghana Limited	UTB	2010	377286000.00	18043000.00	8375000.00	315297000.00	75719000.00	0.107157435	0.08413235	61.68740299
United Bank for Africa (Ghana) Limited	UBA	2010	310547778.00	7279536.00	9786951.01	87195196.00	501890000.00	0.042537126	1.051948758	41.00566965
Universal Merchant Bank Limited	UMB	2010	412521000.00	8350000.00	22287744.00	313700000.00	78000000.00	0.125653763	3.068048982	25.78861194
Zenith Bank (Ghana) Limited	ZBG	2010	552195000.00	12319000.00	13985000.00	269893000.00	254152248.00	0.048258315	1.522445004	46.84892034
Access Bank (Ghana) Plc	ABL	2011	165285000.00	7608000.00	3925000.00	77035000.00	186349000.00	0.076867229	0.445320715	71.36101911
Agricultural Development Bank Limited	ADB	2011	827718000.00	17587000.00	68256000.00	678747000.00	432579000.00	0.046985809	7.705009382	17.66521624
Bank of Africa Ghana Limited	BOA	2011	295625250.00	7104320.00	16502305.00	196217569.00	177145523.00	0.100598416	4.383145044	23.54802974
Barclays Bank of Ghana Limited	BBG	2011	1331782000.00	37404000.00	77879000.00	588636000.00	896194000.00	0.015058771	2.830098385	24.48593331
CAL Bank Limited	CAL	2011	564396000.00	28762000.00	16380000.00	412565000.00	223126000.00	0.061086542	1.256345178	47.98919414
Ecobank Ghana Limited	ECO	2011	1608256000.00	45788000.00	59845000.00	849893000.00	10872000.00	0.021098631	2.689088844	35.62842343
Energy Bank Ghana Limited	EBL	2011	107306608.00	2701884.00	1501287.00	6020889.00	79942233.00	0.016338369	1.964034725	133.4024234

Fidelity Bank Ghana Limited	FBG	2011	896644132.00	16526295.00	19025355.00	409578026.00	337508315.00	0.061815364	0.703984529	54.13444248
First Atlantic Bank Limited	FAB	2011	157892650.00	17892632.00	10883721.00	125937483.00	70180000.00	0.119871248	0.245223397	62.38646544
Ghana Commercial Bank Limited	GCB	2011	2061390000.00	53955000.00	135912000.00	476211000.00	1485570000.00	0.024161852	0.902863497	18.12479398
Guaranty Trust Bank (Ghana) Limited	GTB	2011	266006853.00	18864082.00	13861841.00	113621838.00	186118894.00	0.062716121	0.770858396	32.05161948
HFC/Republic Bank (Ghana) Limited	RBG	2011	230709943.00	12467193.00	16142060.00	210361885.00	146295607.00	0.101012573	2.738420028	26.69579899
National Investment Bank Limited	NIB	2011	722890000.00	28035000.00	22900000.00	465170000.00	209289000.00	0.061384166	0.197849973	38.44179039
Prudential Bank Limited	PBL	2011	459460000.00	24121000.00	15224000.00	293261000.00	125015000.00	0.057815697	0.131006177	36.11265108
Sahel Shara Bank (Ghana)	SAH	2011	61091093.00	5685606.00	4764268.00	38860898.00	39126190.00	0.046897017	0.860259751	20.09800414
Societe General (Ghana) Limited	SGG	2011	625773953.00	63339491.00	33157110.00	344545558.00	174503218.00	0.021664142	0.46697685	25.36642078
Stanbic Bank Ghana Limited	SBG	2011	853071000.00	10611000.00	36452000.00	503448000.00	112813000.00	0.023774106	2.930449534	31.18959179
Standard Chartered Bank (Ghana) Limited	SCB	2011	1479687000.00	18291000.00	55820000.00	596724000.00	799398000.00	0.030663242	5.109288721	35.31103547
UniBank Ghana Limited	UBG	2011	445381225.00	43538215.00	16675441.00	355968067.00	118920345.00	0.076728185	0.944189329	33.93716418
Unique Trust Bank Ghana Limited	UTB	2011	545808000.00	18109000.00	19129000.00	475232000.00	93663000.00	0.092032363	2.618200895	37.26614042
United Bank for Africa (Ghana) Limited	UBA	2011	403712111.40	9463396.80	15790000.00	113353754.80	672349300.00	0.030839332	1.051948758	36.29705731
Universal Merchant Bank Limited	UMB	2011	427650000.00	12890000.00	28091000.00	316363000.00	137900000.00	0.145450203	2.086820749	21.85028571
Zenith Bank (Ghana) Limited	ZBG	2011	576852223.00	11724496.00	16034040.00	200554868.00	308100349.00	0.064674548	1.933801163	43.64437154
Access Bank (Ghana) Plc	ABL	2012	545352000.00	27804000.00	23749000.00	274373000.00	466685000.00	0.077839634	1.007337074	33.57156091
Agricultural Development Bank Limited	ADB	2012	965018000.00	17074000.00	93440000.00	773694000.00	530904000.00	0.042658272	11.05564015	15.45615368
Bank of Africa Ghana Limited	BOA	2012	364043606.00	5711222.00	18009885.00	305099221.00	116601545.00	0.083750972	6.013519523	31.5152697
Barclays Bank of Ghana Limited	BBG	2012	1454286000.00	35656000.00	85237000.00	708923000.00	993815000.00	0.014385754	3.653971281	23.18511914
CAL Bank Limited	CAL	2012	707648000.00	34548000.00	25165000.00	747385000.00	328423000.00	0.086319752	1.414408938	46.06973972
Ecobank Ghana Limited	ECO	2012	2407615000.00	57503000.00	107286000.00	1394967000.00	1517000.00	0.032190778	3.668469471	31.49379229
Energy Bank Ghana Limited	EBL	2012	115765018.00	4593868.00	3172812.00	16616224.00	72777974.00	0.05774069	2.083026548	71.11626343
Fidelity Bank Ghana Limited	FBG	2012	1080889000.00	27123000.00	40376000.00	636763000.00	422167000.00	0.086913642	0.976145707	33.01542996

First Atlantic Bank Limited	FAB	2012	200378383.00	19234473.00	11908627.00	135890244.00	124793000.00	0.104929867	0.294916892	61.06218878
Ghana Commercial Bank Limited	GCB	2012	2334608000.00	73404000.00	144435000.00	847872000.00	1946836000.00	0.021837071	0.930317149	20.57720082
Guaranty Trust Bank (Ghana) Limited	GTB	2012	476122180.00	19420787.00	20002680.00	243209397.00	168224591.00	0.04345652	1.05413586	34.14379338
HFC/Republic Bank (Ghana) Limited	RBG	2012	312963215.00	13280265.00	21096216.00	335814761.00	144334664.00	0.074566038	3.056032466	27.86220012
National Investment Bank Limited	NIB	2012	700529061.00	27006477.00	24813000.00	449657856.00	288139000.00	0.064648282	0.236166754	35.34191754
Prudential Bank Limited	PBL	2012	555195000.00	24899000.00	21899000.00	425207000.00	136382000.00	0.063880258	0.221856299	30.89670761
Sahel Shara Bank (Ghana)	SAH	2012	106907738.00	7022771.00	7226930.00	65155201.00	101071953.00	0.073277044	0.800932096	24.72203813
Societe General (Ghana) Limited	SGG	2012	859085205.00	67914664.00	53557884.00	520100260.00	120448594.00	0.107089214	0.60011854	20.3317694
Stanbic Bank Ghana Limited	SBG	2012	1281628000.00	16364000.00	54385000.00	659878000.00	250742000.00	0.107612349	2.914568565	31.3978119
Standard Chartered Bank (Ghana) Limited	SCB	2012	1704198000.00	23315000.00	76710000.00	959597000.00	1117715000.00	0.031089111	4.506069054	31.16521966
UniBank Ghana Limited	UBG	2012	694466966.00	52108735.00	19692500.00	536244953.00	220331961.00	0.095142557	1.119117802	45.60774858
Unique Trust Bank Ghana Limited	UTB	2012	797782000.00	21033000.00	25608000.00	679648000.00	161135000.00	0.091028627	3.080968003	38.53893315
United Bank for Africa (Ghana) Limited	UBA	2012	428633944.00	7085157.00	19263800.00	278235197.00	799100820.00	0.041707115	0.757739031	36.60806726
Universal Merchant Bank Limited	UMB	2012	502628000.00	15346900.00	33709200.00	325892650.00	184029000.00	0.148503734	1.840376586	19.444918
Zenith Bank (Ghana) Limited	ZBG	2012	780684242.00	13470903.00	20402281.00	326367194.00	596942211.00	0.032442469	2.146158947	46.53829187
Access Bank (Ghana) Plc	ABL	2013	726982000.00	29161000.00	27463000.00	433690000.00	187593000.00	0.05444564	1.060663215	36.09707607
Agricultural Development Bank Limited	ADB	2013	1061102000.00	29769000.00	117793000.00	914350000.00	325865000.00	0.052480346	1.326077463	13.76788943
Bank of Africa Ghana Limited	BOA	2013	406151243.00	7040882.00	18764825.00	338732549.00	139986889.00	0.118332668	2.683989307	33.73130312
Barclays Bank of Ghana Limited	BBG	2013	1592324000.00	35199000.00	92275000.00	887042000.00	731239000.00	0.015965344	0.380351715	25.20844216
CAL Bank Limited	CAL	2013	799220000.00	44980000.00	41231000.00	981160000.00	278646000.00	0.154398038	1.646776345	37.8104339
Ecobank Ghana Limited	ECO	2013	3220777000.00	71863000.00	140748000.00	2124530000.00	1522000.00	0.022963713	3.708292167	32.8559198
Energy Bank Ghana Limited	EBL	2013	92618000.00	6385000.00	4622372.00	13688000.00	109083981.00	0.136114416	1.223957087	53.05306453
Fidelity Bank Ghana Limited	FBG	2013	1355980000.00	43228000.00	52201000.00	805967000.00	468705000.00	0.100250741	1.248496345	32.368537
First Atlantic Bank Limited	FAB	2013	202854000.00	23836000.00	13208000.00	148694000.00	177234000.00	0.113332397	0.266193992	63.16713083

Ghana Commercial Bank Limited	GCB	2013	2630283000.00	81399000.00	169996000.00	960707000.00	1747087000.00	0.035054783	0.676961633	19.94811643
Ghana Home Loans Bank Limited	GHL	2013	5339000.00	1437000.00	3284000.00	209492000.00	2890189.00	1.440719236	68.19902575	23.22124178
GN Bank	GNB	2013	233905000.00	16067000.00	63400000.00	165694000.00	10289005.00	0.051302879	4.723594946	8.888843565
Guaranty Trust Bank (Ghana) Limited	GTB	2013	661124685.00	21724000.00	22846678.00	296848000.00	325864000.00	0.045511506	1.110186522	41.0479808
HFC/Republic Bank (Ghana) Limited	RBG	2013	453589000.00	16455000.00	32858000.00	516063000.00	151921000.00	0.086891437	1.206320267	29.61427963
National Investment Bank Limited	NIB	2013	759234000.00	28734000.00	29667000.00	515624000.00	377595000.00	0.060439864	1.11425489	66.58745407
Prudential Bank Limited	PBL	2013	693129000.00	32064000.00	29576000.00	525485000.00	106401000.00	0.062386655	0.180139721	28.08378415
Sahel Shara Bank (Ghana)	SAH	2013	124727000.00	16385000.00	10519000.00	90646000.00	287100000.00	0.1031811	0.394780415	20.28633901
Societe General (Ghana) Limited	SGG	2013	926130000.00	82727000.00	53557884.00	740403000.00	143627893.00	0.026081378	0.492666832	22.71473234
Stanbic Bank Ghana Limited	SBG	2013	1557680000.00	45543000.00	73176000.00	975584000.00	392296000.00	0.039782882	1.303273829	40.05209358
Standard Chartered Bank (Ghana) Limited	SCB	2013	1779108000.00	27947000.00	84431000.00	1130244000.00	1009329000.00	0.053423401	0.794360754	35.39408511
UniBank Ghana Limited	UBG	2013	892284821.00	94756637.00	24569578.00	825276289.00	155847000.00	0.159241112	0.611570132	52.86903068
Unique Trust Bank Ghana Limited	UTB	2013	920261000.00	30426000.00	32390000.00	917053000.00	135296000.00	0.126302212	0.913823703	41.25767212
United Bank for Africa (Ghana) Limited	UBA	2013	651477056.00	7664751.00	24046000.00	172421307.00	943168000.00	0.066311681	0.280765807	64.48181057
Universal Merchant Bank Limited	UMB	2013	541247000.00	17077000.00	41151000.00	337049000.00	247071000.00	0.142328733	1.514903086	17.69888946
Zenith Bank (Ghana) Limited	ZBG	2013	1066493105.00	13332982.00	29509518.00	676782866.00	773534307.00	0.045863887	3.589745865	65.08497177
Access Bank (Ghana) Plc	ABL	2014	1199681000.00	52953000.00	36258000.00	853055000.00	721817000.00	0.061261285	1.014730044	47.40228363
Agricultural Development Bank Limited	ADB	2014	1462139000.00	34862000.00	130485000.00	1124139000.00	911722000.00	0.068669942	2.696517698	16.52864314
Bank of Africa Ghana Limited	BOA	2014	548160852.00	7134720.00	22669517.00	338549441.00	271671707.00	0.056029472	0.715200316	40.68884233
Barclays Bank of Ghana Limited	BBG	2014	2033073000.00	47594000.00	102930000.00	1510112000.00	1335867000.00	0.032343157	4.17998067	28.96436413
CAL Bank Limited	CAL	2014	1395841000.00	76604000.00	59687000.00	1337776000.00	639343000.00	0.122960996	1.38461438	45.36234021
Ecobank Ghana Limited	ECO	2014	4028124000.00	133915000.00	186863000.00	2707093000.00	1522000.00	0.029209131	2.829854759	30.34110552
Energy Bank Ghana Limited	EBL	2014	166943133.00	6428912.00	5890283.00	22050000.00	9750000.00	0.06834737	3.06473817	53.32066371
FBNBank (Ghana) Limited	FBN	2014	166464004.00	8425560.00	16142155.00	155755674.00	73702205.00	0.084950125	1.411502618	22.3089274

Fidelity Bank Ghana Limited	FBG	2014	1777313000.00	40606000.00	83632000.00	1559530000.00	823306000.00	0.093581716	0.416367039	36.11396355
First Atlantic Bank Limited	FAB	2014	511618975.00	31024941.00	19650838.00	337300161.00	235980000.00	0.085065127	0.99686997	47.41342675
Ghana Commercial Bank Limited	GCB	2014	3078071000.00	123936000.00	259868000.00	1240577000.00	2652468000.00	0.03020788	0.765338562	16.28834254
Ghana Home Loans Bank Limited	GHL	2014	18146237.00	2674537.00	5602000.00	230764000.00	3381492.00	0.449729605	29.50062011	2.745032845
GN Bank	GNB	2014	354987000.00	28037900.00	88642900.00	98000500.00	7390170.00	0.067317958	2.987527597	7.183000364
Guaranty Trust Bank (Ghana) Limited	GTB	2014	788579000.00	25756000.00	25570000.00	475164000.00	202888000.00	0.049130144	1.371059171	45.40805632
HFC/Republic Bank (Ghana) Limited	RBG	2014	660933000.00	55046000.00	55350000.00	664875000.00	525718000.00	0.097810217	1.701249864	23.92682927
National Investment Bank Limited	NIB	2014	1343814000.00	185976000.00	46278000.00	769594000.00	469367000.00	0.060333499	0.581919172	50.12260685
Prudential Bank Limited	PBL	2014	885540000.00	38957000.00	38588000.00	760450000.00	225052000.00	0.078745172	0.183484355	28.91085311
Sahel Shara Bank (Ghana)	SAH	2014	207358465.00	16118603.00	13406258.00	115027635.00	216115363.00	0.096542184	0.498366763	26.34945971
Societe General (Ghana) Limited	SGG	2014	1127429783.00	79141492.00	60184066.00	883044221.00	337196973.00	0.03919209	0.823968216	27.84706111
Stanbic Bank Ghana Limited	SBG	2014	2418005000.00	55225000.00	95180000.00	1661205000.00	199550000.00	0.041168236	1.776387506	38.43261189
Standard Chartered Bank (Ghana) Limited	SCB	2014	2198585000.00	25270000.00	129559000.00	1278362000.00	1575779000.00	0.040139453	0.835338346	27.0633225
UniBank Ghana Limited	UBG	2014	1338427231.50	142134955.50	36854367.00	1237914433.50	248900000.00	0.159241112	0.611570132	72.57936046
Unique Trust Bank Ghana Limited	UTB	2014	965627000.00	27434000.00	42107000.00	1197423000.00	253367000.00	0.159504653	3.643726762	38.67318973
United Bank for Africa (Ghana) Limited	UBA	2014	1042321997.00	9311000.00	28231000.00	421903242.00	1104497000.00	0.11363571	3.447320374	74.33735964
Universal Merchant Bank Limited	UMB	2014	786089800.00	33800254.00	46981000.00	468524000.00	253673000.00	0.110295287	0.934229666	16.55519861
Zenith Bank (Ghana) Limited	ZBG	2014	1846745159.00	13076471.00	47573092.00	1097357356.00	1290937764.00	0.071097012	7.042549094	64.6028897
Access Bank (Ghana) Plc	ABL	2015	1726179000.00	93117000.00	43625000.00	1211825000.00	356734000.00	0.08904233	0.798951856	55.57927794
Agricultural Development Bank Limited	ADB	2015	1513508474.81	108076003.89	141505000.00	1088071287.32	375570810.29	0.088605638	0.993782118	15.08177571
Bank of Africa Ghana Limited	BOA	2015	625592038.00	16643816.00	28407741.00	387493948.00	447669758.00	0.050459379	1.77570276	40.37623678
Barclays Bank of Ghana Limited	BBG	2015	2846412000.00	53405000.00	149024000.00	1663080000.00	1071962000.00	0.029249806	4.543544612	24.23173449
CAL Bank Limited	CAL	2015	1544523000.00	133638000.00	80477000.00	1806115000.00	293566000.00	0.141261736	1.077769796	41.63971072
Ecobank Ghana Limited	ECO	2015	4664513000.00	261684000.00	245769000.00	3116749000.00	594255000.00	0.026911491	0.703268064	26.80357165

Energy Bank Ghana Limited	EBL	2015	214585584.00	6479202.00	6506425.00	32919226.00	9750000.00	0.056966017	3.327806418	53.70686483
FBNBank (Ghana) Limited	FBN	2015	207530793.00	10290433.00	9300000.00	120741921.00	73702205.00	0.075811323	1.322101801	47.94089763
Fidelity Bank Ghana Limited	FBG	2015	3003029000.00	95833000.00	108198000.00	1489843000.00	1374247000.00	0.081738471	0.300825394	38.02114642
First Atlantic Bank Limited	FAB	2015	885164153.00	47548118.00	29939205.00	370400176.00	290527931.00	0.076827094	0.895448901	37.95309996
First National Bank (Ghana) Limited	FNB	2015	146400000.00	10261000.00	9300000.00	1365000.00	95870000.00	0.068306011	1.325894162	15.86774194
Ghana Commercial Bank Limited	GCB	2015	3368405711.34	158020104.48	225160000.00	1492622509.30	2128328646.93	0.03193534	2.693138328	20.56132337
Ghana Home Loans Bank Limited	GHL	2015	18146237.00	3595691.00	7681540.00	299087000.00	10725121.00	0.48298763	31.30246731	49.64610742
GN Bank	GNB	2015	403199423.00	34700149.00	82900000.00	74143034.00	3930793.00	0.069196528	2.221837722	8.261446671
Guaranty Trust Bank (Ghana) Limited	GTB	2015	1116339182.00	28182212.00	25432000.00	637879910.00	254423461.00	0.052330319	1.631738488	54.17759244
HFC/Republic Bank (Ghana) Limited	RBG	2015	923409000.00	57919000.00	70288000.00	861877000.00	223395000.00	0.123100381	2.34251282	22.28572445
National Investment Bank Limited	NIB	2015	1781931000.00	220081000.00	58358000.00	755320000.00	489488309.00	0.109015444	0.812768935	45.48978718
OmniBSIC Bank Ghana Limited	OMN	2015	391375204.00	52780000.00	17319453.00	191447207.00	60631091.00	0.080406218	0.099848427	14.30365636
Prudential Bank Limited	PBL	2015	1093462000.00	92226000.00	46511000.00	849649000.00	162624000.00	0.09355332	0.121473337	29.92758702
Sahel Shara Bank (Ghana)	SAH	2015	391375204.00	19299500.00	17319453.00	191447207.00	190289000.00	0.098531178	0.56631291	28.76785612
Societe General (Ghana) Limited	SGG	2015	1395809526.00	87427087.00	81684827.00	911472524.00	130020187.00	0.038273158	0.873577133	24.51791783
Stanbic Bank Ghana Limited	SBG	2015	3154561673.44	62325455.39	136619000.00	1680217683.57	280045000.00	0.039883572	2.339092416	31.29618135
Standard Chartered Bank (Ghana) Limited	SCB	2015	2422382000.00	28244000.00	145422000.00	1219459000.00	919458000.00	0.048188106	8.04673559	23.17013932
UniBank Ghana Limited	UBG	2015	2728142189.00	156011870.00	55281550.50	2475190684.00	386824156.00	0.181789603	0.83575846	69.29857125
Unique Trust Bank Ghana Limited	UTB	2015	1072975000.00	18284000.00	54739100.00	1028217000.00	270969000.00	0.211812018	6.617807919	35.88301598
United Bank for Africa (Ghana) Limited	UBA	2015	1767284187.00	10240464.00	37735364.00	764609838.00	1365106887.00	0.052221232	5.345978854	63.97195745
Universal Merchant Bank Limited	UMB	2015	898219336.32	49713776.56	47618000.00	640093686.45	260658321.48	0.113547027	1.249573142	29.78631478
Zenith Bank (Ghana) Limited	ZBG	2015	2044642010.00	94004146.00	58233265.00	983074431.00	721261329.00	0.083968256	1.512124444	43.77446563
Access Bank (Ghana) Plc	ABL	2016	2009146000.00	110356000.00	57597000.00	1285612000.00	422821000.00	0.107114167	0.683959187	46.52339532
Agricultural Development Bank Limited	ADB	2016	2147450000.00	105015000.00	136038000.00	1005302000.00	1180589000.00	0.077651168	1.21971147	22.3135668

Bank of Africa Ghana Limited	BOA	2016	679980171.00	47116819.00	36805037.00	447086581.00	196665949.00	0.032862666	0.750678139	31.0957945
Barclays Bank of Ghana Limited	BBG	2016	2853313000.00	59663000.00	170575000.00	2093662000.00	1056426000.00	0.032853388	1.455759851	31.00581562
CAL Bank Limited	CAL	2016	2312391000.00	252228000.00	73110000.00	1966394000.00	2038000000.00	0.131596257	1.369241321	49.2320476
Ecobank Ghana Limited	ECO	2016	5316625000.00	316661000.00	315993000.00	3480471000.00	578985000.00	0.033373992	0.055867316	25.39774615
Energy Bank Ghana Limited	EBL	2016	228851267.00	4335797.00	7542876.00	88980628.00	9750000.00	0.082045065	3.510848179	48.27113889
FBNBank (Ghana) Limited	FBN	2016	277968875.00	11494124.00	18234621.00	93149172.00	157501031.00	0.078729574	1.784600288	31.00753194
Fidelity Bank Ghana Limited	FBG	2016	2375619000.00	93019000.00	105823000.00	1314793000.00	1658568000.00	0.111688364	0.306313764	39.43946023
First Atlantic Bank Limited	FAB	2016	1042813852.00	24500964.00	42053569.00	233156314.00	568497000.00	0.07835535	2.024000117	34.29051943
First National Bank (Ghana) Limited	FNB	2016	135398000.00	21267000.00	25501000.00	3289000.00	155437000.00	0.046315307	0.156815724	11.13324968
Ghana Commercial Bank Limited	GCB	2016	3908345000.00	191062000.00	302396000.00	1412977000.00	2658741000.00	0.034246721	1.290413583	20.00556886
Ghana Home Loans Bank Limited	GHL	2016	22485780.00	4860332.00	12481556.00	351286000.00	85515183.00	0.56268037	42.91887879	43.65821072
GN Bank	GNB	2016	624343000.00	41748000.00	95600000.00	179194000.00	225788000.00	0.068391894	1.916954106	6.839160523
Guaranty Trust Bank (Ghana) Limited	GTB	2016	1111110789.00	24250750.00	30127737.00	626562584.00	407901016.00	0.070309644	1.99589724	51.29286262
HFC/Republic Bank (Ghana) Limited	RBG	2016	1558210000.00	62977000.00	84264000.00	919964000.00	514500000.00	0.10036067	0.904838274	22.02804282
National Investment Bank Limited	NIB	2016	2138317200.00	264097200.00	70029600.00	906384000.00	524985209.00	0.109015444	0.812768935	45.25470067
OmniBSIC Bank Ghana Limited	OMN	2016	462461000.00	49460000.00	21689000.00	181354000.00	185134204.00	0.101937244	0.257298827	22.68535262
Prudential Bank Limited	PBL	2016	1325008000.00	92688000.00	57973000.00	913471000.00	367154000.00	0.089404743	0.666547989	28.13639108
Societe General (Ghana) Limited	SGG	2016	1791064063.00	87325289.00	95946310.00	942307572.00	541130745.00	0.034506551	1.019332704	25.52298469
Stanbic Bank Ghana Limited	SBG	2016	3595818000.00	72441000.00	163940000.00	1677234000.00	679083000.00	0.030550489	1.607970624	32.9999878
Standard Chartered Bank (Ghana) Limited	SCB	2016	3197673000.00	29413000.00	137587000.00	1262636000.00	1278875000.00	0.028047583	1.564546289	31.78762528
UniBank Ghana Limited	UBG	2016	2615879000.00	175243000.00	66788000.00	3009255000.00	949679000.00	0.039938927	1.062536021	85.99134575
United Bank for Africa (Ghana) Limited	UBA	2016	2973611756.00	13994907.00	42474461.00	1845645572.00	1128439566.00	0.088273853	6.256030712	88.11802678
Universal Merchant Bank Limited	UMB	2016	1406009000.00	61657000.00	49407000.00	752906000.00	666708000.00	0.113987179	1.497705046	56.46853685
Zenith Bank (Ghana) Limited	ZBG	2016	2627866376.00	130061809.00	61270606.00	1012054694.00	1373358114.00	0.06637089	0.579452666	55.55265386

Access Bank (Ghana) Plc	ABL	2017	2131529000.00	121419000.00	61971000.00	877675000.00	906258000.00	0.091953241	0.750640345	51.63005277
Agricultural Development Bank Limited	ADB	2017	2541010000.00	105117000.00	167052000.00	1139356000.00	1191366000.00	0.083136627	1.18272972	21.22179321
Bank of Africa Ghana Limited	BOA	2017	884659078.00	55333527.00	37563143.00	495750311.00	135410947.00	0.039559382	0.664194242	35.75462093
Barclays Bank of Ghana Limited	BBG	2017	3161861000.00	57874000.00	205067000.00	2593012000.00	1747994000.00	0.043500331	1.691312161	29.03458382
CAL Bank Limited	CAL	2017	2428201000.00	278730000.00	100255000.00	1853674000.00	1481191000.00	0.132945337	0.676001866	42.01923096
Ecobank Ghana Limited	ECO	2017	6447818000.00	456003000.00	343108000.00	2685759000.00	2462208000.00	0.024419269	0.056096122	26.518449
Energy Bank Ghana Limited	EBL	2017	255553260.00	5622288.00	8948403.00	88813014.00	9750000.00	0.084886309	2.038653125	42.09181996
FBNBank (Ghana) Limited	FBN	2017	293167852.00	12187720.00	20369561.00	66706038.00	272566602.00	0.109271742	2.065337241	26.81959984
Fidelity Bank Ghana Limited	FBG	2017	3843312000.00	111386000.00	114502000.00	1026794000.00	2539950000.00	0.062726107	1.152227389	46.96903111
First Atlantic Bank Limited	FAB	2017	1378961100.00	137531784.00	48350962.00	249797797.00	126722000.00	0.084764736	0.340094054	35.21420821
First National Bank (Ghana) Limited	FNB	2017	103374000.00	22545000.00	35270000.00	28518000.00	76523000.00	0.081606594	0.519760479	7.380039694
Ghana Commercial Bank Limited	GCB	2017	6956190000.00	222861000.00	360660000.00	2099330000.00	4911211000.00	0.042054918	1.518699997	26.50183275
Ghana Home Loans Bank Limited	GHL	2017	21396297.00	8885143.00	20613520.00	456728000.00	48376626.00	0.788252098	10.00550019	29.67911478
Guaranty Trust Bank (Ghana) Limited	GTB	2017	1467120773.00	25973551.00	34514819.00	396464980.00	856587581.00	0.06617563	2.154979348	54.29196123
HFC/Republic Bank (Ghana) Limited	RBG	2017	1712646000.00	64720000.00	79829000.00	809923000.00	479700000.00	0.090912541	0.902734858	26.04436984
National Investment Bank Limited	NIB	2017	2565980640.00	316916640.00	84035520.00	1087660800.00	582783401.00	0.109015444	0.812768935	45.02082906
OmniBSIC Bank Ghana Limited	OMN	2017	352890000.00	51327000.00	22419000.00	251789000.00	208900100.00	0.150953555	0.374987823	27.0162952
Prudential Bank Limited	PBL	2017	1465665000.00	173792000.00	73371000.00	925815000.00	173125000.00	0.107774969	0.917591143	29.77790953
Societe General (Ghana) Limited	SGG	2017	1988298745.00	278799650.00	100512163.00	1409551517.00	235927507.00	0.030270601	0.378517552	27.75527063
Stanbic Bank Ghana Limited	SBG	2017	3361159000.00	78422000.00	198108000.00	1874757000.00	645408000.00	0.02771663	1.0933029	26.56709472
Standard Chartered Bank (Ghana) Limited	SCB	2017	3420164000.00	31587000.00	149689000.00	1385696000.00	1256941000.00	0.033991352	2.577927628	31.91272572
United Bank for Africa (Ghana) Limited	UBA	2017	2073671821.00	28850322.00	44869080.00	1098846411.00	1257684598.00	0.07126303	4.320344328	66.0426074
Universal Merchant Bank Limited	UMB	2017	1948855000.00	64848000.00	62727000.00	350783000.00	865456000.00	0.126622555	1.665864792	47.59521418
Zenith Bank (Ghana) Limited	ZBG	2017	3473416209.00	185197952.00	63497940.00	804676754.00	2414593611.00	0.066634426	0.491113897	73.55980224

Access Bank (Ghana) Plc	ABL	2018	2452076000.00	126150000.00	66554000.00	815559000.00	677306000.00	0.072792605	0.766706302	53.20402981
Agricultural Development Bank Limited	ADB	2018	2541010000.00	98846000.00	181232000.00	1068814000.00	1938438000.00	0.08396307	1.409040325	19.84966783
Bank of Africa Ghana Limited	BOA	2018	790270010.00	53756909.00	45319703.00	207226955.00	429515423.00	0.044585022	0.8430489	27.76664521
Barclays Bank of Ghana Limited	BBG	2018	4720459000.00	51349000.00	224429000.00	3204859000.00	3657802000.00	0.041569898	2.412938908	40.077539
CAL Bank Limited	CAL	2018	3078682000.00	435493000.00	122308000.00	2428002000.00	2439042000.00	0.115881406	0.527255318	44.19871145
Consolidated Bank Ghana Limited	CBG	2018	5512313000.00	123623000.00	57504000.00	3546000.00	7354442000.00	0.061461133	0.663315079	130.2297753
Ecobank Ghana Limited	ECO	2018	7627083000.00	443013000.00	378839000.00	4123153000.00	3077571000.00	0.027872779	0.582055154	27.60432796
Energy Bank Ghana Limited	EBL	2018	159503435.00	5141517.00	8907738.00	73567174.00	9750000.00	0.092101879	2.101364247	31.16163464
FBNBank (Ghana) Limited	FBN	2018	304313552.00	10414972.00	22818116.00	71905033.00	889636557.00	0.070230822	1.673360236	43.37010422
Fidelity Bank Ghana Limited	FBG	2018	3979129000.00	110204000.00	155791000.00	1419472000.00	5243737000.00	0.072494257	1.212015898	45.03355778
First Atlantic Bank Limited	FAB	2018	1249471878.00	132539410.00	53750202.00	387230774.00	666107809.00	0.073970393	0.446644489	34.34150383
First National Bank (Ghana) Limited	FNB	2018	182826000.00	20381000.00	48104000.00	84633000.00	469343000.00	0.067807642	0.855110152	13.31739564
Ghana Commercial Bank Limited	GCB	2018	8334997000.00	237247000.00	425962000.00	2799041000.00	6629163000.00	0.046556465	0.20794362	24.96713557
Ghana Home Loans Bank Limited	GHL	2018	74276451.00	32479383.00	46825787.00	561648176.00	55606792.00	0.281040891	1.827066727	14.71219072
Guaranty Trust Bank (Ghana) Limited	GTB	2018	1664299711.00	48023210.00	45495279.00	424714417.00	1708034681.00	0.063044821	1.191098284	50.1977796
HFC/Republic Bank (Ghana) Limited	RBG	2018	2161420000.00	61343000.00	93026000.00	1175066000.00	948665000.00	0.063900121	1.076227116	30.72246469
National Investment Bank Limited	NIB	2018	3012689000.00	380299968.00	100842624.00	1305192960.00	601782938.00	0.111421333	0.812768935	44.78816608
OmniBSIC Bank Ghana Limited	OMN	2018	306987000.00	42335000.00	24840000.00	176936000.00	241375664.00	0.211158779	0.599244124	29.56068651
Prudential Bank Limited	PBL	2018	1744465000.00	214994000.00	94660000.00	1110957000.00	452328000.00	0.097300318	0.321199661	25.22179379
Societe General (Ghana) Limited	SGG	2018	2161382598.00	289214114.00	116975473.00	1665284201.00	133606037.00	0.035136929	0.339263868	29.33398177
Stanbic Bank Ghana Limited	SBG	2018	4282535000.00	87729000.00	226776000.00	2584735000.00	682264000.00	0.019534925	1.830717323	27.36188133
Standard Chartered Bank (Ghana) Limited	SCB	2018	4302072000.00	64846000.00	165048000.00	1302095000.00	4051420000.00	0.028816347	1.752922308	36.11976516
United Bank for Africa (Ghana) Limited	UBA	2018	2114717879.00	28350497.00	49997313.00	634206101.00	2536668000.00	0.079307067	2.327642228	71.27814789
Universal Merchant Bank Limited	UMB	2018	1719276000.00	56146000.00	87406000.00	748099000.00	991182000.00	0.113473927	2.374274214	28.87131318

Zenith Bank (Ghana) Limited	ZBG	2018	3407542026.00	182306520.00	87645809.00	733084008.00	4277965370.00	0.079778588	0.693693155	63.57947717
Access Bank (Ghana) Plc	ABL	2019	3009606000.00	227426000.00	70363000.00	1292867000.00	1351908000.00	0.07139805	0.382748674	66.96272189
Agricultural Development Bank Limited	ADB	2019	3392209000.00	95766000.00	206711000.00	1468653000.00	1522828000.00	0.056339394	1.394492826	22.1452124
Bank of Africa Ghana Limited	BOA	2019	1083816478.00	58917180.00	47396041.00	725543689.00	734891613.00	0.042467357	0.840519064	43.2056239
Barclays Bank of Ghana Limited (ABSA Bank)	BBG	2019	5142907000.00	105174000.00	279774000.00	4082295000.00	2550401000.00	0.065564281	1.169604655	42.07877072
CAL Bank Limited	CAL	2019	3694513000.00	504166000.00	131074000.00	2920026000.00	2706333000.00	0.106903129	0.530353098	53.70843951
Consolidated Bank Ghana Limited	CBG	2019	5096350000.00	104394000.00	209864000.00	227878000.00	5405844000.00	0.106913183	1.802038431	33.08328251
Ecobank Ghana Limited	ECO	2019	9725040000.00	428491000.00	340709000.00	5318113000.00	3748046000.00	0.02154058	0.683645631	38.73561896
FBNBank (Ghana) Limited	FBN	2019	349063000.00	11251000.00	27333000.00	262081000.00	741781000.00	0.118663393	1.407074927	46.47832291
Fidelity Bank Ghana Limited	FBG	2019	4855157000.00	163886000.00	205211000.00	2454186000.00	4304126000.00	0.083753213	0.881429774	51.05974826
First Atlantic Bank Limited	FAB	2019	2044685509.00	151403584.00	66016083.00	454657563.00	852070539.00	0.031570968	0.533671627	42.00509149
First National Bank (Ghana) Limited	FNB	2019	487549000.00	38991000.00	49920000.00	105670000.00	491036000.00	0.054741164	0.406016773	19.75739183
Ghana Commercial Bank Limited	GCB	2019	9340608000.00	271645000.00	493523000.00	3587653000.00	6048094000.00	0.041469999	0.28071564	25.15939683
Guaranty Trust Bank (Ghana) Limited	GTB	2019	2149049215.00	116182565.00	55952253.00	569536071.00	1591459777.00	0.042347972	0.904092813	58.14208858
HFC/Republic Bank (Ghana) Limited	RBG	2019	2525003000.00	90073000.00	111422000.00	1411342000.00	553202000.00	0.071695756	0.572679937	29.85265028
National Investment Bank Limited	NIB	2019	3615226800.00	459159000.00	121011148.80	1566231552.00	492017390.00	0.111421333	0.807814287	44.55670549
OmniBSIC Bank Ghana Limited	OMN	2019	686744434.00	63781094.00	34063279.00	457104849.00	297767411.00	0.122195384	0.71864556	25.57666278
Prudential Bank Limited	PBL	2019	2093786000.00	223563000.00	111358000.00	1657080000.00	834203000.00	0.087294021	0.926038745	28.6975251
Societe General (Ghana) Limited	SGG	2019	3169705971.00	290868619.00	119840819.00	2643394001.00	91967892.00	0.027836985	0.416078556	37.08176601
Stanbic Bank Ghana Limited	SBG	2019	6755312000.00	229276000.00	269458000.00	3946591000.00	670894000.00	0.022043689	0.717327588	34.4977028
Standard Chartered Bank (Ghana) Limited	SCB	2019	5419304000.00	285596000.00	177005000.00	1770666000.00	2349386000.00	0.028596661	0.420282497	43.04184628
United Bank for Africa (Ghana) Limited	UBA	2019	2338800005.00	44180726.00	44540726.00	948607338.00	2885906206.00	0.073291487	1.263376817	100.9790534
Universal Merchant Bank Limited	UMB	2019	1825443000.00	96281000.00	97543000.00	887455000.00	332758000.00	0.097304599	1.448603567	28.03756292
Zenith Bank (Ghana) Limited	ZBG	2019	4457056000.00	162424000.00	142732000.00	648250000.00	4155528000.00	0.066979639	0.583472886	46.87809321

Access Bank (Ghana) Plc	ABL	2020	3891856000.00	273942000.00	82114000.00	1126926000.00	2018889000.00	0.067973738	0.349453534	70.92308254
Agricultural Development Bank Limited	ADB	2020	4281037000.00	95800000.00	233468000.00	1911988000.00	2222139000.00	0.049881839	1.441503132	24.48213031
Bank of Africa Ghana Limited	BOA	2020	1204062141.00	58536972.00	49454768.00	751878958.00	819892912.00	0.042426785	0.807229489	41.64731938
Barclays Bank of Ghana Limited (ABSA Bank)	BBG	2020	5384356000.00	161460000.00	299502000.00	4481173000.00	3318260000.00	0.069707501	1.532311408	41.89111592
CAL Bank Limited	CAL	2020	4164301000.00	418451000.00	140344000.00	2400950000.00	2681487000.00	0.097245372	0.757876072	56.31459129
Consolidated Bank Ghana Limited	CBG	2020	6866118000.00	115616000.00	253643000.00	861736000.00	7060759000.00	0.091150924	1.485339399	39.27473654
Ecobank Ghana Limited	ECO	2020	11386442000.00	580170000.00	368052000.00	4926367000.00	5761976000.00	0.02016846	0.769988107	43.15263604
FBNBank (Ghana) Limited	FBN	2020	766953000.00	15944000.00	36205000.00	533202000.00	741781000.00	0.075678692	1.690792775	50.03676288
Fidelity Bank Ghana Limited	FBG	2020	6165233000.00	170150000.00	228252000.00	2392426000.00	4942369000.00	0.074667413	0.781269468	40.5291038
First Atlantic Bank Limited	FAB	2020	2649300224.00	169865601.00	74680645.00	609414018.00	872826131.00	0.031421633	0.417063547	45.03371725
First National Bank (Ghana) Limited	FNB	2020	1189502000.00	59482000.00	72133000.00	753104000.00	643222000.00	0.084223482	0.526831647	32.63857042
Ghana Commercial Bank Limited	GCB	2020	11352518000.00	280013000.00	559950000.00	3612588000.00	8607508000.00	0.037899521	0.517686679	27.36790071
Guaranty Trust Bank (Ghana) Limited	GTB	2020	2995393368.00	104651923.00	56279786.00	1057579838.00	1647944648.00	0.027100148	0.822631296	72.51430021
HFC/Republic Bank (Ghana) Limited	RBG	2020	2769403000.00	118251000.00	126042000.00	1525099000.00	997182000.00	0.071469916	0.520367692	28.94102759
National Investment Bank Limited	NIB	2020	4338272160.00	550990800.00	145213378.56	1879477862.40	659178290.00	0.111421333	0.807814287	44.32644105
OmniBSIC Bank Ghana Limited	OMN	2020	1081000000.00	61978000.00	48534000.00	314210000.00	613618000.00	0.071567068	0.98005744	28.57821321
Prudential Bank Limited	PBL	2020	2460542000.00	234324000.00	111521000.00	1717792000.00	1213832000.00	0.114608895	0.995856165	35.59494624
Societe General (Ghana) Limited	SGG	2020	3481343321.00	290748100.00	128691845.00	2562706675.00	548786063.00	0.032818197	0.452921395	39.74771169
Stanbic Bank Ghana Limited	SBG	2020	9666965000.00	255863000.00	308200000.00	4373529000.00	2419358000.00	0.019907282	2.232100773	41.34371188
Standard Chartered Bank (Ghana) Limited	SCB	2020	5751627000.00	258440000.00	209281000.00	1695213000.00	2419537000.00	0.02692386	0.17788655	38.37746379
United Bank for Africa (Ghana) Limited	UBA	2020	2786764201.00	67328683.00	61186565.00	1108455471.00	1722016024.00	0.078333288	0.743953985	64.55904599
Universal Merchant Bank Limited	UMB	2020	2268795000.00	80756000.00	99967000.00	1188272000.00	497125000.00	0.073642176	1.255720937	32.61375254
Zenith Bank (Ghana) Limited	ZBG	2020	5799266000.00	162001000.00	133795000.00	1057205000.00	4505323000.00	0.046732983	0.590625984	60.05142195
Access Bank (Ghana) Plc	ABL	2021	4622976000.00	359243000.00	89356000.00	1166868000.00	3580454000.00	0.061629565	0.312971999	83.43503514

Agricultural Development Bank Limited	ADB	2021	4927216000.00	113735000.00	250281000.00	2828312000.00	2400655000.00	0.050314214	1.360267288	25.78749086
Bank of Africa Ghana Limited	BOA	2021	1431611829.00	52403522.00	50954127.00	883821254.00	1479984951.00	0.029064115	0.978954869	61.98972721
Barclays Bank of Ghana Limited (ABSA Bank)	BBG	2021	7944122000.00	143938000.00	341983000.00	4785114000.00	3541278000.00	0.04484133	0.798663313	46.89574628
CAL Bank Limited	CAL	2021	5161933000.00	412938000.00	151110000.00	2239520000.00	2675533000.00	0.099017945	0.7890555	66.25887102
Consolidated Bank Ghana Limited	CBG	2021	6751075000.00	146608000.00	332753000.00	1330480000.00	6119974000.00	0.127552279	1.486337717	32.30974326
Ecobank Ghana Limited	ECO	2021	12877525000.00	570888000.00	397044000.00	5634861000.00	7777023000.00	0.015107018	0.810074831	44.97405577
FBNBank (Ghana) Limited	FBN	2021	888249000.00	17892000.00	53118000.00	602166000.00	928690000.00	0.098488149	1.960429242	35.9953688
Fidelity Bank Ghana Limited	FBG	2021	8264429000.00	175615000.00	254821000.00	2278591000.00	7704694000.00	0.087355581	1.358893033	52.38908881
First Atlantic Bank Limited	FAB	2021	3772886340.00	181641691.00	102733778.00	1011135561.00	1450388977.00	0.023049142	0.484721957	45.50597502
First National Bank (Ghana) Limited	FNB	2021	1106257000.00	54126000.00	106136000.00	780740000.00	744727000.00	0.109233207	0.828825333	23.38254692
Ghana Commercial Bank Limited	GCB	2021	13154527000.00	301332000.00	637316000.00	4306380000.00	9707421000.00	0.036833479	0.22662379	28.87880894
Guaranty Trust Bank (Ghana) Limited	GTB	2021	3725426725.00	117207705.00	63296654.00	1647640588.00	1050574111.00	0.037609045	0.572074361	79.55319408
HFC/Republic Bank (Ghana) Limited	RBG	2021	3165079000.00	137121000.00	132464000.00	1747995000.00	1243178000.00	0.057034279	0.56935845	31.90496286
National Investment Bank Limited	NIB	2021	5205926592.00	661188960.00	174256054.27	2255373434.88	782901087.00	0.111421333	0.807814287	44.0973666
OmniBSIC Bank Ghana Limited	OMN	2021	1448616000.00	63640000.00	43194000.00	382817000.00	1040801000.00	0.084664259	0.816923319	45.98143261
Prudential Bank Limited	PBL	2021	2864068000.00	227021000.00	144277000.00	1509558000.00	1914496000.00	0.083672245	1.085335718	30.40576114
Societe General (Ghana) Limited	SGG	2021	3391140683.00	255268418.00	135516867.00	2504366677.00	1474119134.00	0.032434637	0.58994884	40.12063029
Stanbic Bank Ghana Limited	SBG	2021	9936698000.00	253842000.00	326813000.00	5185128000.00	2772551000.00	0.023167253	20.42659607	42.96982372
Standard Chartered Bank (Ghana) Limited	SCB	2021	7554457000.00	37958000.00	245459000.00	1886799000.00	3761388000.00	0.025472512	2.181358343	35.02601656
United Bank for Africa (Ghana) Limited	UBA	2021	4075498353.00	63388093.00	65856828.00	1032519321.00	2782040225.00	0.041601713	0.910740602	81.58910822
Universal Merchant Bank Limited	UMB	2021	2924248000.00	135050000.00	118333000.00	1284759000.00	1167941000.00	0.065519067	0.945057386	33.63804687
Zenith Bank (Ghana) Limited	ZBG	2021	6391081000.00	168837000.00	129781000.00	1498900000.00	4555649000.00	0.048203739	0.732001872	68.30172367
Access Bank (Ghana) Plc	ABL	2022	7398646000.00	385596000.00	143664000.00	1640650000.00	3954001000.00	0.061957282	0.404589259	70.00515787
Agricultural Development Bank Limited	ADB	2022	5864851000.00	216332000.00	336029000.00	3242189000.00	1316584000.00	0.080146793	0.866404415	22.0597627

Bank of Africa Ghana Limited	BOA	2022	2038486937.00	56924147.00	66748838.00	1048677865.00	1427102134.00	0.044710249	1.498342839	54.46102603
Barclays Bank of Ghana Limited (ABSA Bank)	BBG	2022	11177398000.00	216905000.00	427812000.00	5135435000.00	3958094000.00	0.053136428	0.193536341	39.97614373
CAL Bank Limited	CAL	2022	6116174000.00	622319000.00	155567000.00	3190359000.00	4946980000.00	0.112771481	0.662997594	59.26227285
Consolidated Bank Ghana Limited	CBG	2022	7836791000.00	189714000.00	428089000.00	2056142000.00	6731794000.00	0.141522978	1.798559938	24.79944124
Ecobank Ghana Limited	ECO	2022	19590418000.00	1253410000.00	514453000.00	8802239000.00	7734214000.00	0.020077877	0.52247788	50.09997998
FBNBank (Ghana) Limited	FBN	2022	1207121000.00	21918000.00	52803000.00	550247000.00	1511978000.00	0.103527318	3.009489917	53.67980986
Fidelity Bank Ghana Limited	FBG	2022	9393360000.00	185058000.00	288185000.00	2815748000.00	5957780000.00	0.104267376	1.05690108	47.83696931
First Atlantic Bank Limited	FAB	2022	6119099515.00	553614697.00	112945145.00	1486925175.00	1661134879.00	0.026059609	0.229633392	65.76901923
First National Bank (Ghana) Limited	FNB	2022	1920381000.00	53114000.00	137695000.00	981200000.00	683281000.00	0.094687981	1.13416425	22.28396093
Ghana Commercial Bank Limited	GCB	2022	17532247000.00	428550000.00	796993000.00	5482215000.00	8610561000.00	0.041181601	0.244081204	26.96939371
Guaranty Trust Bank (Ghana) Limited	GTB	2022	5629806824.00	138662359.00	81808976.00	2026344662.00	2134381588.00	0.031303295	0.797407839	87.18831782
HFC/Republic Bank (Ghana) Limited	RBG	2022	4090281000.00	218412000.00	157498000.00	1958017000.00	1015786000.00	0.057256702	0.430461696	32.25623183
National Investment Bank Limited	NIB	2022	6247111910.40	793426752.00	209107265.13	2706448121.86	699016728.00	0.111421333	0.807814287	43.86947598
OmniBSIC Bank Ghana Limited	OMN	2022	2524752000.00	72548000.00	66575000.00	676273000.00	1343430000.00	0.088508099	0.728397253	46.69237702
Prudential Bank Limited	PBL	2022	3381273000.00	226667000.00	158992000.00	1701349000.00	1614943000.00	0.10759912	1.268830487	32.74596206
Societe General (Ghana) Limited	SGG	2022	4239568200.00	292785473.00	171621011.00	3102993067.00	1032670869.00	0.031826514	0.469304978	38.43256758
Stanbic Bank Ghana Limited	SBG	2022	14596310000.00	263728000.00	402366000.00	6429851000.00	1186809000.00	0.023944202	24.38061563	46.22023481
Standard Chartered Bank (Ghana) Limited	SCB	2022	8183887000.00	47103000.00	298472000.00	2050310000.00	3473154000.00	0.024574508	2.196017239	34.73358975
United Bank for Africa (Ghana) Limited	UBA	2022	4736251611.00	72339376.00	80753856.00	1544688879.00	2438908925.00	0.055273332	1.256067415	76.9011178
Universal Merchant Bank Limited	UMB	2022	3565213000.00	155329000.00	136698000.00	1164980000.00	1221990000.00	0.103488627	0.756162726	34.90372939
Zenith Bank (Ghana) Limited	ZBG	2022	8408201000.00	187232000.00	178405000.00	1856211000.00	3820538000.00	0.040883775	1.092356008	54.14405986

Appendix 2: R Codes Used to Estimate Efficiency and Productivity Indices

```
#CALCULATING TECHNICAL & COST EFFICIENCY WITH deaR
library(deaR)
hd=read.delim("clipboard") #copy both year zero and year one
head(hd)
tail(hd)
any(hd <= 0)
h=make_deadata(hd,ni=3,no=2) #this function creates a DEA structure data set #ni=number
    of input, no=number of output
is.deadata(h) #checks if new data is of DEA data class or not
#Categorizing data frame
y1=c(1:15)#data frame for year 1
y2=c(16:31)#data frame for year 2
y3=c(32:47)#data frame for year 3
y4=c(48:64)#data frame for year 4
y5=c(65:81)#data frame for year 5
y6=c(82:98)#data frame for year 6
y7=c(99:119)#data frame for year 7
y8=c(120:140)#data frame for year 8
y9=c(141:160)#data frame for year 9
y10=c(161:181)#data frame for year 10
y11=c(182:203)#data frame for year 11
y12=c(204:226)#data frame for year 12
y13=c(227:249)#data frame for year 13
y14=c(250:274)#data frame for year 14
y15=c(275:300)#data frame for year 15
y16=c(301:328)#data frame for year 16
y17=c(329:354)#data frame for year 17
y18=c(355:378)#data frame for year 18
y19=c(379:403)#data frame for year 19
y20=c(404:426)#data frame for year 20
y21=c(427:449)#data frame for year 21
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y22=c(450:472)#data frame for year 22
y23=c(473:495)#data frame for year 23
yg=c(1:495)#data frame for all years

#CALCULATING TECHNICAL EFFICIENCY
##BCC (1984) & Farrell (1957) Efficiency Approach
#Own Period Eff
E1_1v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y1,dmu_ref=y1);efficiencies(E1_1v)#Tec Eff for yr1 rel to
    F1, column for year is not included in data for cal
E2_2v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y2,dmu_ref=y2);efficiencies(E2_2v)#Tec Eff for yr2 rel to F2
E3_3v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y3,dmu_ref=y3);efficiencies(E3_3v)#Tec Eff for yr3 rel to F3
E4_4v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y4,dmu_ref=y4);efficiencies(E4_4v)#Tec Eff for yr4 rel to F4
E5_5v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y5,dmu_ref=y5);efficiencies(E5_5v)#Tec Eff for yr2 rel to F5
E6_6v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y6,dmu_ref=y6);efficiencies(E6_6v)#Tec Eff for yr3 rel to F6
E7_7v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y7,dmu_ref=y7);efficiencies(E7_7v)#Tec Eff for yr4 rel to F7
E8_8v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y8,dmu_ref=y8);efficiencies(E8_8v)#Tec Eff for yr2 rel to F8
E9_9v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y9,dmu_ref=y9);efficiencies(E9_9v)#Tec Eff for yr3 rel to F9
E10_10v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y10,dmu_ref=y10);efficiencies(E10_10v)#Tec Eff for yr4 rel
    to F10
E11_11v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y11,dmu_ref=y11);efficiencies(E11_11v)#Tec Eff for yr2 rel
    to F11
E12_12v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y12,dmu_ref=y12);efficiencies(E12_12v)#Tec Eff for yr3 rel
    to F12
E13_13v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y13,dmu_ref=y13);efficiencies(E13_13v)#Tec Eff for yr4 rel
    to F13
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E14_14v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y14,dmu_ref=y14);efficiencies(E14_14v)#Tec Eff for yr2 rel
    to F14
E15_15v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y15,dmu_ref=y15);efficiencies(E15_15v)#Tec Eff for yr3 rel
    to F15
E16_16v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y16,dmu_ref=y16);efficiencies(E16_16v)#Tec Eff for yr4 rel
    to F16
E17_17v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y17,dmu_ref=y17);efficiencies(E17_17v)#Tec Eff for yr2 rel
    to F17
E18_18v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y18,dmu_ref=y18);efficiencies(E18_18v)#Tec Eff for yr3 rel
    to F18
E19_19v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y19,dmu_ref=y19);efficiencies(E19_19v)#Tec Eff for yr4 rel
    to F19
E20_20v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y20,dmu_ref=y20);efficiencies(E20_20v)#Tec Eff for yr2 rel
    to F20
E21_21v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y21,dmu_ref=y21);efficiencies(E21_21v)#Tec Eff for yr3 rel
    to F21
E22_22v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y22,dmu_ref=y22);efficiencies(E22_22v)#Tec Eff for yr4 rel
    to F22
E23_23v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y23,dmu_ref=y23);efficiencies(E23_23v)#Tec Eff for yr4 rel
    to F23


#Cross Period Eff
E1_2v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y1,dmu_ref=y2);efficiencies(E1_2v)#Tec Eff for yr1 rel to F2
E1_3v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y1,dmu_ref=y3);efficiencies(E1_3v)#Tec Eff for yr1 rel to F3
E1_4v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y1,dmu_ref=y4);efficiencies(E1_4v)#Tec Eff for yr1 rel to F4
E1_5v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y1,dmu_ref=y5);efficiencies(E1_5v)#Tec Eff for yr1 rel to F5
E1_6v=model_basic(h,orientation
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="io",rts="vrs",dmu_eval=y1,dmu_ref=y6);efficiencies(E1_6v)#Tec Eff for yr1 rel to F6
E1_7v=model_basic(h,orientation
="io",rts="vrs",dmu_eval=y1,dmu_ref=y7);efficiencies(E1_7v)#Tec Eff for yr1 rel to F7
E1_8v=model_basic(h,orientation
="io",rts="vrs",dmu_eval=y1,dmu_ref=y8);efficiencies(E1_8v)#Tec Eff for yr1 rel to F8
E1_9v=model_basic(h,orientation
="io",rts="vrs",dmu_eval=y1,dmu_ref=y9);efficiencies(E1_9v)#Tec Eff for yr1 rel to F9
E1_10v=model_basic(h,orientation
="io",rts="vrs",dmu_eval=y1,dmu_ref=y10);efficiencies(E1_10v)#Tec Eff for yr1 rel to
F10
E1_11v=model_basic(h,orientation
="io",rts="vrs",dmu_eval=y1,dmu_ref=y11);efficiencies(E1_11v)#Tec Eff for yr1 rel to
F11
E1_12v=model_basic(h,orientation
="io",rts="vrs",dmu_eval=y1,dmu_ref=y12);efficiencies(E1_12v)#Tec Eff for yr1 rel to
F12
E1_13v=model_basic(h,orientation
="io",rts="vrs",dmu_eval=y1,dmu_ref=y13);efficiencies(E1_13v)#Tec Eff for yr1 rel to
F13
E1_14v=model_basic(h,orientation
="io",rts="vrs",dmu_eval=y1,dmu_ref=y14);efficiencies(E1_14v)#Tec Eff for yr1 rel to
F14
E1_15v=model_basic(h,orientation
="io",rts="vrs",dmu_eval=y1,dmu_ref=y15);efficiencies(E1_15v)#Tec Eff for yr1 rel to
F15
E1_16v=model_basic(h,orientation
="io",rts="vrs",dmu_eval=y1,dmu_ref=y16);efficiencies(E1_16v)#Tec Eff for yr1 rel to
F16
E1_17v=model_basic(h,orientation
="io",rts="vrs",dmu_eval=y1,dmu_ref=y17);efficiencies(E1_17v)#Tec Eff for yr1 rel to
F17
E1_18v=model_basic(h,orientation
="io",rts="vrs",dmu_eval=y1,dmu_ref=y18);efficiencies(E1_18v)#Tec Eff for yr1 rel to
F18
E1_19v=model_basic(h,orientation
="io",rts="vrs",dmu_eval=y1,dmu_ref=y19);efficiencies(E1_19v)#Tec Eff for yr1 rel to
F19
E1_20v=model_basic(h,orientation
="io",rts="vrs",dmu_eval=y1,dmu_ref=y20);efficiencies(E1_20v)#Tec Eff for yr1 rel to
F20
E1_21v=model_basic(h,orientation
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="io",rts="vrs",dmu_eval=y1,dmu_ref=y21);efficiencies(E1_21v)#Tec Eff for yr1 rel to F21
E1_22v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y1,dmu_ref=y22);efficiencies(E1_22v)#Tec Eff for yr1 rel to F22
E1_23v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y1,dmu_ref=y23);efficiencies(E1_23v)#Tec Eff for yr1 rel to F23

E2_1v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y2,dmu_ref=y1);efficiencies(E2_1v)#Tec Eff for yr2 rel to F1
E2_3v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y2,dmu_ref=y3);efficiencies(E2_3v)#Tec Eff for yr2 rel to F3
E2_4v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y2,dmu_ref=y4);efficiencies(E2_4v)#Tec Eff for yr2 rel to F4
E2_5v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y2,dmu_ref=y5);efficiencies(E2_5v)#Tec Eff for yr2 rel to F5
E2_6v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y2,dmu_ref=y6);efficiencies(E2_6v)#Tec Eff for yr2 rel to F6
E2_7v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y2,dmu_ref=y7);efficiencies(E2_7v)#Tec Eff for yr2 rel to F7
E2_8v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y2,dmu_ref=y8);efficiencies(E2_8v)#Tec Eff for yr2 rel to F8
E2_9v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y2,dmu_ref=y9);efficiencies(E2_9v)#Tec Eff for yr2 rel to F9
E2_10v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y2,dmu_ref=y10);efficiencies(E2_10v)#Tec Eff for yr2 rel to F10
E2_11v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y2,dmu_ref=y11);efficiencies(E2_11v)#Tec Eff for yr2 rel to F11
E2_12v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y2,dmu_ref=y12);efficiencies(E2_12v)#Tec Eff for yr2 rel to F12
E2_13v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y2,dmu_ref=y13);efficiencies(E2_13v)#Tec Eff for yr2 rel to F13
E2_14v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y2,dmu_ref=y14);efficiencies(E2_14v)#Tec Eff for yr2 rel to F14
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E2_15v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y2,dmu_ref=y15);efficiencies(E2_15v)#Tec Eff for yr2 rel to F15

E2_16v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y2,dmu_ref=y16);efficiencies(E2_16v)#Tec Eff for yr2 rel to F16

E2_17v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y2,dmu_ref=y17);efficiencies(E2_17v)#Tec Eff for yr2 rel to F17

E2_18v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y2,dmu_ref=y18);efficiencies(E2_18v)#Tec Eff for yr2 rel to F18

E2_19v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y2,dmu_ref=y19);efficiencies(E2_19v)#Tec Eff for yr2 rel to F19

E2_20v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y2,dmu_ref=y20);efficiencies(E2_20v)#Tec Eff for yr2 rel to F20

E2_21v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y2,dmu_ref=y21);efficiencies(E2_21v)#Tec Eff for yr2 rel to F21

E2_22v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y2,dmu_ref=y22);efficiencies(E2_22v)#Tec Eff for yr2 rel to F22

E2_23v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y2,dmu_ref=y23);efficiencies(E2_23v)#Tec Eff for yr2 rel to F23

E3_1v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y3,dmu_ref=y1);efficiencies(E3_1v)#Tec Eff for yr3 rel to F1

E3_2v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y3,dmu_ref=y2);efficiencies(E3_2v)#Tec Eff for yr3 rel to F2

E3_4v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y3,dmu_ref=y4);efficiencies(E3_4v)#Tec Eff for yr3 rel to F4

E3_5v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y3,dmu_ref=y5);efficiencies(E3_5v)#Tec Eff for yr3 rel to F5

E3_6v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y3,dmu_ref=y6);efficiencies(E3_6v)#Tec Eff for yr3 rel to F6

E3_7v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y3,dmu_ref=y7);efficiencies(E3_7v)#Tec Eff for yr3 rel to F7

E3_8v=model_basic(h,orientation

="io",rts="vrs",dmu_eval=y3,dmu_ref=y8);efficiencies(E3_8v)#Tec Eff for yr3 rel to F8

E3_9v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y3,dmu_ref=y9);efficiencies(E3_9v)#Tec Eff for yr3 rel to F9

E3_10v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y3,dmu_ref=y10);efficiencies(E3_10v)#Tec Eff for yr3 rel to F10

E3_11v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y3,dmu_ref=y11);efficiencies(E3_11v)#Tec Eff for yr3 rel to F11

E3_12v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y3,dmu_ref=y12);efficiencies(E3_12v)#Tec Eff for yr3 rel to F12

E3_13v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y3,dmu_ref=y13);efficiencies(E3_13v)#Tec Eff for yr3 rel to F13

E3_14v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y3,dmu_ref=y14);efficiencies(E3_14v)#Tec Eff for yr3 rel to F14

E3_15v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y3,dmu_ref=y15);efficiencies(E3_15v)#Tec Eff for yr3 rel to F15

E3_16v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y3,dmu_ref=y16);efficiencies(E3_16v)#Tec Eff for yr3 rel to F16

E3_17v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y3,dmu_ref=y17);efficiencies(E3_17v)#Tec Eff for yr3 rel to F17

E3_18v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y3,dmu_ref=y18);efficiencies(E3_18v)#Tec Eff for yr3 rel to F18

E3_19v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y3,dmu_ref=y19);efficiencies(E3_19v)#Tec Eff for yr3 rel to F19

E3_20v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y3,dmu_ref=y20);efficiencies(E3_20v)#Tec Eff for yr3 rel to F20

E3_21v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y3,dmu_ref=y21);efficiencies(E3_21v)#Tec Eff for yr3 rel to F21

E3_22v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y3,dmu_ref=y22);efficiencies(E3_22v)#Tec Eff for yr3 rel to F22

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E3_23v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y3,dmu_ref=y23);efficiencies(E3_23v)#Tec Eff for yr3 rel to
    F23


E4_1v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y4,dmu_ref=y1);efficiencies(E4_1v)#Tec Eff for yr4 rel to F1
E4_2v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y4,dmu_ref=y2);efficiencies(E4_2v)#Tec Eff for yr4 rel to F2
E4_3v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y4,dmu_ref=y3);efficiencies(E4_3v)#Tec Eff for yr4 rel to F3
E4_5v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y4,dmu_ref=y5);efficiencies(E4_5v)#Tec Eff for yr4 rel to F5
E4_6v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y4,dmu_ref=y6);efficiencies(E4_6v)#Tec Eff for yr4 rel to F6
E4_7v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y4,dmu_ref=y7);efficiencies(E4_7v)#Tec Eff for yr4 rel to F7
E4_8v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y4,dmu_ref=y8);efficiencies(E4_8v)#Tec Eff for yr4 rel to F8
E4_9v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y4,dmu_ref=y9);efficiencies(E4_9v)#Tec Eff for yr4 rel to F9
E4_10v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y4,dmu_ref=y10);efficiencies(E4_10v)#Tec Eff for yr4 rel to
    F10
E4_11v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y4,dmu_ref=y11);efficiencies(E4_11v)#Tec Eff for yr4 rel to
    F11
E4_12v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y4,dmu_ref=y12);efficiencies(E4_12v)#Tec Eff for yr4 rel to
    F12
E4_13v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y4,dmu_ref=y13);efficiencies(E4_13v)#Tec Eff for yr4 rel to
    F13
E4_14v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y4,dmu_ref=y14);efficiencies(E4_14v)#Tec Eff for yr4 rel to
    F14
E4_15v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y4,dmu_ref=y15);efficiencies(E4_15v)#Tec Eff for yr4 rel to
    F15
E4_16v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y4,dmu_ref=y16);efficiencies(E4_16v)#Tec Eff for yr4 rel to
    F16
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E4_17v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y4,dmu_ref=y17);efficiencies(E4_17v)#Tec Eff for yr4 rel to
    F17
E4_18v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y4,dmu_ref=y18);efficiencies(E4_18v)#Tec Eff for yr4 rel to
    F18
E4_19v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y4,dmu_ref=y19);efficiencies(E4_19v)#Tec Eff for yr4 rel to
    F19
E4_20v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y4,dmu_ref=y20);efficiencies(E4_20v)#Tec Eff for yr4 rel to
    F20
E4_21v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y4,dmu_ref=y21);efficiencies(E4_21v)#Tec Eff for yr4 rel to
    F21
E4_22v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y4,dmu_ref=y22);efficiencies(E4_22v)#Tec Eff for yr4 rel to
    F22
E4_23v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y4,dmu_ref=y23);efficiencies(E4_23v)#Tec Eff for yr4 rel to
    F23


E5_1v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y5,dmu_ref=y1);efficiencies(E5_1v)#Tec Eff for yr5 rel to F1
E5_2v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y5,dmu_ref=y2);efficiencies(E5_2v)#Tec Eff for yr5 rel to F2
E5_3v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y5,dmu_ref=y3);efficiencies(E5_3v)#Tec Eff for yr5 rel to F3
E5_4v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y5,dmu_ref=y4);efficiencies(E5_4v)#Tec Eff for yr5 rel to F4
E5_6v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y5,dmu_ref=y6);efficiencies(E5_6v)#Tec Eff for yr5 rel to F6
E5_7v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y5,dmu_ref=y7);efficiencies(E5_7v)#Tec Eff for yr5 rel to F7
E5_8v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y5,dmu_ref=y8);efficiencies(E5_8v)#Tec Eff for yr5 rel to F8
E5_9v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y5,dmu_ref=y9);efficiencies(E5_9v)#Tec Eff for yr5 rel to F9
E5_10v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y5,dmu_ref=y10);efficiencies(E5_10v)#Tec Eff for yr5 rel to
    F10
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E5_11v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y5,dmu_ref=y11);efficiencies(E5_11v)#Tec Eff for yr5 rel to
    F11

E5_12v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y5,dmu_ref=y12);efficiencies(E5_12v)#Tec Eff for yr5 rel to
    F12

E5_13v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y5,dmu_ref=y13);efficiencies(E5_13v)#Tec Eff for yr5 rel to
    F13

E5_14v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y5,dmu_ref=y14);efficiencies(E5_14v)#Tec Eff for yr5 rel to
    F14

E5_15v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y5,dmu_ref=y15);efficiencies(E5_15v)#Tec Eff for yr5 rel to
    F15

E5_16v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y5,dmu_ref=y16);efficiencies(E5_16v)#Tec Eff for yr5 rel to
    F16

E5_17v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y5,dmu_ref=y17);efficiencies(E5_17v)#Tec Eff for yr5 rel to
    F17

E5_18v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y5,dmu_ref=y18);efficiencies(E5_18v)#Tec Eff for yr5 rel to
    F18

E5_19v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y5,dmu_ref=y19);efficiencies(E5_19v)#Tec Eff for yr5 rel to
    F19

E5_20v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y5,dmu_ref=y20);efficiencies(E5_20v)#Tec Eff for yr5 rel to
    F20

E5_21v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y5,dmu_ref=y21);efficiencies(E5_21v)#Tec Eff for yr5 rel to
    F21

E5_22v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y5,dmu_ref=y22);efficiencies(E5_22v)#Tec Eff for yr5 rel to
    F22

E5_23v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y5,dmu_ref=y23);efficiencies(E5_23v)#Tec Eff for yr5 rel to
    F23


E6_1v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y6,dmu_ref=y1);efficiencies(E6_1v)#Tec Eff for yr6 rel to F1
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E6_2v=model_basic(h,orientation
      ="io",rts="vrs",dmu_eval=y6,dmu_ref=y2);efficiencies(E6_2v)#Tec Eff for yr6 rel to F2
E6_3v=model_basic(h,orientation
      ="io",rts="vrs",dmu_eval=y6,dmu_ref=y3);efficiencies(E6_3v)#Tec Eff for yr6 rel to F3
E6_4v=model_basic(h,orientation
      ="io",rts="vrs",dmu_eval=y6,dmu_ref=y4);efficiencies(E6_4v)#Tec Eff for yr6 rel to F4
E6_5v=model_basic(h,orientation
      ="io",rts="vrs",dmu_eval=y6,dmu_ref=y5);efficiencies(E6_5v)#Tec Eff for yr6 rel to F5
E6_7v=model_basic(h,orientation
      ="io",rts="vrs",dmu_eval=y6,dmu_ref=y7);efficiencies(E6_7v)#Tec Eff for yr6 rel to F7
E6_8v=model_basic(h,orientation
      ="io",rts="vrs",dmu_eval=y6,dmu_ref=y8);efficiencies(E6_8v)#Tec Eff for yr6 rel to F8
E6_9v=model_basic(h,orientation
      ="io",rts="vrs",dmu_eval=y6,dmu_ref=y9);efficiencies(E6_9v)#Tec Eff for yr6 rel to F9
E6_10v=model_basic(h,orientation
      ="io",rts="vrs",dmu_eval=y6,dmu_ref=y10);efficiencies(E6_10v)#Tec Eff for yr6 rel to
      F10
E6_11v=model_basic(h,orientation
      ="io",rts="vrs",dmu_eval=y6,dmu_ref=y11);efficiencies(E6_11v)#Tec Eff for yr6 rel to
      F11
E6_12v=model_basic(h,orientation
      ="io",rts="vrs",dmu_eval=y6,dmu_ref=y12);efficiencies(E6_12v)#Tec Eff for yr6 rel to
      F12
E6_13v=model_basic(h,orientation
      ="io",rts="vrs",dmu_eval=y6,dmu_ref=y13);efficiencies(E6_13v)#Tec Eff for yr6 rel to
      F13
E6_14v=model_basic(h,orientation
      ="io",rts="vrs",dmu_eval=y6,dmu_ref=y14);efficiencies(E6_14v)#Tec Eff for yr6 rel to
      F14
E6_15v=model_basic(h,orientation
      ="io",rts="vrs",dmu_eval=y6,dmu_ref=y15);efficiencies(E6_15v)#Tec Eff for yr6 rel to
      F15
E6_16v=model_basic(h,orientation
      ="io",rts="vrs",dmu_eval=y6,dmu_ref=y16);efficiencies(E6_16v)#Tec Eff for yr6 rel to
      F16
E6_17v=model_basic(h,orientation
      ="io",rts="vrs",dmu_eval=y6,dmu_ref=y17);efficiencies(E6_17v)#Tec Eff for yr6 rel to
      F17
E6_18v=model_basic(h,orientation
      ="io",rts="vrs",dmu_eval=y6,dmu_ref=y18);efficiencies(E6_18v)#Tec Eff for yr6 rel to
      F18
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E6_19v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y6,dmu_ref=y19);efficiencies(E6_19v)#Tec Eff for yr6 rel to F19

E6_20v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y6,dmu_ref=y20);efficiencies(E6_20v)#Tec Eff for yr6 rel to F20

E6_21v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y6,dmu_ref=y21);efficiencies(E6_21v)#Tec Eff for yr6 rel to F21

E6_22v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y6,dmu_ref=y22);efficiencies(E6_22v)#Tec Eff for yr6 rel to F22

E6_23v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y6,dmu_ref=y23);efficiencies(E6_23v)#Tec Eff for yr6 rel to F23

E7_1v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y7,dmu_ref=y1);efficiencies(E7_1v)#Tec Eff for yr7 rel to F1

E7_2v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y7,dmu_ref=y2);efficiencies(E7_2v)#Tec Eff for yr7 rel to F2

E7_3v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y7,dmu_ref=y3);efficiencies(E7_3v)#Tec Eff for yr7 rel to F3

E7_4v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y7,dmu_ref=y4);efficiencies(E7_4v)#Tec Eff for yr7 rel to F4

E7_5v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y7,dmu_ref=y5);efficiencies(E7_5v)#Tec Eff for yr7 rel to F5

E7_6v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y7,dmu_ref=y6);efficiencies(E7_6v)#Tec Eff for yr7 rel to F6

E7_8v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y7,dmu_ref=y8);efficiencies(E7_8v)#Tec Eff for yr7 rel to F8

E7_9v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y7,dmu_ref=y9);efficiencies(E7_9v)#Tec Eff for yr7 rel to F9

E7_10v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y7,dmu_ref=y10);efficiencies(E7_10v)#Tec Eff for yr7 rel to F10

E7_11v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y7,dmu_ref=y11);efficiencies(E7_11v)#Tec Eff for yr7 rel to F11

E7_12v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y7,dmu_ref=y12);efficiencies(E7_12v)#Tec Eff for yr7 rel to F12

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E7_13v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y7,dmu_ref=y13);efficiencies(E7_13v)#Tec Eff for yr7 rel to
    F13
E7_14v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y7,dmu_ref=y14);efficiencies(E7_14v)#Tec Eff for yr7 rel to
    F14
E7_15v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y7,dmu_ref=y15);efficiencies(E7_15v)#Tec Eff for yr7 rel to
    F15
E7_16v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y7,dmu_ref=y16);efficiencies(E7_16v)#Tec Eff for yr7 rel to
    F16
E7_17v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y7,dmu_ref=y17);efficiencies(E7_17v)#Tec Eff for yr7 rel to
    F17
E7_18v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y7,dmu_ref=y18);efficiencies(E7_18v)#Tec Eff for yr7 rel to
    F18
E7_19v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y7,dmu_ref=y19);efficiencies(E7_19v)#Tec Eff for yr7 rel to
    F19
E7_20v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y7,dmu_ref=y20);efficiencies(E7_20v)#Tec Eff for yr7 rel to
    F20
E7_21v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y7,dmu_ref=y21);efficiencies(E7_21v)#Tec Eff for yr7 rel to
    F21
E7_22v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y7,dmu_ref=y22);efficiencies(E7_22v)#Tec Eff for yr7 rel to
    F22
E7_23v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y7,dmu_ref=y23);efficiencies(E7_23v)#Tec Eff for yr7 rel to
    F23


E8_1v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y8,dmu_ref=y1);efficiencies(E8_1v)#Tec Eff for yr8 rel to F1
E8_2v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y8,dmu_ref=y2);efficiencies(E8_2v)#Tec Eff for yr8 rel to F2
E8_3v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y8,dmu_ref=y3);efficiencies(E8_3v)#Tec Eff for yr8 rel to F3
E8_4v=model_basic(h,orientation
```

="io",rts="vrs",dmu_eval=y8,dmu_ref=y4);efficiencies(E8_4v)#Tec Eff for yr8 rel to F4

E8_5v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y8,dmu_ref=y5);efficiencies(E8_5v)#Tec Eff for yr8 rel to F5

E8_6v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y8,dmu_ref=y6);efficiencies(E8_6v)#Tec Eff for yr8 rel to F6

E8_7v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y8,dmu_ref=y7);efficiencies(E8_7v)#Tec Eff for yr8 rel to F7

E8_9v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y8,dmu_ref=y9);efficiencies(E8_9v)#Tec Eff for yr8 rel to F9

E8_10v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y8,dmu_ref=y10);efficiencies(E8_10v)#Tec Eff for yr8 rel to F10

E8_11v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y8,dmu_ref=y11);efficiencies(E8_11v)#Tec Eff for yr8 rel to F11

E8_12v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y8,dmu_ref=y12);efficiencies(E8_12v)#Tec Eff for yr8 rel to F12

E8_13v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y8,dmu_ref=y13);efficiencies(E8_13v)#Tec Eff for yr8 rel to F13

E8_14v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y8,dmu_ref=y14);efficiencies(E8_14v)#Tec Eff for yr8 rel to F14

E8_15v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y8,dmu_ref=y15);efficiencies(E8_15v)#Tec Eff for yr8 rel to F15

E8_16v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y8,dmu_ref=y16);efficiencies(E8_16v)#Tec Eff for yr8 rel to F16

E8_17v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y8,dmu_ref=y17);efficiencies(E8_17v)#Tec Eff for yr8 rel to F17

E8_18v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y8,dmu_ref=y18);efficiencies(E8_18v)#Tec Eff for yr8 rel to F18

E8_19v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y8,dmu_ref=y19);efficiencies(E8_19v)#Tec Eff for yr8 rel to F19

E8_20v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y8,dmu_ref=y20);efficiencies(E8_20v)#Tec Eff for yr8 rel to

F20

E8_21v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y8,dmu_ref=y21);efficiencies(E8_21v)#Tec Eff for yr8 rel to F21

E8_22v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y8,dmu_ref=y22);efficiencies(E8_22v)#Tec Eff for yr8 rel to F22

E8_23v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y8,dmu_ref=y23);efficiencies(E8_23v)#Tec Eff for yr8 rel to F23

E9_1v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y9,dmu_ref=y1);efficiencies(E9_1v)#Tec Eff for yr9 rel to F1

E9_2v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y9,dmu_ref=y2);efficiencies(E9_2v)#Tec Eff for yr9 rel to F2

E9_3v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y9,dmu_ref=y3);efficiencies(E9_3v)#Tec Eff for yr9 rel to F3

E9_4v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y9,dmu_ref=y4);efficiencies(E9_4v)#Tec Eff for yr9 rel to F4

E9_5v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y9,dmu_ref=y5);efficiencies(E9_5v)#Tec Eff for yr9 rel to F5

E9_6v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y9,dmu_ref=y6);efficiencies(E9_6v)#Tec Eff for yr9 rel to F6

E9_7v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y9,dmu_ref=y7);efficiencies(E9_7v)#Tec Eff for yr9 rel to F7

E9_8v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y9,dmu_ref=y8);efficiencies(E9_8v)#Tec Eff for yr9 rel to F8

E9_10v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y9,dmu_ref=y10);efficiencies(E9_10v)#Tec Eff for yr9 rel to F10

E9_11v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y9,dmu_ref=y11);efficiencies(E9_11v)#Tec Eff for yr9 rel to F11

E9_12v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y9,dmu_ref=y12);efficiencies(E9_12v)#Tec Eff for yr9 rel to F12

E9_13v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y9,dmu_ref=y13);efficiencies(E9_13v)#Tec Eff for yr9 rel to F13

E9_14v=model_basic(h,orientation

="io",rts="vrs",dmu_eval=y9,dmu_ref=y14);efficiencies(E9_14v)#Tec Eff for yr9 rel to F14

E9_15v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y9,dmu_ref=y15);efficiencies(E9_15v)#Tec Eff for yr9 rel to F15

E9_16v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y9,dmu_ref=y16);efficiencies(E9_16v)#Tec Eff for yr9 rel to F16

E9_17v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y9,dmu_ref=y17);efficiencies(E9_17v)#Tec Eff for yr9 rel to F17

E9_18v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y9,dmu_ref=y18);efficiencies(E9_18v)#Tec Eff for yr9 rel to F18

E9_19v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y9,dmu_ref=y19);efficiencies(E9_19v)#Tec Eff for yr9 rel to F19

E9_20v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y9,dmu_ref=y20);efficiencies(E9_20v)#Tec Eff for yr9 rel to F20

E9_21v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y9,dmu_ref=y21);efficiencies(E9_21v)#Tec Eff for yr9 rel to F21

E9_22v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y9,dmu_ref=y22);efficiencies(E9_22v)#Tec Eff for yr9 rel to F22

E9_23v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y9,dmu_ref=y23);efficiencies(E9_23v)#Tec Eff for yr9 rel to F23

E10_1v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y10,dmu_ref=y1);efficiencies(E10_1v)#Tec Eff for yr10 rel to F1

E10_2v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y10,dmu_ref=y2);efficiencies(E10_2v)#Tec Eff for yr10 rel to F2

E10_3v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y10,dmu_ref=y3);efficiencies(E10_3v)#Tec Eff for yr10 rel to F3

E10_4v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y10,dmu_ref=y4);efficiencies(E10_4v)#Tec Eff for yr10 rel to F4

E10_5v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y10,dmu_ref=y5);efficiencies(E10_5v)#Tec Eff for yr10 rel to F5

E10_6v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y10,dmu_ref=y6);efficiencies(E10_6v)#Tec Eff for yr10 rel to F6

E10_7v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y10,dmu_ref=y7);efficiencies(E10_7v)#Tec Eff for yr10 rel to F7

E10_8v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y10,dmu_ref=y8);efficiencies(E10_8v)#Tec Eff for yr10 rel to F8

E10_9v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y10,dmu_ref=y9);efficiencies(E10_9v)#Tec Eff for yr10 rel to F9

E10_11v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y10,dmu_ref=y11);efficiencies(E10_11v)#Tec Eff for yr10 rel to F11

E10_12v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y10,dmu_ref=y12);efficiencies(E10_12v)#Tec Eff for yr10 rel to F12

E10_13v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y10,dmu_ref=y13);efficiencies(E10_13v)#Tec Eff for yr10 rel to F13

E10_14v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y10,dmu_ref=y14);efficiencies(E10_14v)#Tec Eff for yr10 rel to F14

E10_15v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y10,dmu_ref=y15);efficiencies(E10_15v)#Tec Eff for yr10 rel to F15

E10_16v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y10,dmu_ref=y16);efficiencies(E10_16v)#Tec Eff for yr10 rel to F16

E10_17v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y10,dmu_ref=y17);efficiencies(E10_17v)#Tec Eff for yr10 rel to F17

E10_18v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y10,dmu_ref=y18);efficiencies(E10_18v)#Tec Eff for yr10 rel to F18

E10_19v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y10,dmu_ref=y19);efficiencies(E10_19v)#Tec Eff for yr10 rel to F19

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E10_20v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y10,dmu_ref=y20);efficiencies(E10_20v)#Tec Eff for yr10
    rel to F20

E10_21v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y10,dmu_ref=y21);efficiencies(E10_21v)#Tec Eff for yr10
    rel to F21

E10_22v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y10,dmu_ref=y22);efficiencies(E10_22v)#Tec Eff for yr10
    rel to F22

E10_23v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y10,dmu_ref=y23);efficiencies(E10_23v)#Tec Eff for yr10
    rel to F23


E11_1v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y11,dmu_ref=y1);efficiencies(E11_1v)#Tec Eff for yr11 rel to
    F1

E11_2v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y11,dmu_ref=y2);efficiencies(E11_2v)#Tec Eff for yr11 rel to
    F2

E11_3v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y11,dmu_ref=y3);efficiencies(E11_3v)#Tec Eff for yr11 rel to
    F3

E11_4v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y11,dmu_ref=y4);efficiencies(E11_4v)#Tec Eff for yr11 rel to
    F4

E11_5v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y11,dmu_ref=y5);efficiencies(E11_5v)#Tec Eff for yr11 rel to
    F5

E11_6v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y11,dmu_ref=y6);efficiencies(E11_6v)#Tec Eff for yr11 rel to
    F6

E11_7v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y11,dmu_ref=y7);efficiencies(E11_7v)#Tec Eff for yr11 rel to
    F7

E11_8v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y11,dmu_ref=y8);efficiencies(E11_8v)#Tec Eff for yr11 rel to
    F8

E11_9v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y11,dmu_ref=y9);efficiencies(E11_9v)#Tec Eff for yr11 rel to
    F9

E11_10v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y11,dmu_ref=y10);efficiencies(E11_10v)#Tec Eff for yr11 rel
```

to F10

E11_12v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y11,dmu_ref=y12);efficiencies(E11_12v)#Tec Eff for yr11 rel to F12

E11_13v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y11,dmu_ref=y13);efficiencies(E11_13v)#Tec Eff for yr11 rel to F13

E11_14v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y11,dmu_ref=y14);efficiencies(E11_14v)#Tec Eff for yr11 rel to F14

E11_15v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y11,dmu_ref=y15);efficiencies(E11_15v)#Tec Eff for yr11 rel to F15

E11_16v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y11,dmu_ref=y16);efficiencies(E11_16v)#Tec Eff for yr11 rel to F16

E11_17v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y11,dmu_ref=y17);efficiencies(E11_17v)#Tec Eff for yr11 rel to F17

E11_18v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y11,dmu_ref=y18);efficiencies(E11_18v)#Tec Eff for yr11 rel to F18

E11_19v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y11,dmu_ref=y19);efficiencies(E11_19v)#Tec Eff for yr11 rel to F19

E11_20v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y11,dmu_ref=y20);efficiencies(E11_20v)#Tec Eff for yr11 rel to F20

E11_21v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y11,dmu_ref=y21);efficiencies(E11_21v)#Tec Eff for yr11 rel to F21

E11_22v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y11,dmu_ref=y22);efficiencies(E11_22v)#Tec Eff for yr11 rel to F22

E11_23v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y11,dmu_ref=y23);efficiencies(E11_23v)#Tec Eff for yr11 rel to F23

E12_1v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y12,dmu_ref=y1);efficiencies(E12_1v)#Tec Eff for yr12 rel to F1

```
E12_2v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y12,dmu_ref=y2);efficiencies(E12_2v)#Tec Eff for yr12 rel
    to F2

E12_3v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y12,dmu_ref=y3);efficiencies(E12_3v)#Tec Eff for yr12 rel
    to F3

E12_4v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y12,dmu_ref=y4);efficiencies(E12_4v)#Tec Eff for yr12 rel
    to F4

E12_5v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y12,dmu_ref=y5);efficiencies(E12_5v)#Tec Eff for yr12 rel
    to F5

E12_6v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y12,dmu_ref=y6);efficiencies(E12_6v)#Tec Eff for yr12 rel
    to F6

E12_7v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y12,dmu_ref=y7);efficiencies(E12_7v)#Tec Eff for yr12 rel
    to F7

E12_8v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y12,dmu_ref=y8);efficiencies(E12_8v)#Tec Eff for yr12 rel
    to F8

E12_9v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y12,dmu_ref=y9);efficiencies(E12_9v)#Tec Eff for yr12 rel
    to F9

E12_10v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y12,dmu_ref=y10);efficiencies(E12_10v)#Tec Eff for yr12
    rel to F10

E12_11v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y12,dmu_ref=y11);efficiencies(E12_11v)#Tec Eff for yr12
    rel to F11

E12_13v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y12,dmu_ref=y13);efficiencies(E12_13v)#Tec Eff for yr12
    rel to F13

E12_14v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y12,dmu_ref=y14);efficiencies(E12_14v)#Tec Eff for yr12
    rel to F14

E12_15v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y12,dmu_ref=y15);efficiencies(E12_15v)#Tec Eff for yr12
    rel to F15

E12_16v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y12,dmu_ref=y16);efficiencies(E12_16v)#Tec Eff for yr12
    rel to F16
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E12_17v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y12,dmu_ref=y17);efficiencies(E12_17v)#Tec Eff for yr12 rel to F17

E12_18v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y12,dmu_ref=y18);efficiencies(E12_18v)#Tec Eff for yr12 rel to F18

E12_19v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y12,dmu_ref=y19);efficiencies(E12_19v)#Tec Eff for yr12 rel to F19

E12_20v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y12,dmu_ref=y20);efficiencies(E12_20v)#Tec Eff for yr12 rel to F20

E12_21v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y12,dmu_ref=y21);efficiencies(E12_21v)#Tec Eff for yr12 rel to F21

E12_22v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y12,dmu_ref=y22);efficiencies(E12_22v)#Tec Eff for yr12 rel to F22

E12_23v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y12,dmu_ref=y23);efficiencies(E12_23v)#Tec Eff for yr12 rel to F23

E13_1v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y13,dmu_ref=y1);efficiencies(E13_1v)#Tec Eff for yr13 rel to F1

E13_2v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y13,dmu_ref=y2);efficiencies(E13_2v)#Tec Eff for yr13 rel to F2

E13_3v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y13,dmu_ref=y3);efficiencies(E13_3v)#Tec Eff for yr13 rel to F3

E13_4v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y13,dmu_ref=y4);efficiencies(E13_4v)#Tec Eff for yr13 rel to F4

E13_5v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y13,dmu_ref=y5);efficiencies(E13_5v)#Tec Eff for yr13 rel to F5

E13_6v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y13,dmu_ref=y6);efficiencies(E13_6v)#Tec Eff for yr13 rel to F6

E13_7v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y13,dmu_ref=y7);efficiencies(E13_7v)#Tec Eff for yr13 rel

to F7

E13_8v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y13,dmu_ref=y8);efficiencies(E13_8v)#Tec Eff for yr13 rel to F8

E13_9v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y13,dmu_ref=y9);efficiencies(E13_9v)#Tec Eff for yr13 rel to F9

E13_10v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y13,dmu_ref=y10);efficiencies(E13_10v)#Tec Eff for yr13 rel to F10

E13_11v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y13,dmu_ref=y11);efficiencies(E13_11v)#Tec Eff for yr13 rel to F11

E13_12v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y13,dmu_ref=y12);efficiencies(E13_12v)#Tec Eff for yr13 rel to F12

E13_14v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y13,dmu_ref=y14);efficiencies(E13_14v)#Tec Eff for yr13 rel to F14

E13_15v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y13,dmu_ref=y15);efficiencies(E13_15v)#Tec Eff for yr13 rel to F15

E13_16v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y13,dmu_ref=y16);efficiencies(E13_16v)#Tec Eff for yr13 rel to F16

E13_17v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y13,dmu_ref=y17);efficiencies(E13_17v)#Tec Eff for yr13 rel to F17

E13_18v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y13,dmu_ref=y18);efficiencies(E13_18v)#Tec Eff for yr13 rel to F18

E13_19v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y13,dmu_ref=y19);efficiencies(E13_19v)#Tec Eff for yr13 rel to F19

E13_20v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y13,dmu_ref=y20);efficiencies(E13_20v)#Tec Eff for yr13 rel to F20

E13_21v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y13,dmu_ref=y21);efficiencies(E13_21v)#Tec Eff for yr13 rel to F21

E13_22v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y13,dmu_ref=y22);efficiencies(E13_22v)#Tec Eff for yr13

rel to F22

E13_23v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y13,dmu_ref=y23);efficiencies(E13_23v)#Tec Eff for yr13 rel to F23

E14_1v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y14,dmu_ref=y1);efficiencies(E14_1v)#Tec Eff for yr14 rel to F1

E14_2v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y14,dmu_ref=y2);efficiencies(E14_2v)#Tec Eff for yr14 rel to F2

E14_3v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y14,dmu_ref=y3);efficiencies(E14_3v)#Tec Eff for yr14 rel to F3

E14_4v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y14,dmu_ref=y4);efficiencies(E14_4v)#Tec Eff for yr14 rel to F4

E14_5v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y14,dmu_ref=y5);efficiencies(E14_5v)#Tec Eff for yr14 rel to F5

E14_6v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y14,dmu_ref=y6);efficiencies(E14_6v)#Tec Eff for yr14 rel to F6

E14_7v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y14,dmu_ref=y7);efficiencies(E14_7v)#Tec Eff for yr14 rel to F7

E14_8v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y14,dmu_ref=y8);efficiencies(E14_8v)#Tec Eff for yr14 rel to F8

E14_9v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y14,dmu_ref=y9);efficiencies(E14_9v)#Tec Eff for yr14 rel to F9

E14_10v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y14,dmu_ref=y10);efficiencies(E14_10v)#Tec Eff for yr14 rel to F10

E14_11v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y14,dmu_ref=y11);efficiencies(E14_11v)#Tec Eff for yr14 rel to F11

E14_12v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y14,dmu_ref=y12);efficiencies(E14_12v)#Tec Eff for yr14 rel to F12

E14_13v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y14,dmu_ref=y13);efficiencies(E14_13v)#Tec Eff for yr14 rel to F13

E14_15v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y14,dmu_ref=y15);efficiencies(E14_15v)#Tec Eff for yr14 rel to F15

E14_16v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y14,dmu_ref=y16);efficiencies(E14_16v)#Tec Eff for yr14 rel to F16

E14_17v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y14,dmu_ref=y17);efficiencies(E14_17v)#Tec Eff for yr14 rel to F17

E14_18v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y14,dmu_ref=y18);efficiencies(E14_18v)#Tec Eff for yr14 rel to F18

E14_19v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y14,dmu_ref=y19);efficiencies(E14_19v)#Tec Eff for yr14 rel to F19

E14_20v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y14,dmu_ref=y20);efficiencies(E14_20v)#Tec Eff for yr14 rel to F20

E14_21v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y14,dmu_ref=y21);efficiencies(E14_21v)#Tec Eff for yr14 rel to F21

E14_22v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y14,dmu_ref=y22);efficiencies(E14_22v)#Tec Eff for yr14 rel to F22

E14_23v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y14,dmu_ref=y23);efficiencies(E14_23v)#Tec Eff for yr14 rel to F23

E15_1v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y15,dmu_ref=y1);efficiencies(E15_1v)#Tec Eff for yr15 rel to F1

E15_2v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y15,dmu_ref=y2);efficiencies(E15_2v)#Tec Eff for yr15 rel to F2

E15_3v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y15,dmu_ref=y3);efficiencies(E15_3v)#Tec Eff for yr15 rel to F3

E15_4v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y15,dmu_ref=y4);efficiencies(E15_4v)#Tec Eff for yr15 rel

to F4

E15_5v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y15,dmu_ref=y5);efficiencies(E15_5v)#Tec Eff for yr15 rel to F5

E15_6v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y15,dmu_ref=y6);efficiencies(E15_6v)#Tec Eff for yr15 rel to F6

E15_7v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y15,dmu_ref=y7);efficiencies(E15_7v)#Tec Eff for yr15 rel to F7

E15_8v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y15,dmu_ref=y8);efficiencies(E15_8v)#Tec Eff for yr15 rel to F8

E15_9v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y15,dmu_ref=y9);efficiencies(E15_9v)#Tec Eff for yr15 rel to F9

E15_10v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y15,dmu_ref=y10);efficiencies(E15_10v)#Tec Eff for yr15 rel to F10

E15_11v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y15,dmu_ref=y11);efficiencies(E15_11v)#Tec Eff for yr15 rel to F11

E15_12v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y15,dmu_ref=y12);efficiencies(E15_12v)#Tec Eff for yr15 rel to F12

E15_13v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y15,dmu_ref=y13);efficiencies(E15_13v)#Tec Eff for yr15 rel to F13

E15_14v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y15,dmu_ref=y14);efficiencies(E15_14v)#Tec Eff for yr15 rel to F14

E15_16v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y15,dmu_ref=y16);efficiencies(E15_16v)#Tec Eff for yr15 rel to F16

E15_17v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y15,dmu_ref=y17);efficiencies(E15_17v)#Tec Eff for yr15 rel to F17

E15_18v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y15,dmu_ref=y18);efficiencies(E15_18v)#Tec Eff for yr15 rel to F18

E15_19v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y15,dmu_ref=y19);efficiencies(E15_19v)#Tec Eff for yr15

rel to F19

E15_20v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y15,dmu_ref=y20);efficiencies(E15_20v)#Tec Eff for yr15 rel to F20

E15_21v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y15,dmu_ref=y21);efficiencies(E15_21v)#Tec Eff for yr15 rel to F21

E15_22v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y15,dmu_ref=y22);efficiencies(E15_22v)#Tec Eff for yr15 rel to F22

E15_23v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y15,dmu_ref=y23);efficiencies(E15_23v)#Tec Eff for yr15 rel to F23

E16_1v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y16,dmu_ref=y1);efficiencies(E16_1v)#Tec Eff for yr16 rel to F1

E16_2v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y16,dmu_ref=y2);efficiencies(E16_2v)#Tec Eff for yr16 rel to F2

E16_3v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y16,dmu_ref=y3);efficiencies(E16_3v)#Tec Eff for yr16 rel to F3

E16_4v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y16,dmu_ref=y4);efficiencies(E16_4v)#Tec Eff for yr16 rel to F4

E16_5v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y16,dmu_ref=y5);efficiencies(E16_5v)#Tec Eff for yr16 rel to F5

E16_6v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y16,dmu_ref=y6);efficiencies(E16_6v)#Tec Eff for yr16 rel to F6

E16_7v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y16,dmu_ref=y7);efficiencies(E16_7v)#Tec Eff for yr16 rel to F7

E16_8v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y16,dmu_ref=y8);efficiencies(E16_8v)#Tec Eff for yr16 rel to F8

E16_9v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y16,dmu_ref=y9);efficiencies(E16_9v)#Tec Eff for yr16 rel to F9

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E16_10v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y16,dmu_ref=y10);efficiencies(E16_10v)#Tec Eff for yr16
    rel to F10

E16_11v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y16,dmu_ref=y11);efficiencies(E16_11v)#Tec Eff for yr16
    rel to F11

E16_12v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y16,dmu_ref=y12);efficiencies(E16_12v)#Tec Eff for yr16
    rel to F12

E16_13v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y16,dmu_ref=y13);efficiencies(E16_13v)#Tec Eff for yr16
    rel to F13

E16_14v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y16,dmu_ref=y14);efficiencies(E16_14v)#Tec Eff for yr16
    rel to F14

E16_15v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y16,dmu_ref=y15);efficiencies(E16_15v)#Tec Eff for yr16
    rel to F15

E16_17v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y16,dmu_ref=y17);efficiencies(E16_17v)#Tec Eff for yr16
    rel to F17

E16_18v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y16,dmu_ref=y18);efficiencies(E16_18v)#Tec Eff for yr16
    rel to F18

E16_19v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y16,dmu_ref=y19);efficiencies(E16_19v)#Tec Eff for yr16
    rel to F19

E16_20v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y16,dmu_ref=y20);efficiencies(E16_20v)#Tec Eff for yr16
    rel to F20

E16_21v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y16,dmu_ref=y21);efficiencies(E16_21v)#Tec Eff for yr16
    rel to F21

E16_22v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y16,dmu_ref=y22);efficiencies(E16_22v)#Tec Eff for yr16
    rel to F22

E16_23v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y16,dmu_ref=y23);efficiencies(E16_23v)#Tec Eff for yr16
    rel to F23


E17_1v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y17,dmu_ref=y1);efficiencies(E17_1v)#Tec Eff for yr17 rel
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to F1

E17_2v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y17,dmu_ref=y2);efficiencies(E17_2v)#Tec Eff for yr17 rel to F2

E17_3v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y17,dmu_ref=y3);efficiencies(E17_3v)#Tec Eff for yr17 rel to F3

E17_4v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y17,dmu_ref=y4);efficiencies(E17_4v)#Tec Eff for yr17 rel to F4

E17_5v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y17,dmu_ref=y5);efficiencies(E17_5v)#Tec Eff for yr17 rel to F5

E17_6v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y17,dmu_ref=y6);efficiencies(E17_6v)#Tec Eff for yr17 rel to F6

E17_7v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y17,dmu_ref=y7);efficiencies(E17_7v)#Tec Eff for yr17 rel to F7

E17_8v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y17,dmu_ref=y8);efficiencies(E17_8v)#Tec Eff for yr17 rel to F8

E17_9v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y17,dmu_ref=y9);efficiencies(E17_9v)#Tec Eff for yr17 rel to F9

E17_10v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y17,dmu_ref=y10);efficiencies(E17_10v)#Tec Eff for yr17 rel to F10

E17_11v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y17,dmu_ref=y11);efficiencies(E17_11v)#Tec Eff for yr17 rel to F11

E17_12v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y17,dmu_ref=y12);efficiencies(E17_12v)#Tec Eff for yr17 rel to F12

E17_13v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y17,dmu_ref=y13);efficiencies(E17_13v)#Tec Eff for yr17 rel to F13

E17_14v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y17,dmu_ref=y14);efficiencies(E17_14v)#Tec Eff for yr17 rel to F14

E17_15v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y17,dmu_ref=y15);efficiencies(E17_15v)#Tec Eff for yr17

rel to F15

E17_16v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y17,dmu_ref=y16);efficiencies(E17_16v)#Tec Eff for yr17 rel to F16

E17_18v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y17,dmu_ref=y18);efficiencies(E17_18v)#Tec Eff for yr17 rel to F18

E17_19v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y17,dmu_ref=y19);efficiencies(E17_19v)#Tec Eff for yr17 rel to F19

E17_20v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y17,dmu_ref=y20);efficiencies(E17_20v)#Tec Eff for yr17 rel to F20

E17_21v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y17,dmu_ref=y21);efficiencies(E17_21v)#Tec Eff for yr17 rel to F21

E17_22v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y17,dmu_ref=y22);efficiencies(E17_22v)#Tec Eff for yr17 rel to F22

E17_23v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y17,dmu_ref=y23);efficiencies(E17_23v)#Tec Eff for yr17 rel to F23

E18_1v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y18,dmu_ref=y1);efficiencies(E18_1v)#Tec Eff for yr18 rel to F1

E18_2v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y18,dmu_ref=y2);efficiencies(E18_2v)#Tec Eff for yr18 rel to F2

E18_3v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y18,dmu_ref=y3);efficiencies(E18_3v)#Tec Eff for yr18 rel to F3

E18_4v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y18,dmu_ref=y4);efficiencies(E18_4v)#Tec Eff for yr18 rel to F4

E18_5v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y18,dmu_ref=y5);efficiencies(E18_5v)#Tec Eff for yr18 rel to F5

E18_6v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y18,dmu_ref=y6);efficiencies(E18_6v)#Tec Eff for yr18 rel to F6

E18_7v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y18,dmu_ref=y7);efficiencies(E18_7v)#Tec Eff for yr18 rel to F7

E18_8v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y18,dmu_ref=y8);efficiencies(E18_8v)#Tec Eff for yr18 rel to F8

E18_9v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y18,dmu_ref=y9);efficiencies(E18_9v)#Tec Eff for yr18 rel to F9

E18_10v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y18,dmu_ref=y10);efficiencies(E18_10v)#Tec Eff for yr18 rel to F10

E18_11v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y18,dmu_ref=y11);efficiencies(E18_11v)#Tec Eff for yr18 rel to F11

E18_12v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y18,dmu_ref=y12);efficiencies(E18_12v)#Tec Eff for yr18 rel to F12

E18_13v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y18,dmu_ref=y13);efficiencies(E18_13v)#Tec Eff for yr18 rel to F13

E18_14v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y18,dmu_ref=y14);efficiencies(E18_14v)#Tec Eff for yr18 rel to F14

E18_15v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y18,dmu_ref=y15);efficiencies(E18_15v)#Tec Eff for yr18 rel to F15

E18_16v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y18,dmu_ref=y16);efficiencies(E18_16v)#Tec Eff for yr18 rel to F16

E18_17v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y18,dmu_ref=y17);efficiencies(E18_17v)#Tec Eff for yr18 rel to F17

E18_19v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y18,dmu_ref=y19);efficiencies(E18_19v)#Tec Eff for yr18 rel to F19

E18_20v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y18,dmu_ref=y20);efficiencies(E18_20v)#Tec Eff for yr18 rel to F20

E18_21v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y18,dmu_ref=y21);efficiencies(E18_21v)#Tec Eff for yr18 rel to F21

E18_22v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y18,dmu_ref=y22);efficiencies(E18_22v)#Tec Eff for yr18 rel to F22

E18_23v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y18,dmu_ref=y23);efficiencies(E18_23v)#Tec Eff for yr18 rel to F23

E19_1v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y19,dmu_ref=y1);efficiencies(E19_1v)#Tec Eff for yr19 rel to F1

E19_2v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y19,dmu_ref=y2);efficiencies(E19_2v)#Tec Eff for yr19 rel to F2

E19_3v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y19,dmu_ref=y3);efficiencies(E19_3v)#Tec Eff for yr19 rel to F3

E19_4v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y19,dmu_ref=y4);efficiencies(E19_4v)#Tec Eff for yr19 rel to F4

E19_5v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y19,dmu_ref=y5);efficiencies(E19_5v)#Tec Eff for yr19 rel to F5

E19_6v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y19,dmu_ref=y6);efficiencies(E19_6v)#Tec Eff for yr19 rel to F6

E19_7v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y19,dmu_ref=y7);efficiencies(E19_7v)#Tec Eff for yr19 rel to F7

E19_8v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y19,dmu_ref=y8);efficiencies(E19_8v)#Tec Eff for yr19 rel to F8

E19_9v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y19,dmu_ref=y9);efficiencies(E19_9v)#Tec Eff for yr19 rel to F9

E19_10v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y19,dmu_ref=y10);efficiencies(E19_10v)#Tec Eff for yr19 rel to F10

E19_11v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y19,dmu_ref=y11);efficiencies(E19_11v)#Tec Eff for yr19 rel to F11

E19_12v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y19,dmu_ref=y12);efficiencies(E19_12v)#Tec Eff for yr19

rel to F12

E19_13v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y19,dmu_ref=y13);efficiencies(E19_13v)#Tec Eff for yr19 rel to F13

E19_14v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y19,dmu_ref=y14);efficiencies(E19_14v)#Tec Eff for yr19 rel to F14

E19_15v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y19,dmu_ref=y15);efficiencies(E19_15v)#Tec Eff for yr19 rel to F15

E19_16v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y19,dmu_ref=y16);efficiencies(E19_16v)#Tec Eff for yr19 rel to F16

E19_17v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y19,dmu_ref=y17);efficiencies(E19_17v)#Tec Eff for yr19 rel to F17

E19_18v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y19,dmu_ref=y18);efficiencies(E19_18v)#Tec Eff for yr19 rel to F18

E19_20v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y19,dmu_ref=y20);efficiencies(E19_20v)#Tec Eff for yr19 rel to F20

E19_21v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y19,dmu_ref=y21);efficiencies(E19_21v)#Tec Eff for yr19 rel to F21

E19_22v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y19,dmu_ref=y22);efficiencies(E19_22v)#Tec Eff for yr19 rel to F22

E19_23v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y19,dmu_ref=y23);efficiencies(E19_23v)#Tec Eff for yr19 rel to F23

E20_1v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y20,dmu_ref=y1);efficiencies(E20_1v)#Tec Eff for yr20 rel to F1

E20_2v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y20,dmu_ref=y2);efficiencies(E20_2v)#Tec Eff for yr20 rel to F2

E20_3v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y20,dmu_ref=y3);efficiencies(E20_3v)#Tec Eff for yr20 rel to F3

E20_4v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y20,dmu_ref=y4);efficiencies(E20_4v)#Tec Eff for yr20 rel to F4

E20_5v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y20,dmu_ref=y5);efficiencies(E20_5v)#Tec Eff for yr20 rel to F5

E20_6v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y20,dmu_ref=y6);efficiencies(E20_6v)#Tec Eff for yr20 rel to F6

E20_7v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y20,dmu_ref=y7);efficiencies(E20_7v)#Tec Eff for yr20 rel to F7

E20_8v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y20,dmu_ref=y8);efficiencies(E20_8v)#Tec Eff for yr20 rel to F8

E20_9v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y20,dmu_ref=y9);efficiencies(E20_9v)#Tec Eff for yr20 rel to F9

E20_10v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y20,dmu_ref=y10);efficiencies(E20_10v)#Tec Eff for yr20 rel to F10

E20_11v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y20,dmu_ref=y11);efficiencies(E20_11v)#Tec Eff for yr20 rel to F11

E20_12v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y20,dmu_ref=y12);efficiencies(E20_12v)#Tec Eff for yr20 rel to F12

E20_13v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y20,dmu_ref=y13);efficiencies(E20_13v)#Tec Eff for yr20 rel to F13

E20_14v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y20,dmu_ref=y14);efficiencies(E20_14v)#Tec Eff for yr20 rel to F14

E20_15v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y20,dmu_ref=y15);efficiencies(E20_15v)#Tec Eff for yr20 rel to F15

E20_16v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y20,dmu_ref=y16);efficiencies(E20_16v)#Tec Eff for yr20 rel to F16

E20_17v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y20,dmu_ref=y17);efficiencies(E20_17v)#Tec Eff for yr20 rel to F17

E20_18v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y20,dmu_ref=y18);efficiencies(E20_18v)#Tec Eff for yr20 rel to F18

E20_19v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y20,dmu_ref=y19);efficiencies(E20_19v)#Tec Eff for yr20 rel to F19

E20_21v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y20,dmu_ref=y21);efficiencies(E20_21v)#Tec Eff for yr20 rel to F21

E20_22v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y20,dmu_ref=y22);efficiencies(E20_22v)#Tec Eff for yr20 rel to F22

E20_23v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y20,dmu_ref=y23);efficiencies(E20_23v)#Tec Eff for yr20 rel to F23

E21_1v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y21,dmu_ref=y1);efficiencies(E21_1v)#Tec Eff for yr21 rel to F1

E21_2v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y21,dmu_ref=y2);efficiencies(E21_2v)#Tec Eff for yr21 rel to F2

E21_3v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y21,dmu_ref=y3);efficiencies(E21_3v)#Tec Eff for yr21 rel to F3

E21_4v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y21,dmu_ref=y4);efficiencies(E21_4v)#Tec Eff for yr21 rel to F4

E21_5v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y21,dmu_ref=y5);efficiencies(E21_5v)#Tec Eff for yr21 rel to F5

E21_6v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y21,dmu_ref=y6);efficiencies(E21_6v)#Tec Eff for yr21 rel to F6

E21_7v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y21,dmu_ref=y7);efficiencies(E21_7v)#Tec Eff for yr21 rel to F7

E21_8v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y21,dmu_ref=y8);efficiencies(E21_8v)#Tec Eff for yr21 rel to F8

E21_9v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y21,dmu_ref=y9);efficiencies(E21_9v)#Tec Eff for yr21 rel

to F9

E21_10v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y21,dmu_ref=y10);efficiencies(E21_10v)#Tec Eff for yr21 rel to F10

E21_11v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y21,dmu_ref=y11);efficiencies(E21_11v)#Tec Eff for yr21 rel to F11

E21_12v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y21,dmu_ref=y12);efficiencies(E21_12v)#Tec Eff for yr21 rel to F12

E21_13v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y21,dmu_ref=y13);efficiencies(E21_13v)#Tec Eff for yr21 rel to F13

E21_14v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y21,dmu_ref=y14);efficiencies(E21_14v)#Tec Eff for yr21 rel to F14

E21_15v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y21,dmu_ref=y15);efficiencies(E21_15v)#Tec Eff for yr21 rel to F15

E21_16v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y21,dmu_ref=y16);efficiencies(E21_16v)#Tec Eff for yr21 rel to F16

E21_17v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y21,dmu_ref=y17);efficiencies(E21_17v)#Tec Eff for yr21 rel to F17

E21_18v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y21,dmu_ref=y18);efficiencies(E21_18v)#Tec Eff for yr21 rel to F18

E21_19v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y21,dmu_ref=y19);efficiencies(E21_19v)#Tec Eff for yr21 rel to F19

E21_20v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y21,dmu_ref=y20);efficiencies(E21_20v)#Tec Eff for yr21 rel to F20

E21_22v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y21,dmu_ref=y22);efficiencies(E21_22v)#Tec Eff for yr21 rel to F22

E21_23v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y21,dmu_ref=y23);efficiencies(E21_23v)#Tec Eff for yr21 rel to F23

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E22_1v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y22,dmu_ref=y1);efficiencies(E22_1v)#Tec Eff for yr22 rel
    to F1
E22_2v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y22,dmu_ref=y2);efficiencies(E22_2v)#Tec Eff for yr22 rel
    to F2
E22_3v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y22,dmu_ref=y3);efficiencies(E22_3v)#Tec Eff for yr22 rel
    to F3
E22_4v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y22,dmu_ref=y4);efficiencies(E22_4v)#Tec Eff for yr22 rel
    to F4
E22_5v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y22,dmu_ref=y5);efficiencies(E22_5v)#Tec Eff for yr22 rel
    to F5
E22_6v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y22,dmu_ref=y6);efficiencies(E22_6v)#Tec Eff for yr22 rel
    to F6
E22_7v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y22,dmu_ref=y7);efficiencies(E22_7v)#Tec Eff for yr22 rel
    to F7
E22_8v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y22,dmu_ref=y8);efficiencies(E22_8v)#Tec Eff for yr22 rel
    to F8
E22_9v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y22,dmu_ref=y9);efficiencies(E22_9v)#Tec Eff for yr22 rel
    to F9
E22_10v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y22,dmu_ref=y10);efficiencies(E22_10v)#Tec Eff for yr22
    rel to F10
E22_11v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y22,dmu_ref=y11);efficiencies(E22_11v)#Tec Eff for yr22
    rel to F11
E22_12v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y22,dmu_ref=y12);efficiencies(E22_12v)#Tec Eff for yr22
    rel to F12
E22_13v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y22,dmu_ref=y13);efficiencies(E22_13v)#Tec Eff for yr22
    rel to F13
E22_14v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y22,dmu_ref=y14);efficiencies(E22_14v)#Tec Eff for yr22
    rel to F14
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E22_15v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y22,dmu_ref=y15);efficiencies(E22_15v)#Tec Eff for yr22 rel to F15

E22_16v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y22,dmu_ref=y16);efficiencies(E22_16v)#Tec Eff for yr22 rel to F16

E22_17v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y22,dmu_ref=y17);efficiencies(E22_17v)#Tec Eff for yr22 rel to F17

E22_18v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y22,dmu_ref=y18);efficiencies(E22_18v)#Tec Eff for yr22 rel to F18

E22_19v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y22,dmu_ref=y19);efficiencies(E22_19v)#Tec Eff for yr22 rel to F19

E22_20v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y22,dmu_ref=y20);efficiencies(E22_20v)#Tec Eff for yr22 rel to F20

E22_21v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y22,dmu_ref=y21);efficiencies(E22_21v)#Tec Eff for yr22 rel to F21

E22_23v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y22,dmu_ref=y23);efficiencies(E22_23v)#Tec Eff for yr22 rel to F23

E23_1v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y23,dmu_ref=y1);efficiencies(E23_1v)#Tec Eff for yr23 rel to F1

E23_2v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y23,dmu_ref=y2);efficiencies(E23_2v)#Tec Eff for yr23 rel to F2

E23_3v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y23,dmu_ref=y3);efficiencies(E23_3v)#Tec Eff for yr23 rel to F3

E23_4v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y23,dmu_ref=y4);efficiencies(E23_4v)#Tec Eff for yr23 rel to F4

E23_5v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y23,dmu_ref=y5);efficiencies(E23_5v)#Tec Eff for yr23 rel to F5

E23_6v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y23,dmu_ref=y6);efficiencies(E23_6v)#Tec Eff for yr23 rel

to F6

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E23_7v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y23,dmu_ref=y7);efficiencies(E23_7v)#Tec Eff for yr23 rel
    to F7

E23_8v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y23,dmu_ref=y8);efficiencies(E23_8v)#Tec Eff for yr23 rel
    to F8

E23_9v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y23,dmu_ref=y9);efficiencies(E23_9v)#Tec Eff for yr23 rel
    to F9

E23_10v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y23,dmu_ref=y10);efficiencies(E23_10v)#Tec Eff for yr23
    rel to F10

E23_11v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y23,dmu_ref=y11);efficiencies(E23_11v)#Tec Eff for yr23
    rel to F11

E23_12v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y23,dmu_ref=y12);efficiencies(E23_12v)#Tec Eff for yr23
    rel to F12

E23_13v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y23,dmu_ref=y13);efficiencies(E23_13v)#Tec Eff for yr23
    rel to F13

E23_14v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y23,dmu_ref=y14);efficiencies(E23_14v)#Tec Eff for yr23
    rel to F14

E23_15v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y23,dmu_ref=y15);efficiencies(E23_15v)#Tec Eff for yr23
    rel to F15

E23_16v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y23,dmu_ref=y16);efficiencies(E23_16v)#Tec Eff for yr23
    rel to F16

E23_17v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y23,dmu_ref=y17);efficiencies(E23_17v)#Tec Eff for yr23
    rel to F17

E23_18v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y23,dmu_ref=y18);efficiencies(E23_18v)#Tec Eff for yr23
    rel to F18

E23_19v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y23,dmu_ref=y19);efficiencies(E23_19v)#Tec Eff for yr23
    rel to F19

E23_20v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y23,dmu_ref=y20);efficiencies(E23_20v)#Tec Eff for yr23
```

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rel to F20
E23_21v=model_basic(h,orientation
="io",rts="vrs",dmu_eval=y23,dmu_ref=y21);efficiencies(E23_21v)#Tec Eff for yr23
rel to F21
E23_22v=model_basic(h,orientation
="io",rts="vrs",dmu_eval=y23,dmu_ref=y22);efficiencies(E23_22v)#Tec Eff for yr23
rel to F22


writexl::write_xlsx(round(data.frame("E1_1v"=efficiencies(E1_1v),"E1_2v"=efficiencies(E1_2v),"E1_3v"=efficiencies(E1_3v),"E1_4v"=efficiencies(E1_4v),"E1_5v"=efficiencies(E1_5v),"E1_6v"=efficiencies(E1_6v),"E1_7v"=efficiencies(E1_7v),"E1_8v"=efficiencies(E1_8v),"E1_9v"=efficiencies(E1_9v),"E1_10v"=efficiencies(E1_10v),"E1_11v"=efficiencies(E1_11v),"E1_12v"=efficiencies(E1_12v),"E1_13v"=efficiencies(E1_13v),"E1_14v"=efficiencies(E1_14v),"E1_15v"=efficiencies(E1_15v),"E1_16v"=efficiencies(E1_16v),"E1_17v"=efficiencies(E1_17v),"E1_18v"=efficiencies(E1_18v),"E1_19v"=efficiencies(E1_19v),"E1_20v"=efficiencies(E1_20v),"E1_21v"=efficiencies(E1_21v),"E1_22v"=efficiencies(E1_22v),"E1_23v"=efficiencies(E1_23v)),3),path="C:/Users/DELL E7450/Documents/eff1.xlsx")
writexl::write_xlsx(round(data.frame("E2_1v"=efficiencies(E2_1v),"E2_2v"=efficiencies(E2_2v),"E2_3v"=efficiencies(E2_3v),"E2_4v"=efficiencies(E2_4v),"E2_5v"=efficiencies(E2_5v),"E2_6v"=efficiencies(E2_6v),"E2_7v"=efficiencies(E2_7v),"E2_8v"=efficiencies(E2_8v),"E2_9v"=efficiencies(E2_9v),"E2_10v"=efficiencies(E2_10v),"E2_11v"=efficiencies(E2_11v),"E2_12v"=efficiencies(E2_12v),"E2_13v"=efficiencies(E2_13v),"E2_14v"=efficiencies(E2_14v),"E2_15v"=efficiencies(E2_15v),"E2_16v"=efficiencies(E2_16v),"E2_17v"=efficiencies(E2_17v),"E2_18v"=efficiencies(E2_18v),"E2_19v"=efficiencies(E2_19v),"E2_20v"=efficiencies(E2_20v),"E2_21v"=efficiencies(E2_21v),"E2_22v"=efficiencies(E2_22v),"E2_23v"=efficiencies(E2_23v)),3),path="C:/Users/DELL E7450/Documents/eff2.xlsx")
writexl::write_xlsx(round(data.frame("E3_1v"=efficiencies(E3_1v),"E3_2v"=efficiencies(E3_2v),"E3_3v"=efficiencies(E3_3v),"E3_4v"=efficiencies(E3_4v),"E3_5v"=efficiencies(E3_5v),"E3_6v"=efficiencies(E3_6v),"E3_7v"=efficiencies(E3_7v),"E3_8v"=efficiencies(E3_8v),"E3_9v"=efficiencies(E3_9v),"E3_10v"=efficiencies(E3_10v),"E3_11v"=efficiencies(E3_11v),"E3_12v"=efficiencies(E3_12v),"E3_13v"=efficiencies(E3_13v),"E3_14v"=efficiencies(E3_14v),"E3_15v"=efficiencies(E3_15v),"E3_16v"=efficiencies(E3_16v),"E3_17v"=efficiencies(E3_17v),"E3_18v"=efficiencies(E3_18v),"E3_19v"=efficiencies(E3_19v),"E3_20v"=efficiencies(E3_20v),"E3_21v"=efficiencies(E3_21v),"E3_22v"=efficiencies(E3_22v),"E3_23v"=efficiencies(E3_23v)),3),path="C:/Users/DELL E7450/Documents/eff3.xlsx")
writexl::write_xlsx(round(data.frame("E4_1v"=efficiencies(E4_1v),"E4_2v"=efficiencies(E4_2v),"E4_3v"=efficiencies(E4_3v),"E4_4v"=efficiencies(E4_4v),"E4_5v"=efficiencies(E4_5v),"E4_6v"=efficiencies(E4_6v),"E4_7v"=efficiencies(E4_7v),"E4_8v"=efficiencies(E4_8v),"E4_9v"=efficiencies(E4_9v),"E4_10v"=efficiencies(E4_10v),"E4_11v"=efficiencies(E4_11v),"E4_12v"=efficiencies(E4_12v),"E4_13v"=efficiencies(E4_13v),"E4_14v"=efficiencies(E4_14v),"E4_15v"=efficiencies(E4_15v),"E4_16v"=efficiencies(E4_16v),"E4_17v"=efficiencies(E4_17v),"E4_18v"=efficiencies(E4_18v),"E4_19v"=efficiencies(E4_19v),"E4_20v"=efficiencies(E4_20v),"E4_21v"=efficiencies(E4_21v),"E4_22v
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"=efficiencies(E4_22v),"E4_23v"=efficiencies(E4_23v)),3),path="C:/Users/DELL E7450/Documents/eff4.xlsx")

writexl::write_xlsx(round(data.frame("E5_1v"=efficiencies(E5_1v),"E5_2v"=efficiencies(E5_2v),"E5_3v"=efficiencies(E5_3v),"E5_4v"=efficiencies(E5_4v),"E5_5v"=efficiencies(E5_5v),"E5_6v"=efficiencies(E5_6v),"E5_7v"=efficiencies(E5_7v),"E5_8v"=efficiencies(E5_8v),"E5_9v"=efficiencies(E5_9v),"E5_10v"=efficiencies(E5_10v),"E5_11v"=efficiencies(E5_11v),"E5_12v"=efficiencies(E5_12v),"E5_13v"=efficiencies(E5_13v),"E5_14v"=efficiencies(E5_14v),"E5_15v"=efficiencies(E5_15v),"E5_16v"=efficiencies(E5_16v),"E5_17v"=efficiencies(E5_17v),"E5_18v"=efficiencies(E5_18v),"E5_19v"=efficiencies(E5_19v),"E5_20v"=efficiencies(E5_20v),"E5_21v"=efficiencies(E5_21v),"E5_22v"=efficiencies(E5_22v),"E5_23v"=efficiencies(E5_23v)),3),path="C:/Users/DELL E7450/Documents/eff5.xlsx")

writexl::write_xlsx(round(data.frame("E6_1v"=efficiencies(E6_1v),"E6_2v"=efficiencies(E6_2v),"E6_3v"=efficiencies(E6_3v),"E6_4v"=efficiencies(E6_4v),"E6_5v"=efficiencies(E6_5v),"E6_6v"=efficiencies(E6_6v),"E6_7v"=efficiencies(E6_7v),"E6_8v"=efficiencies(E6_8v),"E6_9v"=efficiencies(E6_9v),"E6_10v"=efficiencies(E6_10v),"E6_11v"=efficiencies(E6_11v),"E6_12v"=efficiencies(E6_12v),"E6_13v"=efficiencies(E6_13v),"E6_14v"=efficiencies(E6_14v),"E6_15v"=efficiencies(E6_15v),"E6_16v"=efficiencies(E6_16v),"E6_17v"=efficiencies(E6_17v),"E6_18v"=efficiencies(E6_18v),"E6_19v"=efficiencies(E6_19v),"E6_20v"=efficiencies(E6_20v),"E6_21v"=efficiencies(E6_21v),"E6_22v"=efficiencies(E6_22v),"E6_23v"=efficiencies(E6_23v)),3),path="C:/Users/DELL E7450/Documents/eff6.xlsx")

writexl::write_xlsx(round(data.frame("E7_1v"=efficiencies(E7_1v),"E7_2v"=efficiencies(E7_2v),"E7_3v"=efficiencies(E7_3v),"E7_4v"=efficiencies(E7_4v),"E7_5v"=efficiencies(E7_5v),"E7_6v"=efficiencies(E7_6v),"E7_7v"=efficiencies(E7_7v),"E7_8v"=efficiencies(E7_8v),"E7_9v"=efficiencies(E7_9v),"E7_10v"=efficiencies(E7_10v),"E7_11v"=efficiencies(E7_11v),"E7_12v"=efficiencies(E7_12v),"E7_13v"=efficiencies(E7_13v),"E7_14v"=efficiencies(E7_14v),"E7_15v"=efficiencies(E7_15v),"E7_16v"=efficiencies(E7_16v),"E7_17v"=efficiencies(E7_17v),"E7_18v"=efficiencies(E7_18v),"E7_19v"=efficiencies(E7_19v),"E7_20v"=efficiencies(E7_20v),"E7_21v"=efficiencies(E7_21v),"E7_22v"=efficiencies(E7_22v),"E7_23v"=efficiencies(E7_23v)),3),path="C:/Users/DELL E7450/Documents/eff7.xlsx")

writexl::write_xlsx(round(data.frame("E8_1v"=efficiencies(E8_1v),"E8_2v"=efficiencies(E8_2v),"E8_3v"=efficiencies(E8_3v),"E8_4v"=efficiencies(E8_4v),"E8_5v"=efficiencies(E8_5v),"E8_6v"=efficiencies(E8_6v),"E8_7v"=efficiencies(E8_7v),"E8_8v"=efficiencies(E8_8v),"E8_9v"=efficiencies(E8_9v),"E8_10v"=efficiencies(E8_10v),"E8_11v"=efficiencies(E8_11v),"E8_12v"=efficiencies(E8_12v),"E8_13v"=efficiencies(E8_13v),"E8_14v"=efficiencies(E8_14v),"E8_15v"=efficiencies(E8_15v),"E8_16v"=efficiencies(E8_16v),"E8_17v"=efficiencies(E8_17v),"E8_18v"=efficiencies(E8_18v),"E8_19v"=efficiencies(E8_19v),"E8_20v"=efficiencies(E8_20v),"E8_21v"=efficiencies(E8_21v),"E8_22v"=efficiencies(E8_22v),"E8_23v"=efficiencies(E8_23v)),3),path="C:/Users/DELL E7450/Documents/eff8.xlsx")

writexl::write_xlsx(round(data.frame("E9_1v"=efficiencies(E9_1v),"E9_2v"=efficiencies(E9_2v),"E9_3v"=efficiencies(E9_3v),"E9_4v"=efficiencies(E9_4v),"E9_5v"=efficiencies(E9_5v),"E9_6v"=efficiencies(E9_6v),"E9_7v"=efficiencies(E9_7v),"E9_8v"=efficiencies(E9_8v),"E9_9v"=efficiencies(E9_9v),"E9_10v"=efficiencies(E9_10v),"E9_11v"=efficiencies(E9_11v),"E9_12v"=efficiencies(E9_12v),"E9_13v"=efficiencies(E9_13v),"E9_1

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4v"=efficiencies(E9_14v),"E9_15v"=efficiencies(E9_15v),"E9_16v"=efficiencies(E9_16v),"E9_17v"=efficiencies(E9_17v),"E9_18v"=efficiencies(E9_18v),"E9_19v"=efficiencies(E9_19v),"E9_20v"=efficiencies(E9_20v),"E9_21v"=efficiencies(E9_21v),"E9_22v"=efficiencies(E9_22v),"E9_23v"=efficiencies(E9_23v)),3),path="C:/Users/DELL E7450/Documents/eff9.xlsx")

writexl::write_xlsx(round(data.frame("E10_1v"=efficiencies(E10_1v),"E10_2v"=efficiencies(E10_2v),"E10_3v"=efficiencies(E10_3v),"E10_4v"=efficiencies(E10_4v),"E10_5v"=efficiencies(E10_5v),"E10_6v"=efficiencies(E10_6v),"E10_7v"=efficiencies(E10_7v),"E10_8v"=efficiencies(E10_8v),"E10_9v"=efficiencies(E10_9v),"E10_10v"=efficiencies(E10_10v),"E10_11v"=efficiencies(E10_11v),"E10_12v"=efficiencies(E10_12v),"E10_13v"=efficiencies(E10_13v),"E10_14v"=efficiencies(E10_14v),"E10_15v"=efficiencies(E10_15v),"E10_16v"=efficiencies(E10_16v),"E10_17v"=efficiencies(E10_17v),"E10_18v"=efficiencies(E10_18v),"E10_19v"=efficiencies(E10_19v),"E10_20v"=efficiencies(E10_20v),"E10_21v"=efficiencies(E10_21v),"E10_22v"=efficiencies(E10_22v),"E10_23v"=efficiencies(E10_23v)),3),path="C:/Users/DELL E7450/Documents/eff10.xlsx")

writexl::write_xlsx(round(data.frame("E11_1v"=efficiencies(E11_1v),"E11_2v"=efficiencies(E11_2v),"E11_3v"=efficiencies(E11_3v),"E11_4v"=efficiencies(E11_4v),"E11_5v"=efficiencies(E11_5v),"E11_6v"=efficiencies(E11_6v),"E11_7v"=efficiencies(E11_7v),"E11_8v"=efficiencies(E11_8v),"E11_9v"=efficiencies(E11_9v),"E11_10v"=efficiencies(E11_10v),"E11_11v"=efficiencies(E11_11v),"E11_12v"=efficiencies(E11_12v),"E11_13v"=efficiencies(E11_13v),"E11_14v"=efficiencies(E11_14v),"E11_15v"=efficiencies(E11_15v),"E11_16v"=efficiencies(E11_16v),"E11_17v"=efficiencies(E11_17v),"E11_18v"=efficiencies(E11_18v),"E11_19v"=efficiencies(E11_19v),"E11_20v"=efficiencies(E11_20v),"E11_21v"=efficiencies(E11_21v),"E11_22v"=efficiencies(E11_22v),"E11_23v"=efficiencies(E11_23v)),3),path="C:/Users/DELL E7450/Documents/eff11.xlsx")

writexl::write_xlsx(round(data.frame("E12_1v"=efficiencies(E12_1v),"E12_2v"=efficiencies(E12_2v),"E12_3v"=efficiencies(E12_3v),"E12_4v"=efficiencies(E12_4v),"E12_5v"=efficiencies(E12_5v),"E12_6v"=efficiencies(E12_6v),"E12_7v"=efficiencies(E12_7v),"E12_8v"=efficiencies(E12_8v),"E12_9v"=efficiencies(E12_9v),"E12_10v"=efficiencies(E12_10v),"E12_11v"=efficiencies(E12_11v),"E12_12v"=efficiencies(E12_12v),"E12_13v"=efficiencies(E12_13v),"E12_14v"=efficiencies(E12_14v),"E12_15v"=efficiencies(E12_15v),"E12_16v"=efficiencies(E12_16v),"E12_17v"=efficiencies(E12_17v),"E12_18v"=efficiencies(E12_18v),"E12_19v"=efficiencies(E12_19v),"E12_20v"=efficiencies(E12_20v),"E12_21v"=efficiencies(E12_21v),"E12_22v"=efficiencies(E12_22v),"E12_23v"=efficiencies(E12_23v)),3),path="C:/Users/DELL E7450/Documents/eff12.xlsx")

writexl::write_xlsx(round(data.frame("E13_1v"=efficiencies(E13_1v),"E13_2v"=efficiencies(E13_2v),"E13_3v"=efficiencies(E13_3v),"E13_4v"=efficiencies(E13_4v),"E13_5v"=efficiencies(E13_5v),"E13_6v"=efficiencies(E13_6v),"E13_7v"=efficiencies(E13_7v),"E13_8v"=efficiencies(E13_8v),"E13_9v"=efficiencies(E13_9v),"E13_10v"=efficiencies(E13_10v),"E13_11v"=efficiencies(E13_11v),"E13_12v"=efficiencies(E13_12v),"E13_13v"=efficiencies(E13_13v),"E13_14v"=efficiencies(E13_14v),"E13_15v"=efficiencies(E13_15v),"E13_16v"=efficiencies(E13_16v),"E13_17v"=efficiencies(E13_17v),"E13_18v"=efficiencies(E13_18v),"E13_19v"=efficiencies(E13_19v),"E13_20v"=efficiencies(E13_20v),"E13_21v"=efficiencies(E13_21v),"E13_22v"=efficiencies(E13_22v),"E13_23v"=efficiencies(E13_23v)),3),path="C:/Users/DELL E7450/Documents/eff13.xlsx")

writexl::write_xlsx(round(data.frame("E14_1v"=efficiencies(E14_1v),"E14_2v"=efficiencies(E14_2v),"E14_3v"=efficiencies(E14_3v),"E14_4v"=efficiencies(E14_4v),"E14_5v"=ef
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ficiencies(E14_5v),"E14_6v"=efficiencies(E14_6v),"E14_7v"=efficiencies(E14_7v),"E1
4_8v"=efficiencies(E14_8v),"E14_9v"=efficiencies(E14_9v),"E14_10v"=efficiencies(E
14_10v),"E14_11v"=efficiencies(E14_11v),"E14_12v"=efficiencies(E14_12v),"E14_13
v"=efficiencies(E14_13v),"E14_14v"=efficiencies(E14_14v),"E14_15v"=efficiencies(E
14_15v),"E14_16v"=efficiencies(E14_16v),"E14_17v"=efficiencies(E14_17v),"E14_18
v"=efficiencies(E14_18v),"E14_19v"=efficiencies(E14_19v),"E14_20v"=efficiencies(E
14_20v),"E14_21v"=efficiencies(E14_21v),"E14_22v"=efficiencies(E14_22v),"E14_23
v"=efficiencies(E14_23v)),3),path="C:/Users/DELL E7450/Documents/eff14.xlsx")

writexl::write_xlsx(round(data.frame("E15_1v"=efficiencies(E15_1v),"E15_2v"=efficiencies
(E15_2v),"E15_3v"=efficiencies(E15_3v),"E15_4v"=efficiencies(E15_4v),"E15_5v"=ef
ficiencies(E15_5v),"E15_6v"=efficiencies(E15_6v),"E15_7v"=efficiencies(E15_7v),"E1
5_8v"=efficiencies(E15_8v),"E15_9v"=efficiencies(E15_9v),"E15_10v"=efficiencies(E
15_10v),"E15_11v"=efficiencies(E15_11v),"E15_12v"=efficiencies(E15_12v),"E15_13
v"=efficiencies(E15_13v),"E15_14v"=efficiencies(E15_14v),"E15_15v"=efficiencies(E
15_15v),"E15_16v"=efficiencies(E15_16v),"E15_17v"=efficiencies(E15_17v),"E15_18
v"=efficiencies(E15_18v),"E15_19v"=efficiencies(E15_19v),"E15_20v"=efficiencies(E
15_20v),"E15_21v"=efficiencies(E15_21v),"E15_22v"=efficiencies(E15_22v),"E15_23
v"=efficiencies(E15_23v)),3),path="C:/Users/DELL E7450/Documents/eff15.xlsx")

writexl::write_xlsx(round(data.frame("E16_1v"=efficiencies(E16_1v),"E16_2v"=efficiencies
(E16_2v),"E16_3v"=efficiencies(E16_3v),"E16_4v"=efficiencies(E16_4v),"E16_5v"=ef
ficiencies(E16_5v),"E16_6v"=efficiencies(E16_6v),"E16_7v"=efficiencies(E16_7v),"E1
6_8v"=efficiencies(E16_8v),"E16_9v"=efficiencies(E16_9v),"E16_10v"=efficiencies(E
16_10v),"E16_11v"=efficiencies(E16_11v),"E16_12v"=efficiencies(E16_12v),"E16_13
v"=efficiencies(E16_13v),"E16_14v"=efficiencies(E16_14v),"E16_15v"=efficiencies(E
16_15v),"E16_16v"=efficiencies(E16_16v),"E16_17v"=efficiencies(E16_17v),"E16_18
v"=efficiencies(E16_18v),"E16_19v"=efficiencies(E16_19v),"E16_20v"=efficiencies(E
16_20v),"E16_21v"=efficiencies(E16_21v),"E16_22v"=efficiencies(E16_22v),"E16_23
v"=efficiencies(E16_23v)),3),path="C:/Users/DELL E7450/Documents/eff16.xlsx")

writexl::write_xlsx(round(data.frame("E17_1v"=efficiencies(E17_1v),"E17_2v"=efficiencies
(E17_2v),"E17_3v"=efficiencies(E17_3v),"E17_4v"=efficiencies(E17_4v),"E17_5v"=ef
ficiencies(E17_5v),"E17_6v"=efficiencies(E17_6v),"E17_7v"=efficiencies(E17_7v),"E1
7_8v"=efficiencies(E17_8v),"E17_9v"=efficiencies(E17_9v),"E17_10v"=efficiencies(E
17_10v),"E17_11v"=efficiencies(E17_11v),"E17_12v"=efficiencies(E17_12v),"E17_13
v"=efficiencies(E17_13v),"E17_14v"=efficiencies(E17_14v),"E17_15v"=efficiencies(E
17_15v),"E17_16v"=efficiencies(E17_16v),"E17_17v"=efficiencies(E17_17v),"E17_18
v"=efficiencies(E17_18v),"E17_19v"=efficiencies(E17_19v),"E17_20v"=efficiencies(E
17_20v),"E17_21v"=efficiencies(E17_21v),"E17_22v"=efficiencies(E17_22v),"E17_23
v"=efficiencies(E17_23v)),3),path="C:/Users/DELL E7450/Documents/eff17.xlsx")

writexl::write_xlsx(round(data.frame("E18_1v"=efficiencies(E18_1v),"E18_2v"=efficiencies
(E18_2v),"E18_3v"=efficiencies(E18_3v),"E18_4v"=efficiencies(E18_4v),"E18_5v"=ef
ficiencies(E18_5v),"E18_6v"=efficiencies(E18_6v),"E18_7v"=efficiencies(E18_7v),"E1
8_8v"=efficiencies(E18_8v),"E18_9v"=efficiencies(E18_9v),"E18_10v"=efficiencies(E
18_10v),"E18_11v"=efficiencies(E18_11v),"E18_12v"=efficiencies(E18_12v),"E18_13
v"=efficiencies(E18_13v),"E18_14v"=efficiencies(E18_14v),"E18_15v"=efficiencies(E
18_15v),"E18_16v"=efficiencies(E18_16v),"E18_17v"=efficiencies(E18_17v),"E18_18
v"=efficiencies(E18_18v),"E18_19v"=efficiencies(E18_19v),"E18_20v"=efficiencies(E
18_20v),"E18_21v"=efficiencies(E18_21v),"E18_22v"=efficiencies(E18_22v),"E18_23
v"=efficiencies(E18_23v)),3),path="C:/Users/DELL E7450/Documents/eff18.xlsx")
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writexl::write_xlsx(round(data.frame("E19_1v"=efficiencies(E19_1v),"E19_2v"=efficiencies(E19_2v),"E19_3v"=efficiencies(E19_3v),"E19_4v"=efficiencies(E19_4v),"E19_5v"=efficiencies(E19_5v),"E19_6v"=efficiencies(E19_6v),"E19_7v"=efficiencies(E19_7v),"E19_8v"=efficiencies(E19_8v),"E19_9v"=efficiencies(E19_9v),"E19_10v"=efficiencies(E19_10v),"E19_11v"=efficiencies(E19_11v),"E19_12v"=efficiencies(E19_12v),"E19_13v"=efficiencies(E19_13v),"E19_14v"=efficiencies(E19_14v),"E19_15v"=efficiencies(E19_15v),"E19_16v"=efficiencies(E19_16v),"E19_17v"=efficiencies(E19_17v),"E19_18v"=efficiencies(E19_18v),"E19_19v"=efficiencies(E19_19v),"E19_20v"=efficiencies(E19_20v),"E19_21v"=efficiencies(E19_21v),"E19_22v"=efficiencies(E19_22v),"E19_23v"=efficiencies(E19_23v)),3),path="C:/Users/DELL E7450/Documents/eff19.xlsx")

writexl::write_xlsx(round(data.frame("E20_1v"=efficiencies(E20_1v),"E20_2v"=efficiencies(E20_2v),"E20_3v"=efficiencies(E20_3v),"E20_4v"=efficiencies(E20_4v),"E20_5v"=efficiencies(E20_5v),"E20_6v"=efficiencies(E20_6v),"E20_7v"=efficiencies(E20_7v),"E20_8v"=efficiencies(E20_8v),"E20_9v"=efficiencies(E20_9v),"E20_10v"=efficiencies(E20_10v),"E20_11v"=efficiencies(E20_11v),"E20_12v"=efficiencies(E20_12v),"E20_13v"=efficiencies(E20_13v),"E20_14v"=efficiencies(E20_14v),"E20_15v"=efficiencies(E20_15v),"E20_16v"=efficiencies(E20_16v),"E20_17v"=efficiencies(E20_17v),"E20_18v"=efficiencies(E20_18v),"E20_19v"=efficiencies(E20_19v),"E20_20v"=efficiencies(E20_20v),"E20_21v"=efficiencies(E20_21v),"E20_22v"=efficiencies(E20_22v),"E20_23v"=efficiencies(E20_23v)),3),path="C:/Users/DELL E7450/Documents/eff20.xlsx")

writexl::write_xlsx(round(data.frame("E21_1v"=efficiencies(E21_1v),"E21_2v"=efficiencies(E21_2v),"E21_3v"=efficiencies(E21_3v),"E21_4v"=efficiencies(E21_4v),"E21_5v"=efficiencies(E21_5v),"E21_6v"=efficiencies(E21_6v),"E21_7v"=efficiencies(E21_7v),"E21_8v"=efficiencies(E21_8v),"E21_9v"=efficiencies(E21_9v),"E21_10v"=efficiencies(E21_10v),"E21_11v"=efficiencies(E21_11v),"E21_12v"=efficiencies(E21_12v),"E21_13v"=efficiencies(E21_13v),"E21_14v"=efficiencies(E21_14v),"E21_15v"=efficiencies(E21_15v),"E21_16v"=efficiencies(E21_16v),"E21_17v"=efficiencies(E21_17v),"E21_18v"=efficiencies(E21_18v),"E21_19v"=efficiencies(E21_19v),"E21_20v"=efficiencies(E21_20v),"E21_21v"=efficiencies(E21_21v),"E21_22v"=efficiencies(E21_22v),"E21_23v"=efficiencies(E21_23v)),3),path="C:/Users/DELL E7450/Documents/eff21.xlsx")

writexl::write_xlsx(round(data.frame("E22_1v"=efficiencies(E22_1v),"E22_2v"=efficiencies(E22_2v),"E22_3v"=efficiencies(E22_3v),"E22_4v"=efficiencies(E22_4v),"E22_5v"=efficiencies(E22_5v),"E22_6v"=efficiencies(E22_6v),"E22_7v"=efficiencies(E22_7v),"E22_8v"=efficiencies(E22_8v),"E22_9v"=efficiencies(E22_9v),"E22_10v"=efficiencies(E22_10v),"E22_11v"=efficiencies(E22_11v),"E22_12v"=efficiencies(E22_12v),"E22_13v"=efficiencies(E22_13v),"E22_14v"=efficiencies(E22_14v),"E22_15v"=efficiencies(E22_15v),"E22_16v"=efficiencies(E22_16v),"E22_17v"=efficiencies(E22_17v),"E22_18v"=efficiencies(E22_18v),"E22_19v"=efficiencies(E22_19v),"E22_20v"=efficiencies(E22_20v),"E22_21v"=efficiencies(E22_21v),"E22_22v"=efficiencies(E22_22v),"E22_23v"=efficiencies(E22_23v)),3),path="C:/Users/DELL E7450/Documents/eff22.xlsx")

writexl::write_xlsx(round(data.frame("E23_1v"=efficiencies(E23_1v),"E23_2v"=efficiencies(E23_2v),"E23_3v"=efficiencies(E23_3v),"E23_4v"=efficiencies(E23_4v),"E23_5v"=efficiencies(E23_5v),"E23_6v"=efficiencies(E23_6v),"E23_7v"=efficiencies(E23_7v),"E23_8v"=efficiencies(E23_8v),"E23_9v"=efficiencies(E23_9v),"E23_10v"=efficiencies(E23_10v),"E23_11v"=efficiencies(E23_11v),"E23_12v"=efficiencies(E23_12v),"E23_13v"=efficiencies(E23_13v),"E23_14v"=efficiencies(E23_14v),"E23_15v"=efficiencies(E23_15v),"E23_16v"=efficiencies(E23_16v),"E23_17v"=efficiencies(E23_17v),"E23_18v"=efficiencies(E23_18v),"E23_19v"=efficiencies(E23_19v),"E23_20v"=efficiencies(E
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23_20v),"E23_21v"=efficiencies(E23_21v),"E23_22v"=efficiencies(E23_22v),"E23_23v"=efficiencies(E23_23v)),3),path="C:/Users/DELL E7450/Documents/eff23.xlsx")

#CALCULATING COST EFFICIENCY

#Fare at al (1985)

#Own Period VRS

C1_1v=model_profit(h,price_input=t(hd[y1,7:9]),rts="vrs",dmu_eval=y1,dmu_ref=y1,restricted_optimal = FALSE);efficiencies(C1_1v)#Cost Eff for yr1 rel to F1 #input_prices=t(hd[y1,5:6])

C2_2v=model_profit(h,price_input=t(hd[y2,7:9]),rts="vrs",dmu_eval=y2,dmu_ref=y2,restricted_optimal = FALSE);efficiencies(C2_2v)#Cost Eff for yr2 rel to F2

C3_3v=model_profit(h,price_input=t(hd[y3,7:9]),rts="vrs",dmu_eval=y3,dmu_ref=y3,restricted_optimal = FALSE);efficiencies(C3_3v)#Cost Eff for yr3 rel to F3

C4_4v=model_profit(h,price_input=t(hd[y4,7:9]),rts="vrs",dmu_eval=y4,dmu_ref=y4,restricted_optimal = FALSE);efficiencies(C4_4v)#Cost Eff for yr4 rel to F4

C5_5v=model_profit(h,price_input=t(hd[y5,7:9]),rts="vrs",dmu_eval=y5,dmu_ref=y5,restricted_optimal = FALSE);efficiencies(C5_5v)

C6_6v=model_profit(h,price_input=t(hd[y6,7:9]),rts="vrs",dmu_eval=y6,dmu_ref=y6,restricted_optimal = FALSE);efficiencies(C6_6v)

C7_7v=model_profit(h,price_input=t(hd[y7,7:9]),rts="vrs",dmu_eval=y7,dmu_ref=y7,restricted_optimal = FALSE);efficiencies(C7_7v)

C8_8v=model_profit(h,price_input=t(hd[y8,7:9]),rts="vrs",dmu_eval=y8,dmu_ref=y8,restricted_optimal = FALSE);efficiencies(C8_8v)

C9_9v=model_profit(h,price_input=t(hd[y9,7:9]),rts="vrs",dmu_eval=y9,dmu_ref=y9,restricted_optimal = FALSE);efficiencies(C9_9v)

C10_10v=model_profit(h,price_input=t(hd[y10,7:9]),rts="vrs",dmu_eval=y10,dmu_ref=y10,restricted_optimal = FALSE);efficiencies(C10_10v)

C11_11v=model_profit(h,price_input=t(hd[y11,7:9]),rts="vrs",dmu_eval=y11,dmu_ref=y11,restricted_optimal = FALSE);efficiencies(C11_11v)

C12_12v=model_profit(h,price_input=t(hd[y12,7:9]),rts="vrs",dmu_eval=y12,dmu_ref=y12,restricted_optimal = FALSE);efficiencies(C12_12v)

C13_13v=model_profit(h,price_input=t(hd[y13,7:9]),rts="vrs",dmu_eval=y13,dmu_ref=y13,restricted_optimal = FALSE);efficiencies(C13_13v)

C14_14v=model_profit(h,price_input=t(hd[y14,7:9]),rts="vrs",dmu_eval=y14,dmu_ref=y14,restricted_optimal = FALSE);efficiencies(C14_14v)

C15_15v=model_profit(h,price_input=t(hd[y15,7:9]),rts="vrs",dmu_eval=y15,dmu_ref=y15,restricted_optimal = FALSE);efficiencies(C15_15v)

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C16_16v=model_profit(h,price_input=t(hd[y16,7:9]),rts="vrs",dmu_eval=y16,dmu_ref=y16,
    restricted_optimal = FALSE);efficiencies(C16_16v)
C17_17v=model_profit(h,price_input=t(hd[y17,7:9]),rts="vrs",dmu_eval=y17,dmu_ref=y17,
    restricted_optimal = FALSE);efficiencies(C17_17v)
C18_18v=model_profit(h,price_input=t(hd[y18,7:9]),rts="vrs",dmu_eval=y18,dmu_ref=y18,
    restricted_optimal = FALSE);efficiencies(C18_18v)
C19_19v=model_profit(h,price_input=t(hd[y19,7:9]),rts="vrs",dmu_eval=y19,dmu_ref=y19,
    restricted_optimal = FALSE);efficiencies(C19_19v)
C20_20v=model_profit(h,price_input=t(hd[y20,7:9]),rts="vrs",dmu_eval=y20,dmu_ref=y20,
    restricted_optimal = FALSE);efficiencies(C20_20v)
C21_21v=model_profit(h,price_input=t(hd[y21,7:9]),rts="vrs",dmu_eval=y21,dmu_ref=y21,
    restricted_optimal = FALSE);efficiencies(C21_21v)
C22_22v=model_profit(h,price_input=t(hd[y22,7:9]),rts="vrs",dmu_eval=y22,dmu_ref=y22,
    restricted_optimal = FALSE);efficiencies(C22_22v)
C23_23v=model_profit(h,price_input=t(hd[y23,7:9]),rts="vrs",dmu_eval=y23,dmu_ref=y23,
    restricted_optimal = FALSE);efficiencies(C23_23v)

#Cross Period VRS
C1_2v=model_profit(h,price_input=t(hd[y1,7:9]),rts="vrs",dmu_eval=y1,dmu_ref=y2,restric
    ted_optimal = FALSE);efficiencies(C1_2v)#Cost Eff for yr1 rel to F2
C1_3v=model_profit(h,price_input=t(hd[y1,7:9]),rts="vrs",dmu_eval=y1,dmu_ref=y3,restric
    ted_optimal = FALSE);efficiencies(C1_3v)#Cost Eff for yr1 rel to F3
C1_4v=model_profit(h,price_input=t(hd[y1,7:9]),rts="vrs",dmu_eval=y1,dmu_ref=y4,restric
    ted_optimal = FALSE);efficiencies(C1_4v)#Cost Eff for yr1 rel to F4
C1_5v=model_profit(h,price_input=t(hd[y1,7:9]),rts="vrs",dmu_eval=y1,dmu_ref=y5,restric
    ted_optimal = FALSE);efficiencies(C1_5v)
C1_6v=model_profit(h,price_input=t(hd[y1,7:9]),rts="vrs",dmu_eval=y1,dmu_ref=y6,restric
    ted_optimal = FALSE);efficiencies(C1_6v)
C1_7v=model_profit(h,price_input=t(hd[y1,7:9]),rts="vrs",dmu_eval=y1,dmu_ref=y7,restric
    ted_optimal = FALSE);efficiencies(C1_7v)
C1_8v=model_profit(h,price_input=t(hd[y1,7:9]),rts="vrs",dmu_eval=y1,dmu_ref=y8,restric
    ted_optimal = FALSE);efficiencies(C1_8v)
C1_9v=model_profit(h,price_input=t(hd[y1,7:9]),rts="vrs",dmu_eval=y1,dmu_ref=y9,restric
    ted_optimal = FALSE);efficiencies(C1_9v)
C1_10v=model_profit(h,price_input=t(hd[y1,7:9]),rts="vrs",dmu_eval=y1,dmu_ref=y10,rest
    ricted_optimal = FALSE);efficiencies(C1_10v)
C1_11v=model_profit(h,price_input=t(hd[y1,7:9]),rts="vrs",dmu_eval=y1,dmu_ref=y11,restr
    icted_optimal = FALSE);efficiencies(C1_11v)
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C1_12v=model_profit(h,price_input=t(hd[y1,7:9]),rts="vrs",dmu_eval=y1,dmu_ref=y12,restricted_optimal = FALSE);efficiencies(C1_12v)

C1_13v=model_profit(h,price_input=t(hd[y1,7:9]),rts="vrs",dmu_eval=y1,dmu_ref=y13,restricted_optimal = FALSE);efficiencies(C1_13v)

C1_14v=model_profit(h,price_input=t(hd[y1,7:9]),rts="vrs",dmu_eval=y1,dmu_ref=y14,restricted_optimal = FALSE);efficiencies(C1_14v)

C1_15v=model_profit(h,price_input=t(hd[y1,7:9]),rts="vrs",dmu_eval=y1,dmu_ref=y15,restricted_optimal = FALSE);efficiencies(C1_15v)

C1_16v=model_profit(h,price_input=t(hd[y1,7:9]),rts="vrs",dmu_eval=y1,dmu_ref=y16,restricted_optimal = FALSE);efficiencies(C1_16v)

C1_17v=model_profit(h,price_input=t(hd[y1,7:9]),rts="vrs",dmu_eval=y1,dmu_ref=y17,restricted_optimal = FALSE);efficiencies(C1_17v)

C1_18v=model_profit(h,price_input=t(hd[y1,7:9]),rts="vrs",dmu_eval=y1,dmu_ref=y18,restricted_optimal = FALSE);efficiencies(C1_18v)

C1_19v=model_profit(h,price_input=t(hd[y1,7:9]),rts="vrs",dmu_eval=y1,dmu_ref=y19,restricted_optimal = FALSE);efficiencies(C1_19v)

C1_20v=model_profit(h,price_input=t(hd[y1,7:9]),rts="vrs",dmu_eval=y1,dmu_ref=y20,restricted_optimal = FALSE);efficiencies(C1_20v)

C1_21v=model_profit(h,price_input=t(hd[y1,7:9]),rts="vrs",dmu_eval=y1,dmu_ref=y21,restricted_optimal = FALSE);efficiencies(C1_21v)

C1_22v=model_profit(h,price_input=t(hd[y1,7:9]),rts="vrs",dmu_eval=y1,dmu_ref=y22,restricted_optimal = FALSE);efficiencies(C1_22v)

C1_23v=model_profit(h,price_input=t(hd[y1,7:9]),rts="vrs",dmu_eval=y1,dmu_ref=y23,restricted_optimal = FALSE);efficiencies(C1_23v)


C2_1v=model_profit(h,price_input=t(hd[y2,7:9]),rts="vrs",dmu_eval=y2,dmu_ref=y1,restricted_optimal = FALSE);efficiencies(C2_1v)#Cost Eff for yr2 rel to F1

C2_3v=model_profit(h,price_input=t(hd[y2,7:9]),rts="vrs",dmu_eval=y2,dmu_ref=y3,restricted_optimal = FALSE);efficiencies(C2_3v)#Cost Eff for yr2 rel to F3

C2_4v=model_profit(h,price_input=t(hd[y2,7:9]),rts="vrs",dmu_eval=y2,dmu_ref=y4,restricted_optimal = FALSE);efficiencies(C2_4v)#Cost Eff for yr2 rel to F4

C2_5v=model_profit(h,price_input=t(hd[y2,7:9]),rts="vrs",dmu_eval=y2,dmu_ref=y5,restricted_optimal = FALSE);efficiencies(C2_5v)

C2_6v=model_profit(h,price_input=t(hd[y2,7:9]),rts="vrs",dmu_eval=y2,dmu_ref=y6,restricted_optimal = FALSE);efficiencies(C2_6v)

C2_7v=model_profit(h,price_input=t(hd[y2,7:9]),rts="vrs",dmu_eval=y2,dmu_ref=y7,restricted_optimal = FALSE);efficiencies(C2_7v)

C2_8v=model_profit(h,price_input=t(hd[y2,7:9]),rts="vrs",dmu_eval=y2,dmu_ref=y8,restricted_optimal = FALSE);efficiencies(C2_8v)
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C2_9v=model_profit(h,price_input=t(hd[y2,7:9]),rts="vrs",dmu_eval=y2,dmu_ref=y9,restricted_optimal = FALSE);efficiencies(C2_9v)
C2_10v=model_profit(h,price_input=t(hd[y2,7:9]),rts="vrs",dmu_eval=y2,dmu_ref=y10,restricted_optimal = FALSE);efficiencies(C2_10v)
C2_11v=model_profit(h,price_input=t(hd[y2,7:9]),rts="vrs",dmu_eval=y2,dmu_ref=y11,restricted_optimal = FALSE);efficiencies(C2_11v)
C2_12v=model_profit(h,price_input=t(hd[y2,7:9]),rts="vrs",dmu_eval=y2,dmu_ref=y12,restricted_optimal = FALSE);efficiencies(C2_12v)
C2_13v=model_profit(h,price_input=t(hd[y2,7:9]),rts="vrs",dmu_eval=y2,dmu_ref=y13,restricted_optimal = FALSE);efficiencies(C2_13v)
C2_14v=model_profit(h,price_input=t(hd[y2,7:9]),rts="vrs",dmu_eval=y2,dmu_ref=y14,restricted_optimal = FALSE);efficiencies(C2_14v)
C2_15v=model_profit(h,price_input=t(hd[y2,7:9]),rts="vrs",dmu_eval=y2,dmu_ref=y15,restricted_optimal = FALSE);efficiencies(C2_15v)
C2_16v=model_profit(h,price_input=t(hd[y2,7:9]),rts="vrs",dmu_eval=y2,dmu_ref=y16,restricted_optimal = FALSE);efficiencies(C2_16v)
C2_17v=model_profit(h,price_input=t(hd[y2,7:9]),rts="vrs",dmu_eval=y2,dmu_ref=y17,restricted_optimal = FALSE);efficiencies(C2_17v)
C2_18v=model_profit(h,price_input=t(hd[y2,7:9]),rts="vrs",dmu_eval=y2,dmu_ref=y18,restricted_optimal = FALSE);efficiencies(C2_18v)
C2_19v=model_profit(h,price_input=t(hd[y2,7:9]),rts="vrs",dmu_eval=y2,dmu_ref=y19,restricted_optimal = FALSE);efficiencies(C2_19v)
C2_20v=model_profit(h,price_input=t(hd[y2,7:9]),rts="vrs",dmu_eval=y2,dmu_ref=y20,restricted_optimal = FALSE);efficiencies(C2_20v)
C2_21v=model_profit(h,price_input=t(hd[y2,7:9]),rts="vrs",dmu_eval=y2,dmu_ref=y21,restricted_optimal = FALSE);efficiencies(C2_21v)
C2_22v=model_profit(h,price_input=t(hd[y2,7:9]),rts="vrs",dmu_eval=y2,dmu_ref=y22,restricted_optimal = FALSE);efficiencies(C2_22v)
C2_23v=model_profit(h,price_input=t(hd[y2,7:9]),rts="vrs",dmu_eval=y2,dmu_ref=y23,restricted_optimal = FALSE);efficiencies(C2_23v)

C3_1v=model_profit(h,price_input=t(hd[y3,7:9]),rts="vrs",dmu_eval=y3,dmu_ref=y1,restricted_optimal = FALSE);efficiencies(C3_1v)#Cost Eff for yr3 rel to F1
C3_2v=model_profit(h,price_input=t(hd[y3,7:9]),rts="vrs",dmu_eval=y3,dmu_ref=y2,restricted_optimal = FALSE);efficiencies(C3_2v)#Cost Eff for yr3 rel to F2
C3_4v=model_profit(h,price_input=t(hd[y3,7:9]),rts="vrs",dmu_eval=y3,dmu_ref=y4,restricted_optimal = FALSE);efficiencies(C3_4v)#Cost Eff for yr3 rel to F4
C3_5v=model_profit(h,price_input=t(hd[y3,7:9]),rts="vrs",dmu_eval=y3,dmu_ref=y5,restricted_optimal = FALSE);efficiencies(C3_5v)
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C3_6v=model_profit(h,price_input=t(hd[y3,7:9]),rts="vrs",dmu_eval=y3,dmu_ref=y6,restricted_optimal = FALSE);efficiencies(C3_6v)

C3_7v=model_profit(h,price_input=t(hd[y3,7:9]),rts="vrs",dmu_eval=y3,dmu_ref=y7,restricted_optimal = FALSE);efficiencies(C3_7v)

C3_8v=model_profit(h,price_input=t(hd[y3,7:9]),rts="vrs",dmu_eval=y3,dmu_ref=y8,restricted_optimal = FALSE);efficiencies(C3_8v)

C3_9v=model_profit(h,price_input=t(hd[y3,7:9]),rts="vrs",dmu_eval=y3,dmu_ref=y9,restricted_optimal = FALSE);efficiencies(C3_9v)

C3_10v=model_profit(h,price_input=t(hd[y3,7:9]),rts="vrs",dmu_eval=y3,dmu_ref=y10,restricted_optimal = FALSE);efficiencies(C3_10v)

C3_11v=model_profit(h,price_input=t(hd[y3,7:9]),rts="vrs",dmu_eval=y3,dmu_ref=y11,restricted_optimal = FALSE);efficiencies(C3_11v)

C3_12v=model_profit(h,price_input=t(hd[y3,7:9]),rts="vrs",dmu_eval=y3,dmu_ref=y12,restricted_optimal = FALSE);efficiencies(C3_12v)

C3_13v=model_profit(h,price_input=t(hd[y3,7:9]),rts="vrs",dmu_eval=y3,dmu_ref=y13,restricted_optimal = FALSE);efficiencies(C3_13v)

C3_14v=model_profit(h,price_input=t(hd[y3,7:9]),rts="vrs",dmu_eval=y3,dmu_ref=y14,restricted_optimal = FALSE);efficiencies(C3_14v)

C3_15v=model_profit(h,price_input=t(hd[y3,7:9]),rts="vrs",dmu_eval=y3,dmu_ref=y15,restricted_optimal = FALSE);efficiencies(C3_15v)

C3_16v=model_profit(h,price_input=t(hd[y3,7:9]),rts="vrs",dmu_eval=y3,dmu_ref=y16,restricted_optimal = FALSE);efficiencies(C3_16v)

C3_17v=model_profit(h,price_input=t(hd[y3,7:9]),rts="vrs",dmu_eval=y3,dmu_ref=y17,restricted_optimal = FALSE);efficiencies(C3_17v)

C3_18v=model_profit(h,price_input=t(hd[y3,7:9]),rts="vrs",dmu_eval=y3,dmu_ref=y18,restricted_optimal = FALSE);efficiencies(C3_18v)

C3_19v=model_profit(h,price_input=t(hd[y3,7:9]),rts="vrs",dmu_eval=y3,dmu_ref=y19,restricted_optimal = FALSE);efficiencies(C3_19v)

C3_20v=model_profit(h,price_input=t(hd[y3,7:9]),rts="vrs",dmu_eval=y3,dmu_ref=y20,restricted_optimal = FALSE);efficiencies(C3_20v)

C3_21v=model_profit(h,price_input=t(hd[y3,7:9]),rts="vrs",dmu_eval=y3,dmu_ref=y21,restricted_optimal = FALSE);efficiencies(C3_21v)

C3_22v=model_profit(h,price_input=t(hd[y3,7:9]),rts="vrs",dmu_eval=y3,dmu_ref=y22,restricted_optimal = FALSE);efficiencies(C3_22v)

C3_23v=model_profit(h,price_input=t(hd[y3,7:9]),rts="vrs",dmu_eval=y3,dmu_ref=y23,restricted_optimal = FALSE);efficiencies(C3_23v)

C4_1v=model_profit(h,price_input=t(hd[y4,7:9]),rts="vrs",dmu_eval=y4,dmu_ref=y1,restricted_optimal = FALSE);efficiencies(C4_1v)#Cost Eff for yr4 rel to F1

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C4_2v=model_profit(h,price_input=t(hd[y4,7:9]),rts="vrs",dmu_eval=y4,dmu_ref=y2,restricted_optimal = FALSE);efficiencies(C4_2v)#Cost Eff for yr4 rel to F2
C4_3v=model_profit(h,price_input=t(hd[y4,7:9]),rts="vrs",dmu_eval=y4,dmu_ref=y3,restricted_optimal = FALSE);efficiencies(C4_3v)#Cost Eff for yr4 rel to F3
C4_5v=model_profit(h,price_input=t(hd[y4,7:9]),rts="vrs",dmu_eval=y4,dmu_ref=y5,restricted_optimal = FALSE);efficiencies(C4_5v)
C4_6v=model_profit(h,price_input=t(hd[y4,7:9]),rts="vrs",dmu_eval=y4,dmu_ref=y6,restricted_optimal = FALSE);efficiencies(C4_6v)
C4_7v=model_profit(h,price_input=t(hd[y4,7:9]),rts="vrs",dmu_eval=y4,dmu_ref=y7,restricted_optimal = FALSE);efficiencies(C4_7v)
C4_8v=model_profit(h,price_input=t(hd[y4,7:9]),rts="vrs",dmu_eval=y4,dmu_ref=y8,restricted_optimal = FALSE);efficiencies(C4_8v)
C4_9v=model_profit(h,price_input=t(hd[y4,7:9]),rts="vrs",dmu_eval=y4,dmu_ref=y9,restricted_optimal = FALSE);efficiencies(C4_9v)
C4_10v=model_profit(h,price_input=t(hd[y4,7:9]),rts="vrs",dmu_eval=y4,dmu_ref=y10,restricted_optimal = FALSE);efficiencies(C4_10v)
C4_11v=model_profit(h,price_input=t(hd[y4,7:9]),rts="vrs",dmu_eval=y4,dmu_ref=y11,restricted_optimal = FALSE);efficiencies(C4_11v)
C4_12v=model_profit(h,price_input=t(hd[y4,7:9]),rts="vrs",dmu_eval=y4,dmu_ref=y12,restricted_optimal = FALSE);efficiencies(C4_12v)
C4_13v=model_profit(h,price_input=t(hd[y4,7:9]),rts="vrs",dmu_eval=y4,dmu_ref=y13,restricted_optimal = FALSE);efficiencies(C4_13v)
C4_14v=model_profit(h,price_input=t(hd[y4,7:9]),rts="vrs",dmu_eval=y4,dmu_ref=y14,restricted_optimal = FALSE);efficiencies(C4_14v)
C4_15v=model_profit(h,price_input=t(hd[y4,7:9]),rts="vrs",dmu_eval=y4,dmu_ref=y15,restricted_optimal = FALSE);efficiencies(C4_15v)
C4_16v=model_profit(h,price_input=t(hd[y4,7:9]),rts="vrs",dmu_eval=y4,dmu_ref=y16,restricted_optimal = FALSE);efficiencies(C4_16v)
C4_17v=model_profit(h,price_input=t(hd[y4,7:9]),rts="vrs",dmu_eval=y4,dmu_ref=y17,restricted_optimal = FALSE);efficiencies(C4_17v)
C4_18v=model_profit(h,price_input=t(hd[y4,7:9]),rts="vrs",dmu_eval=y4,dmu_ref=y18,restricted_optimal = FALSE);efficiencies(C4_18v)
C4_19v=model_profit(h,price_input=t(hd[y4,7:9]),rts="vrs",dmu_eval=y4,dmu_ref=y19,restricted_optimal = FALSE);efficiencies(C4_19v)
C4_20v=model_profit(h,price_input=t(hd[y4,7:9]),rts="vrs",dmu_eval=y4,dmu_ref=y20,restricted_optimal = FALSE);efficiencies(C4_20v)
C4_21v=model_profit(h,price_input=t(hd[y4,7:9]),rts="vrs",dmu_eval=y4,dmu_ref=y21,restricted_optimal = FALSE);efficiencies(C4_21v)
C4_22v=model_profit(h,price_input=t(hd[y4,7:9]),rts="vrs",dmu_eval=y4,dmu_ref=y22,rest
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ricted_optimal = FALSE);efficiencies(C4_22v)

C4_23v=model_profit(h,price_input=t(hd[y4,7:9]),rts="vrs",dmu_eval=y4,dmu_ref=y23,restricted_optimal = FALSE);efficiencies(C4_23v)

C5_1v=model_profit(h,price_input=t(hd[y5,7:9]),rts="vrs",dmu_eval=y5,dmu_ref=y1,restricted_optimal = FALSE);efficiencies(C5_1v)#Cost Eff for yr5 rel to F1

C5_2v=model_profit(h,price_input=t(hd[y5,7:9]),rts="vrs",dmu_eval=y5,dmu_ref=y2,restricted_optimal = FALSE);efficiencies(C5_2v)

C5_3v=model_profit(h,price_input=t(hd[y5,7:9]),rts="vrs",dmu_eval=y5,dmu_ref=y3,restricted_optimal = FALSE);efficiencies(C5_3v)

C5_4v=model_profit(h,price_input=t(hd[y5,7:9]),rts="vrs",dmu_eval=y5,dmu_ref=y4,restricted_optimal = FALSE);efficiencies(C5_4v)

C5_6v=model_profit(h,price_input=t(hd[y5,7:9]),rts="vrs",dmu_eval=y5,dmu_ref=y6,restricted_optimal = FALSE);efficiencies(C5_6v)

C5_7v=model_profit(h,price_input=t(hd[y5,7:9]),rts="vrs",dmu_eval=y5,dmu_ref=y7,restricted_optimal = FALSE);efficiencies(C5_7v)

C5_8v=model_profit(h,price_input=t(hd[y5,7:9]),rts="vrs",dmu_eval=y5,dmu_ref=y8,restricted_optimal = FALSE);efficiencies(C5_8v)

C5_9v=model_profit(h,price_input=t(hd[y5,7:9]),rts="vrs",dmu_eval=y5,dmu_ref=y9,restricted_optimal = FALSE);efficiencies(C5_9v)

C5_10v=model_profit(h,price_input=t(hd[y5,7:9]),rts="vrs",dmu_eval=y5,dmu_ref=y10,restricted_optimal = FALSE);efficiencies(C5_10v)

C5_11v=model_profit(h,price_input=t(hd[y5,7:9]),rts="vrs",dmu_eval=y5,dmu_ref=y11,restricted_optimal = FALSE);efficiencies(C5_11v)

C5_12v=model_profit(h,price_input=t(hd[y5,7:9]),rts="vrs",dmu_eval=y5,dmu_ref=y12,restricted_optimal = FALSE);efficiencies(C5_12v)

C5_13v=model_profit(h,price_input=t(hd[y5,7:9]),rts="vrs",dmu_eval=y5,dmu_ref=y13,restricted_optimal = FALSE);efficiencies(C5_13v)

C5_14v=model_profit(h,price_input=t(hd[y5,7:9]),rts="vrs",dmu_eval=y5,dmu_ref=y14,restricted_optimal = FALSE);efficiencies(C5_14v)

C5_15v=model_profit(h,price_input=t(hd[y5,7:9]),rts="vrs",dmu_eval=y5,dmu_ref=y15,restricted_optimal = FALSE);efficiencies(C5_15v)

C5_16v=model_profit(h,price_input=t(hd[y5,7:9]),rts="vrs",dmu_eval=y5,dmu_ref=y16,restricted_optimal = FALSE);efficiencies(C5_16v)

C5_17v=model_profit(h,price_input=t(hd[y5,7:9]),rts="vrs",dmu_eval=y5,dmu_ref=y17,restricted_optimal = FALSE);efficiencies(C5_17v)

C5_18v=model_profit(h,price_input=t(hd[y5,7:9]),rts="vrs",dmu_eval=y5,dmu_ref=y18,restricted_optimal = FALSE);efficiencies(C5_18v)

C5_19v=model_profit(h,price_input=t(hd[y5,7:9]),rts="vrs",dmu_eval=y5,dmu_ref=y19,restricted_optimal = FALSE);efficiencies(C5_19v)

C5_20v=model_profit(h,price_input=t(hd[y5,7:9]),rts="vrs",dmu_eval=y5,dmu_ref=y20,restricted_optimal = FALSE);efficiencies(C5_20v)

C5_21v=model_profit(h,price_input=t(hd[y5,7:9]),rts="vrs",dmu_eval=y5,dmu_ref=y21,restricted_optimal = FALSE);efficiencies(C5_21v)

C5_22v=model_profit(h,price_input=t(hd[y5,7:9]),rts="vrs",dmu_eval=y5,dmu_ref=y22,restricted_optimal = FALSE);efficiencies(C5_22v)

C5_23v=model_profit(h,price_input=t(hd[y5,7:9]),rts="vrs",dmu_eval=y5,dmu_ref=y23,restricted_optimal = FALSE);efficiencies(C5_23v)

C6_1v=model_profit(h,price_input=t(hd[y6,7:9]),rts="vrs",dmu_eval=y6,dmu_ref=y1,restricted_optimal = FALSE);efficiencies(C6_1v)#Cost Eff for yr6 rel to F1

C6_2v=model_profit(h,price_input=t(hd[y6,7:9]),rts="vrs",dmu_eval=y6,dmu_ref=y2,restricted_optimal = FALSE);efficiencies(C6_2v)

C6_3v=model_profit(h,price_input=t(hd[y6,7:9]),rts="vrs",dmu_eval=y6,dmu_ref=y3,restricted_optimal = FALSE);efficiencies(C6_3v)

C6_4v=model_profit(h,price_input=t(hd[y6,7:9]),rts="vrs",dmu_eval=y6,dmu_ref=y4,restricted_optimal = FALSE);efficiencies(C6_4v)

C6_5v=model_profit(h,price_input=t(hd[y6,7:9]),rts="vrs",dmu_eval=y6,dmu_ref=y5,restricted_optimal = FALSE);efficiencies(C6_5v)

C6_7v=model_profit(h,price_input=t(hd[y6,7:9]),rts="vrs",dmu_eval=y6,dmu_ref=y7,restricted_optimal = FALSE);efficiencies(C6_7v)

C6_8v=model_profit(h,price_input=t(hd[y6,7:9]),rts="vrs",dmu_eval=y6,dmu_ref=y8,restricted_optimal = FALSE);efficiencies(C6_8v)

C6_9v=model_profit(h,price_input=t(hd[y6,7:9]),rts="vrs",dmu_eval=y6,dmu_ref=y9,restricted_optimal = FALSE);efficiencies(C6_9v)

C6_10v=model_profit(h,price_input=t(hd[y6,7:9]),rts="vrs",dmu_eval=y6,dmu_ref=y10,restricted_optimal = FALSE);efficiencies(C6_10v)

C6_11v=model_profit(h,price_input=t(hd[y6,7:9]),rts="vrs",dmu_eval=y6,dmu_ref=y11,restricted_optimal = FALSE);efficiencies(C6_11v)

C6_12v=model_profit(h,price_input=t(hd[y6,7:9]),rts="vrs",dmu_eval=y6,dmu_ref=y12,restricted_optimal = FALSE);efficiencies(C6_12v)

C6_13v=model_profit(h,price_input=t(hd[y6,7:9]),rts="vrs",dmu_eval=y6,dmu_ref=y13,restricted_optimal = FALSE);efficiencies(C6_13v)

C6_14v=model_profit(h,price_input=t(hd[y6,7:9]),rts="vrs",dmu_eval=y6,dmu_ref=y14,restricted_optimal = FALSE);efficiencies(C6_14v)

C6_15v=model_profit(h,price_input=t(hd[y6,7:9]),rts="vrs",dmu_eval=y6,dmu_ref=y15,restricted_optimal = FALSE);efficiencies(C6_15v)

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C6_16v=model_profit(h,price_input=t(hd[y6,7:9]),rts="vrs",dmu_eval=y6,dmu_ref=y16,restricted_optimal = FALSE);efficiencies(C6_16v)

C6_17v=model_profit(h,price_input=t(hd[y6,7:9]),rts="vrs",dmu_eval=y6,dmu_ref=y17,restricted_optimal = FALSE);efficiencies(C6_17v)

C6_18v=model_profit(h,price_input=t(hd[y6,7:9]),rts="vrs",dmu_eval=y6,dmu_ref=y18,restricted_optimal = FALSE);efficiencies(C6_18v)

C6_19v=model_profit(h,price_input=t(hd[y6,7:9]),rts="vrs",dmu_eval=y6,dmu_ref=y19,restricted_optimal = FALSE);efficiencies(C6_19v)

C6_20v=model_profit(h,price_input=t(hd[y6,7:9]),rts="vrs",dmu_eval=y6,dmu_ref=y20,restricted_optimal = FALSE);efficiencies(C6_20v)

C6_21v=model_profit(h,price_input=t(hd[y6,7:9]),rts="vrs",dmu_eval=y6,dmu_ref=y21,restricted_optimal = FALSE);efficiencies(C6_21v)

C6_22v=model_profit(h,price_input=t(hd[y6,7:9]),rts="vrs",dmu_eval=y6,dmu_ref=y22,restricted_optimal = FALSE);efficiencies(C6_22v)

C6_23v=model_profit(h,price_input=t(hd[y6,7:9]),rts="vrs",dmu_eval=y6,dmu_ref=y23,restricted_optimal = FALSE);efficiencies(C6_23v)


C7_1v=model_profit(h,price_input=t(hd[y7,7:9]),rts="vrs",dmu_eval=y7,dmu_ref=y1,restricted_optimal = FALSE);efficiencies(C7_1v)#Cost Eff for yr7 rel to F1

C7_2v=model_profit(h,price_input=t(hd[y7,7:9]),rts="vrs",dmu_eval=y7,dmu_ref=y2,restricted_optimal = FALSE);efficiencies(C7_2v)

C7_3v=model_profit(h,price_input=t(hd[y7,7:9]),rts="vrs",dmu_eval=y7,dmu_ref=y3,restricted_optimal = FALSE);efficiencies(C7_3v)

C7_4v=model_profit(h,price_input=t(hd[y7,7:9]),rts="vrs",dmu_eval=y7,dmu_ref=y4,restricted_optimal = FALSE);efficiencies(C7_4v)

C7_5v=model_profit(h,price_input=t(hd[y7,7:9]),rts="vrs",dmu_eval=y7,dmu_ref=y5,restricted_optimal = FALSE);efficiencies(C7_5v)

C7_6v=model_profit(h,price_input=t(hd[y7,7:9]),rts="vrs",dmu_eval=y7,dmu_ref=y6,restricted_optimal = FALSE);efficiencies(C7_6v)

C7_8v=model_profit(h,price_input=t(hd[y7,7:9]),rts="vrs",dmu_eval=y7,dmu_ref=y8,restricted_optimal = FALSE);efficiencies(C7_8v)

C7_9v=model_profit(h,price_input=t(hd[y7,7:9]),rts="vrs",dmu_eval=y7,dmu_ref=y9,restricted_optimal = FALSE);efficiencies(C7_9v)

C7_10v=model_profit(h,price_input=t(hd[y7,7:9]),rts="vrs",dmu_eval=y7,dmu_ref=y10,restricted_optimal = FALSE);efficiencies(C7_10v)

C7_11v=model_profit(h,price_input=t(hd[y7,7:9]),rts="vrs",dmu_eval=y7,dmu_ref=y11,restricted_optimal = FALSE);efficiencies(C7_11v)

C7_12v=model_profit(h,price_input=t(hd[y7,7:9]),rts="vrs",dmu_eval=y7,dmu_ref=y12,restricted_optimal = FALSE);efficiencies(C7_12v)
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C7_13v=model_profit(h,price_input=t(hd[y7,7:9]),rts="vrs",dmu_eval=y7,dmu_ref=y13,restricted_optimal = FALSE);efficiencies(C7_13v)

C7_14v=model_profit(h,price_input=t(hd[y7,7:9]),rts="vrs",dmu_eval=y7,dmu_ref=y14,restricted_optimal = FALSE);efficiencies(C7_14v)

C7_15v=model_profit(h,price_input=t(hd[y7,7:9]),rts="vrs",dmu_eval=y7,dmu_ref=y15,restricted_optimal = FALSE);efficiencies(C7_15v)

C7_16v=model_profit(h,price_input=t(hd[y7,7:9]),rts="vrs",dmu_eval=y7,dmu_ref=y16,restricted_optimal = FALSE);efficiencies(C7_16v)

C7_17v=model_profit(h,price_input=t(hd[y7,7:9]),rts="vrs",dmu_eval=y7,dmu_ref=y17,restricted_optimal = FALSE);efficiencies(C7_17v)

C7_18v=model_profit(h,price_input=t(hd[y7,7:9]),rts="vrs",dmu_eval=y7,dmu_ref=y18,restricted_optimal = FALSE);efficiencies(C7_18v)

C7_19v=model_profit(h,price_input=t(hd[y7,7:9]),rts="vrs",dmu_eval=y7,dmu_ref=y19,restricted_optimal = FALSE);efficiencies(C7_19v)

C7_20v=model_profit(h,price_input=t(hd[y7,7:9]),rts="vrs",dmu_eval=y7,dmu_ref=y20,restricted_optimal = FALSE);efficiencies(C7_20v)

C7_21v=model_profit(h,price_input=t(hd[y7,7:9]),rts="vrs",dmu_eval=y7,dmu_ref=y21,restricted_optimal = FALSE);efficiencies(C7_21v)

C7_22v=model_profit(h,price_input=t(hd[y7,7:9]),rts="vrs",dmu_eval=y7,dmu_ref=y22,restricted_optimal = FALSE);efficiencies(C7_22v)

C7_23v=model_profit(h,price_input=t(hd[y7,7:9]),rts="vrs",dmu_eval=y7,dmu_ref=y23,restricted_optimal = FALSE);efficiencies(C7_23v)

C8_1v=model_profit(h,price_input=t(hd[y8,7:9]),rts="vrs",dmu_eval=y8,dmu_ref=y1,restricted_optimal = FALSE);efficiencies(C8_1v)#Cost Eff for yr8 rel to F1

C8_2v=model_profit(h,price_input=t(hd[y8,7:9]),rts="vrs",dmu_eval=y8,dmu_ref=y2,restricted_optimal = FALSE);efficiencies(C8_2v)

C8_3v=model_profit(h,price_input=t(hd[y8,7:9]),rts="vrs",dmu_eval=y8,dmu_ref=y3,restricted_optimal = FALSE);efficiencies(C8_3v)

C8_4v=model_profit(h,price_input=t(hd[y8,7:9]),rts="vrs",dmu_eval=y8,dmu_ref=y4,restricted_optimal = FALSE);efficiencies(C8_4v)

C8_5v=model_profit(h,price_input=t(hd[y8,7:9]),rts="vrs",dmu_eval=y8,dmu_ref=y5,restricted_optimal = FALSE);efficiencies(C8_5v)

C8_6v=model_profit(h,price_input=t(hd[y8,7:9]),rts="vrs",dmu_eval=y8,dmu_ref=y6,restricted_optimal = FALSE);efficiencies(C8_6v)

C8_7v=model_profit(h,price_input=t(hd[y8,7:9]),rts="vrs",dmu_eval=y8,dmu_ref=y7,restricted_optimal = FALSE);efficiencies(C8_7v)

C8_9v=model_profit(h,price_input=t(hd[y8,7:9]),rts="vrs",dmu_eval=y8,dmu_ref=y9,restricted_optimal = FALSE);efficiencies(C8_9v)

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C8_10v=model_profit(h,price_input=t(hd[y8,7:9]),rts="vrs",dmu_eval=y8,dmu_ref=y10,restricted_optimal = FALSE);efficiencies(C8_10v)

C8_11v=model_profit(h,price_input=t(hd[y8,7:9]),rts="vrs",dmu_eval=y8,dmu_ref=y11,restricted_optimal = FALSE);efficiencies(C8_11v)

C8_12v=model_profit(h,price_input=t(hd[y8,7:9]),rts="vrs",dmu_eval=y8,dmu_ref=y12,restricted_optimal = FALSE);efficiencies(C8_12v)

C8_13v=model_profit(h,price_input=t(hd[y8,7:9]),rts="vrs",dmu_eval=y8,dmu_ref=y13,restricted_optimal = FALSE);efficiencies(C8_13v)

C8_14v=model_profit(h,price_input=t(hd[y8,7:9]),rts="vrs",dmu_eval=y8,dmu_ref=y14,restricted_optimal = FALSE);efficiencies(C8_14v)

C8_15v=model_profit(h,price_input=t(hd[y8,7:9]),rts="vrs",dmu_eval=y8,dmu_ref=y15,restricted_optimal = FALSE);efficiencies(C8_15v)

C8_16v=model_profit(h,price_input=t(hd[y8,7:9]),rts="vrs",dmu_eval=y8,dmu_ref=y16,restricted_optimal = FALSE);efficiencies(C8_16v)

C8_17v=model_profit(h,price_input=t(hd[y8,7:9]),rts="vrs",dmu_eval=y8,dmu_ref=y17,restricted_optimal = FALSE);efficiencies(C8_17v)

C8_18v=model_profit(h,price_input=t(hd[y8,7:9]),rts="vrs",dmu_eval=y8,dmu_ref=y18,restricted_optimal = FALSE);efficiencies(C8_18v)

C8_19v=model_profit(h,price_input=t(hd[y8,7:9]),rts="vrs",dmu_eval=y8,dmu_ref=y19,restricted_optimal = FALSE);efficiencies(C8_19v)

C8_20v=model_profit(h,price_input=t(hd[y8,7:9]),rts="vrs",dmu_eval=y8,dmu_ref=y20,restricted_optimal = FALSE);efficiencies(C8_20v)

C8_21v=model_profit(h,price_input=t(hd[y8,7:9]),rts="vrs",dmu_eval=y8,dmu_ref=y21,restricted_optimal = FALSE);efficiencies(C8_21v)

C8_22v=model_profit(h,price_input=t(hd[y8,7:9]),rts="vrs",dmu_eval=y8,dmu_ref=y22,restricted_optimal = FALSE);efficiencies(C8_22v)

C8_23v=model_profit(h,price_input=t(hd[y8,7:9]),rts="vrs",dmu_eval=y8,dmu_ref=y23,restricted_optimal = FALSE);efficiencies(C8_23v)


C9_1v=model_profit(h,price_input=t(hd[y9,7:9]),rts="vrs",dmu_eval=y9,dmu_ref=y1,restricted_optimal = FALSE);efficiencies(C9_1v)#Cost Eff for yr9 rel to F1

C9_2v=model_profit(h,price_input=t(hd[y9,7:9]),rts="vrs",dmu_eval=y9,dmu_ref=y2,restricted_optimal = FALSE);efficiencies(C9_2v)

C9_3v=model_profit(h,price_input=t(hd[y9,7:9]),rts="vrs",dmu_eval=y9,dmu_ref=y3,restricted_optimal = FALSE);efficiencies(C9_3v)

C9_4v=model_profit(h,price_input=t(hd[y9,7:9]),rts="vrs",dmu_eval=y9,dmu_ref=y4,restricted_optimal = FALSE);efficiencies(C9_4v)

C9_5v=model_profit(h,price_input=t(hd[y9,7:9]),rts="vrs",dmu_eval=y9,dmu_ref=y5,restricted_optimal = FALSE);efficiencies(C9_5v)
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C9_6v=model_profit(h,price_input=t(hd[y9,7:9]),rts="vrs",dmu_eval=y9,dmu_ref=y6,restricted_optimal = FALSE);efficiencies(C9_6v)

C9_7v=model_profit(h,price_input=t(hd[y9,7:9]),rts="vrs",dmu_eval=y9,dmu_ref=y7,restricted_optimal = FALSE);efficiencies(C9_7v)

C9_8v=model_profit(h,price_input=t(hd[y9,7:9]),rts="vrs",dmu_eval=y9,dmu_ref=y8,restricted_optimal = FALSE);efficiencies(C9_8v)

C9_10v=model_profit(h,price_input=t(hd[y9,7:9]),rts="vrs",dmu_eval=y9,dmu_ref=y10,restricted_optimal = FALSE);efficiencies(C9_10v)

C9_11v=model_profit(h,price_input=t(hd[y9,7:9]),rts="vrs",dmu_eval=y9,dmu_ref=y11,restricted_optimal = FALSE);efficiencies(C9_11v)

C9_12v=model_profit(h,price_input=t(hd[y9,7:9]),rts="vrs",dmu_eval=y9,dmu_ref=y12,restricted_optimal = FALSE);efficiencies(C9_12v)

C9_13v=model_profit(h,price_input=t(hd[y9,7:9]),rts="vrs",dmu_eval=y9,dmu_ref=y13,restricted_optimal = FALSE);efficiencies(C9_13v)

C9_14v=model_profit(h,price_input=t(hd[y9,7:9]),rts="vrs",dmu_eval=y9,dmu_ref=y14,restricted_optimal = FALSE);efficiencies(C9_14v)

C9_15v=model_profit(h,price_input=t(hd[y9,7:9]),rts="vrs",dmu_eval=y9,dmu_ref=y15,restricted_optimal = FALSE);efficiencies(C9_15v)

C9_16v=model_profit(h,price_input=t(hd[y9,7:9]),rts="vrs",dmu_eval=y9,dmu_ref=y16,restricted_optimal = FALSE);efficiencies(C9_16v)

C9_17v=model_profit(h,price_input=t(hd[y9,7:9]),rts="vrs",dmu_eval=y9,dmu_ref=y17,restricted_optimal = FALSE);efficiencies(C9_17v)

C9_18v=model_profit(h,price_input=t(hd[y9,7:9]),rts="vrs",dmu_eval=y9,dmu_ref=y18,restricted_optimal = FALSE);efficiencies(C9_18v)

C9_19v=model_profit(h,price_input=t(hd[y9,7:9]),rts="vrs",dmu_eval=y9,dmu_ref=y19,restricted_optimal = FALSE);efficiencies(C9_19v)

C9_20v=model_profit(h,price_input=t(hd[y9,7:9]),rts="vrs",dmu_eval=y9,dmu_ref=y20,restricted_optimal = FALSE);efficiencies(C9_20v)

C9_21v=model_profit(h,price_input=t(hd[y9,7:9]),rts="vrs",dmu_eval=y9,dmu_ref=y21,restricted_optimal = FALSE);efficiencies(C9_21v)

C9_22v=model_profit(h,price_input=t(hd[y9,7:9]),rts="vrs",dmu_eval=y9,dmu_ref=y22,restricted_optimal = FALSE);efficiencies(C9_22v)

C9_23v=model_profit(h,price_input=t(hd[y9,7:9]),rts="vrs",dmu_eval=y9,dmu_ref=y23,restricted_optimal = FALSE);efficiencies(C9_23v)

C10_1v=model_profit(h,price_input=t(hd[y10,7:9]),rts="vrs",dmu_eval=y10,dmu_ref=y1,restricted_optimal = FALSE);efficiencies(C10_1v)#Cost Eff for yr10 rel to F1

C10_2v=model_profit(h,price_input=t(hd[y10,7:9]),rts="vrs",dmu_eval=y10,dmu_ref=y2,restricted_optimal = FALSE);efficiencies(C10_2v)

C10_3v=model_profit(h,price_input=t(hd[y10,7:9]),rts="vrs",dmu_eval=y10,dmu_ref=y3,restricted_optimal = FALSE);efficiencies(C10_3v)

C10_4v=model_profit(h,price_input=t(hd[y10,7:9]),rts="vrs",dmu_eval=y10,dmu_ref=y4,restricted_optimal = FALSE);efficiencies(C10_4v)

C10_5v=model_profit(h,price_input=t(hd[y10,7:9]),rts="vrs",dmu_eval=y10,dmu_ref=y5,restricted_optimal = FALSE);efficiencies(C10_5v)

C10_6v=model_profit(h,price_input=t(hd[y10,7:9]),rts="vrs",dmu_eval=y10,dmu_ref=y6,restricted_optimal = FALSE);efficiencies(C10_6v)

C10_7v=model_profit(h,price_input=t(hd[y10,7:9]),rts="vrs",dmu_eval=y10,dmu_ref=y7,restricted_optimal = FALSE);efficiencies(C10_7v)

C10_8v=model_profit(h,price_input=t(hd[y10,7:9]),rts="vrs",dmu_eval=y10,dmu_ref=y8,restricted_optimal = FALSE);efficiencies(C10_8v)

C10_9v=model_profit(h,price_input=t(hd[y10,7:9]),rts="vrs",dmu_eval=y10,dmu_ref=y9,restricted_optimal = FALSE);efficiencies(C10_9v)

C10_11v=model_profit(h,price_input=t(hd[y10,7:9]),rts="vrs",dmu_eval=y10,dmu_ref=y11, restricted_optimal = FALSE);efficiencies(C10_11v)

C10_12v=model_profit(h,price_input=t(hd[y10,7:9]),rts="vrs",dmu_eval=y10,dmu_ref=y12, restricted_optimal = FALSE);efficiencies(C10_12v)

C10_13v=model_profit(h,price_input=t(hd[y10,7:9]),rts="vrs",dmu_eval=y10,dmu_ref=y13, restricted_optimal = FALSE);efficiencies(C10_13v)

C10_14v=model_profit(h,price_input=t(hd[y10,7:9]),rts="vrs",dmu_eval=y10,dmu_ref=y14, restricted_optimal = FALSE);efficiencies(C10_14v)

C10_15v=model_profit(h,price_input=t(hd[y10,7:9]),rts="vrs",dmu_eval=y10,dmu_ref=y15, restricted_optimal = FALSE);efficiencies(C10_15v)

C10_16v=model_profit(h,price_input=t(hd[y10,7:9]),rts="vrs",dmu_eval=y10,dmu_ref=y16, restricted_optimal = FALSE);efficiencies(C10_16v)

C10_17v=model_profit(h,price_input=t(hd[y10,7:9]),rts="vrs",dmu_eval=y10,dmu_ref=y17, restricted_optimal = FALSE);efficiencies(C10_17v)

C10_18v=model_profit(h,price_input=t(hd[y10,7:9]),rts="vrs",dmu_eval=y10,dmu_ref=y18, restricted_optimal = FALSE);efficiencies(C10_18v)

C10_19v=model_profit(h,price_input=t(hd[y10,7:9]),rts="vrs",dmu_eval=y10,dmu_ref=y19, restricted_optimal = FALSE);efficiencies(C10_19v)

C10_20v=model_profit(h,price_input=t(hd[y10,7:9]),rts="vrs",dmu_eval=y10,dmu_ref=y20, restricted_optimal = FALSE);efficiencies(C10_20v)

C10_21v=model_profit(h,price_input=t(hd[y10,7:9]),rts="vrs",dmu_eval=y10,dmu_ref=y21, restricted_optimal = FALSE);efficiencies(C10_21v)

C10_22v=model_profit(h,price_input=t(hd[y10,7:9]),rts="vrs",dmu_eval=y10,dmu_ref=y22, restricted_optimal = FALSE);efficiencies(C10_22v)

C10_23v=model_profit(h,price_input=t(hd[y10,7:9]),rts="vrs",dmu_eval=y10,dmu_ref=y23,

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restricted_optimal = FALSE);efficiencies(C10_23v)

C11_1v=model_profit(h,price_input=t(hd[y11,7:9]),rts="vrs",dmu_eval=y11,dmu_ref=y1,res
    tricted_optimal = FALSE);efficiencies(C11_1v)#Cost Eff for yr11 rel to F1
C11_2v=model_profit(h,price_input=t(hd[y11,7:9]),rts="vrs",dmu_eval=y11,dmu_ref=y2,res
    tricted_optimal = FALSE);efficiencies(C11_2v)
C11_3v=model_profit(h,price_input=t(hd[y11,7:9]),rts="vrs",dmu_eval=y11,dmu_ref=y3,res
    tricted_optimal = FALSE);efficiencies(C11_3v)
C11_4v=model_profit(h,price_input=t(hd[y11,7:9]),rts="vrs",dmu_eval=y11,dmu_ref=y4,res
    tricted_optimal = FALSE);efficiencies(C11_4v)
C11_5v=model_profit(h,price_input=t(hd[y11,7:9]),rts="vrs",dmu_eval=y11,dmu_ref=y5,res
    tricted_optimal = FALSE);efficiencies(C11_5v)
C11_6v=model_profit(h,price_input=t(hd[y11,7:9]),rts="vrs",dmu_eval=y11,dmu_ref=y6,res
    tricted_optimal = FALSE);efficiencies(C11_6v)
C11_7v=model_profit(h,price_input=t(hd[y11,7:9]),rts="vrs",dmu_eval=y11,dmu_ref=y7,res
    tricted_optimal = FALSE);efficiencies(C11_7v)
C11_8v=model_profit(h,price_input=t(hd[y11,7:9]),rts="vrs",dmu_eval=y11,dmu_ref=y8,res
    tricted_optimal = FALSE);efficiencies(C11_8v)
C11_9v=model_profit(h,price_input=t(hd[y11,7:9]),rts="vrs",dmu_eval=y11,dmu_ref=y9,res
    tricted_optimal = FALSE);efficiencies(C11_9v)
C11_10v=model_profit(h,price_input=t(hd[y11,7:9]),rts="vrs",dmu_eval=y11,dmu_ref=y10,r
    estricted_optimal = FALSE);efficiencies(C11_10v)
C11_12v=model_profit(h,price_input=t(hd[y11,7:9]),rts="vrs",dmu_eval=y11,dmu_ref=y12,r
    estricted_optimal = FALSE);efficiencies(C11_12v)
C11_13v=model_profit(h,price_input=t(hd[y11,7:9]),rts="vrs",dmu_eval=y11,dmu_ref=y13,r
    estricted_optimal = FALSE);efficiencies(C11_13v)
C11_14v=model_profit(h,price_input=t(hd[y11,7:9]),rts="vrs",dmu_eval=y11,dmu_ref=y14,r
    estricted_optimal = FALSE);efficiencies(C11_14v)
C11_15v=model_profit(h,price_input=t(hd[y11,7:9]),rts="vrs",dmu_eval=y11,dmu_ref=y15,r
    estricted_optimal = FALSE);efficiencies(C11_15v)
C11_16v=model_profit(h,price_input=t(hd[y11,7:9]),rts="vrs",dmu_eval=y11,dmu_ref=y16,r
    estricted_optimal = FALSE);efficiencies(C11_16v)
C11_17v=model_profit(h,price_input=t(hd[y11,7:9]),rts="vrs",dmu_eval=y11,dmu_ref=y17,r
    estricted_optimal = FALSE);efficiencies(C11_17v)
C11_18v=model_profit(h,price_input=t(hd[y11,7:9]),rts="vrs",dmu_eval=y11,dmu_ref=y18,r
    estricted_optimal = FALSE);efficiencies(C11_18v)
C11_19v=model_profit(h,price_input=t(hd[y11,7:9]),rts="vrs",dmu_eval=y11,dmu_ref=y19,r
    estricted_optimal = FALSE);efficiencies(C11_19v)
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C11_20v=model_profit(h,price_input=t(hd[y11,7:9]),rts="vrs",dmu_eval=y11,dmu_ref=y20,restricted_optimal = FALSE);efficiencies(C11_20v)
C11_21v=model_profit(h,price_input=t(hd[y11,7:9]),rts="vrs",dmu_eval=y11,dmu_ref=y21,restricted_optimal = FALSE);efficiencies(C11_21v)
C11_22v=model_profit(h,price_input=t(hd[y11,7:9]),rts="vrs",dmu_eval=y11,dmu_ref=y22,restricted_optimal = FALSE);efficiencies(C11_22v)
C11_23v=model_profit(h,price_input=t(hd[y11,7:9]),rts="vrs",dmu_eval=y11,dmu_ref=y23,restricted_optimal = FALSE);efficiencies(C11_23v)

C12_1v=model_profit(h,price_input=t(hd[y12,7:9]),rts="vrs",dmu_eval=y12,dmu_ref=y1,restricted_optimal = FALSE);efficiencies(C12_1v)#Cost Eff for yr12 rel to F1
C12_2v=model_profit(h,price_input=t(hd[y12,7:9]),rts="vrs",dmu_eval=y12,dmu_ref=y2,restricted_optimal = FALSE);efficiencies(C12_2v)
C12_3v=model_profit(h,price_input=t(hd[y12,7:9]),rts="vrs",dmu_eval=y12,dmu_ref=y3,restricted_optimal = FALSE);efficiencies(C12_3v)
C12_4v=model_profit(h,price_input=t(hd[y12,7:9]),rts="vrs",dmu_eval=y12,dmu_ref=y4,restricted_optimal = FALSE);efficiencies(C12_4v)
C12_5v=model_profit(h,price_input=t(hd[y12,7:9]),rts="vrs",dmu_eval=y12,dmu_ref=y5,restricted_optimal = FALSE);efficiencies(C12_5v)
C12_6v=model_profit(h,price_input=t(hd[y12,7:9]),rts="vrs",dmu_eval=y12,dmu_ref=y6,restricted_optimal = FALSE);efficiencies(C12_6v)
C12_7v=model_profit(h,price_input=t(hd[y12,7:9]),rts="vrs",dmu_eval=y12,dmu_ref=y7,restricted_optimal = FALSE);efficiencies(C12_7v)
C12_8v=model_profit(h,price_input=t(hd[y12,7:9]),rts="vrs",dmu_eval=y12,dmu_ref=y8,restricted_optimal = FALSE);efficiencies(C12_8v)
C12_9v=model_profit(h,price_input=t(hd[y12,7:9]),rts="vrs",dmu_eval=y12,dmu_ref=y9,restricted_optimal = FALSE);efficiencies(C12_9v)
C12_10v=model_profit(h,price_input=t(hd[y12,7:9]),rts="vrs",dmu_eval=y12,dmu_ref=y10,restricted_optimal = FALSE);efficiencies(C12_10v)
C12_11v=model_profit(h,price_input=t(hd[y12,7:9]),rts="vrs",dmu_eval=y12,dmu_ref=y11,restricted_optimal = FALSE);efficiencies(C12_11v)
C12_13v=model_profit(h,price_input=t(hd[y12,7:9]),rts="vrs",dmu_eval=y12,dmu_ref=y13,restricted_optimal = FALSE);efficiencies(C12_13v)
C12_14v=model_profit(h,price_input=t(hd[y12,7:9]),rts="vrs",dmu_eval=y12,dmu_ref=y14,restricted_optimal = FALSE);efficiencies(C12_14v)
C12_15v=model_profit(h,price_input=t(hd[y12,7:9]),rts="vrs",dmu_eval=y12,dmu_ref=y15,restricted_optimal = FALSE);efficiencies(C12_15v)
C12_16v=model_profit(h,price_input=t(hd[y12,7:9]),rts="vrs",dmu_eval=y12,dmu_ref=y16,restricted_optimal = FALSE);efficiencies(C12_16v)
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C12_17v=model_profit(h,price_input=t(hd[y12,7:9]),rts="vrs",dmu_eval=y12,dmu_ref=y17, restricted_optimal = FALSE);efficiencies(C12_17v)

C12_18v=model_profit(h,price_input=t(hd[y12,7:9]),rts="vrs",dmu_eval=y12,dmu_ref=y18, restricted_optimal = FALSE);efficiencies(C12_18v)

C12_19v=model_profit(h,price_input=t(hd[y12,7:9]),rts="vrs",dmu_eval=y12,dmu_ref=y19, restricted_optimal = FALSE);efficiencies(C12_19v)

C12_20v=model_profit(h,price_input=t(hd[y12,7:9]),rts="vrs",dmu_eval=y12,dmu_ref=y20, restricted_optimal = FALSE);efficiencies(C12_20v)

C12_21v=model_profit(h,price_input=t(hd[y12,7:9]),rts="vrs",dmu_eval=y12,dmu_ref=y21, restricted_optimal = FALSE);efficiencies(C12_21v)

C12_22v=model_profit(h,price_input=t(hd[y12,7:9]),rts="vrs",dmu_eval=y12,dmu_ref=y22, restricted_optimal = FALSE);efficiencies(C12_22v)

C12_23v=model_profit(h,price_input=t(hd[y12,7:9]),rts="vrs",dmu_eval=y12,dmu_ref=y23, restricted_optimal = FALSE);efficiencies(C12_23v)

C13_1v=model_profit(h,price_input=t(hd[y13,7:9]),rts="vrs",dmu_eval=y13,dmu_ref=y1,restricted_optimal = FALSE);efficiencies(C13_1v)#Cost Eff for yr13 rel to F1

C13_2v=model_profit(h,price_input=t(hd[y13,7:9]),rts="vrs",dmu_eval=y13,dmu_ref=y2,restricted_optimal = FALSE);efficiencies(C13_2v)

C13_3v=model_profit(h,price_input=t(hd[y13,7:9]),rts="vrs",dmu_eval=y13,dmu_ref=y3,restricted_optimal = FALSE);efficiencies(C13_3v)

C13_4v=model_profit(h,price_input=t(hd[y13,7:9]),rts="vrs",dmu_eval=y13,dmu_ref=y4,restricted_optimal = FALSE);efficiencies(C13_4v)

C13_5v=model_profit(h,price_input=t(hd[y13,7:9]),rts="vrs",dmu_eval=y13,dmu_ref=y5,restricted_optimal = FALSE);efficiencies(C13_5v)

C13_6v=model_profit(h,price_input=t(hd[y13,7:9]),rts="vrs",dmu_eval=y13,dmu_ref=y6,restricted_optimal = FALSE);efficiencies(C13_6v)

C13_7v=model_profit(h,price_input=t(hd[y13,7:9]),rts="vrs",dmu_eval=y13,dmu_ref=y7,restricted_optimal = FALSE);efficiencies(C13_7v)

C13_8v=model_profit(h,price_input=t(hd[y13,7:9]),rts="vrs",dmu_eval=y13,dmu_ref=y8,restricted_optimal = FALSE);efficiencies(C13_8v)

C13_9v=model_profit(h,price_input=t(hd[y13,7:9]),rts="vrs",dmu_eval=y13,dmu_ref=y9,restricted_optimal = FALSE);efficiencies(C13_9v)

C13_10v=model_profit(h,price_input=t(hd[y13,7:9]),rts="vrs",dmu_eval=y13,dmu_ref=y10, restricted_optimal = FALSE);efficiencies(C13_10v)

C13_11v=model_profit(h,price_input=t(hd[y13,7:9]),rts="vrs",dmu_eval=y13,dmu_ref=y11, restricted_optimal = FALSE);efficiencies(C13_11v)

C13_12v=model_profit(h,price_input=t(hd[y13,7:9]),rts="vrs",dmu_eval=y13,dmu_ref=y12, restricted_optimal = FALSE);efficiencies(C13_12v)

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C13_14v=model_profit(h,price_input=t(hd[y13,7:9]),rts="vrs",dmu_eval=y13,dmu_ref=y14,
    restricted_optimal = FALSE);efficiencies(C13_14v)

C13_15v=model_profit(h,price_input=t(hd[y13,7:9]),rts="vrs",dmu_eval=y13,dmu_ref=y15,
    restricted_optimal = FALSE);efficiencies(C13_15v)

C13_16v=model_profit(h,price_input=t(hd[y13,7:9]),rts="vrs",dmu_eval=y13,dmu_ref=y16,
    restricted_optimal = FALSE);efficiencies(C13_16v)

C13_17v=model_profit(h,price_input=t(hd[y13,7:9]),rts="vrs",dmu_eval=y13,dmu_ref=y17,
    restricted_optimal = FALSE);efficiencies(C13_17v)

C13_18v=model_profit(h,price_input=t(hd[y13,7:9]),rts="vrs",dmu_eval=y13,dmu_ref=y18,
    restricted_optimal = FALSE);efficiencies(C13_18v)

C13_19v=model_profit(h,price_input=t(hd[y13,7:9]),rts="vrs",dmu_eval=y13,dmu_ref=y19,
    restricted_optimal = FALSE);efficiencies(C13_19v)

C13_20v=model_profit(h,price_input=t(hd[y13,7:9]),rts="vrs",dmu_eval=y13,dmu_ref=y20,
    restricted_optimal = FALSE);efficiencies(C13_20v)

C13_21v=model_profit(h,price_input=t(hd[y13,7:9]),rts="vrs",dmu_eval=y13,dmu_ref=y21,
    restricted_optimal = FALSE);efficiencies(C13_21v)

C13_22v=model_profit(h,price_input=t(hd[y13,7:9]),rts="vrs",dmu_eval=y13,dmu_ref=y22,
    restricted_optimal = FALSE);efficiencies(C13_22v)

C13_23v=model_profit(h,price_input=t(hd[y13,7:9]),rts="vrs",dmu_eval=y13,dmu_ref=y23,
    restricted_optimal = FALSE);efficiencies(C13_23v)


C14_1v=model_profit(h,price_input=t(hd[y14,7:9]),rts="vrs",dmu_eval=y14,dmu_ref=y1,res
    tricted_optimal = FALSE);efficiencies(C14_1v)#Cost Eff for yr4 rel to F1

C14_2v=model_profit(h,price_input=t(hd[y14,7:9]),rts="vrs",dmu_eval=y14,dmu_ref=y2,res
    tricted_optimal = FALSE);efficiencies(C14_2v)#Cost Eff for yr4 rel to F2

C14_3v=model_profit(h,price_input=t(hd[y14,7:9]),rts="vrs",dmu_eval=y14,dmu_ref=y3,res
    tricted_optimal = FALSE);efficiencies(C14_3v)#Cost Eff for yr4 rel to F3

C14_4v=model_profit(h,price_input=t(hd[y14,7:9]),rts="vrs",dmu_eval=y14,dmu_ref=y4,res
    tricted_optimal = FALSE);efficiencies(C14_4v)

C14_5v=model_profit(h,price_input=t(hd[y14,7:9]),rts="vrs",dmu_eval=y14,dmu_ref=y5,res
    tricted_optimal = FALSE);efficiencies(C14_5v)

C14_6v=model_profit(h,price_input=t(hd[y14,7:9]),rts="vrs",dmu_eval=y14,dmu_ref=y6,res
    tricted_optimal = FALSE);efficiencies(C14_6v)

C14_7v=model_profit(h,price_input=t(hd[y14,7:9]),rts="vrs",dmu_eval=y14,dmu_ref=y7,res
    tricted_optimal = FALSE);efficiencies(C14_7v)

C14_8v=model_profit(h,price_input=t(hd[y14,7:9]),rts="vrs",dmu_eval=y14,dmu_ref=y8,res
    tricted_optimal = FALSE);efficiencies(C14_8v)

C14_9v=model_profit(h,price_input=t(hd[y14,7:9]),rts="vrs",dmu_eval=y14,dmu_ref=y9,res
    tricted_optimal = FALSE);efficiencies(C14_9v)
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C14_10v=model_profit(h,price_input=t(hd[y14,7:9]),rts="vrs",dmu_eval=y14,dmu_ref=y10,
    restricted_optimal = FALSE);efficiencies(C14_10v)
C14_11v=model_profit(h,price_input=t(hd[y14,7:9]),rts="vrs",dmu_eval=y14,dmu_ref=y11,
    restricted_optimal = FALSE);efficiencies(C14_11v)
C14_12v=model_profit(h,price_input=t(hd[y14,7:9]),rts="vrs",dmu_eval=y14,dmu_ref=y12,
    restricted_optimal = FALSE);efficiencies(C14_12v)
C14_13v=model_profit(h,price_input=t(hd[y14,7:9]),rts="vrs",dmu_eval=y14,dmu_ref=y13,
    restricted_optimal = FALSE);efficiencies(C14_13v)
C14_15v=model_profit(h,price_input=t(hd[y14,7:9]),rts="vrs",dmu_eval=y14,dmu_ref=y15,
    restricted_optimal = FALSE);efficiencies(C14_15v)
C14_16v=model_profit(h,price_input=t(hd[y14,7:9]),rts="vrs",dmu_eval=y14,dmu_ref=y16,
    restricted_optimal = FALSE);efficiencies(C14_16v)
C14_17v=model_profit(h,price_input=t(hd[y14,7:9]),rts="vrs",dmu_eval=y14,dmu_ref=y17,
    restricted_optimal = FALSE);efficiencies(C14_17v)
C14_18v=model_profit(h,price_input=t(hd[y14,7:9]),rts="vrs",dmu_eval=y14,dmu_ref=y18,
    restricted_optimal = FALSE);efficiencies(C14_18v)
C14_19v=model_profit(h,price_input=t(hd[y14,7:9]),rts="vrs",dmu_eval=y14,dmu_ref=y19,
    restricted_optimal = FALSE);efficiencies(C14_19v)
C14_20v=model_profit(h,price_input=t(hd[y14,7:9]),rts="vrs",dmu_eval=y14,dmu_ref=y20,
    restricted_optimal = FALSE);efficiencies(C14_20v)
C14_21v=model_profit(h,price_input=t(hd[y14,7:9]),rts="vrs",dmu_eval=y14,dmu_ref=y21,
    restricted_optimal = FALSE);efficiencies(C14_21v)
C14_22v=model_profit(h,price_input=t(hd[y14,7:9]),rts="vrs",dmu_eval=y14,dmu_ref=y22,
    restricted_optimal = FALSE);efficiencies(C14_22v)
C14_23v=model_profit(h,price_input=t(hd[y14,7:9]),rts="vrs",dmu_eval=y14,dmu_ref=y23,
    restricted_optimal = FALSE);efficiencies(C14_23v)


C15_1v=model_profit(h,price_input=t(hd[y15,7:9]),rts="vrs",dmu_eval=y15,dmu_ref=y1,res
    tricted_optimal = FALSE);efficiencies(C15_1v)#Cost Eff for yr15 rel to F1
C15_2v=model_profit(h,price_input=t(hd[y15,7:9]),rts="vrs",dmu_eval=y15,dmu_ref=y2,res
    tricted_optimal = FALSE);efficiencies(C15_2v)
C15_3v=model_profit(h,price_input=t(hd[y15,7:9]),rts="vrs",dmu_eval=y15,dmu_ref=y3,res
    tricted_optimal = FALSE);efficiencies(C15_3v)
C15_4v=model_profit(h,price_input=t(hd[y15,7:9]),rts="vrs",dmu_eval=y15,dmu_ref=y4,res
    tricted_optimal = FALSE);efficiencies(C15_4v)
C15_5v=model_profit(h,price_input=t(hd[y15,7:9]),rts="vrs",dmu_eval=y15,dmu_ref=y5,res
    tricted_optimal = FALSE);efficiencies(C15_5v)
C15_6v=model_profit(h,price_input=t(hd[y15,7:9]),rts="vrs",dmu_eval=y15,dmu_ref=y6,res
    tricted_optimal = FALSE);efficiencies(C15_6v)
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C15_7v=model_profit(h,price_input=t(hd[y15,7:9]),rts="vrs",dmu_eval=y15,dmu_ref=y7,restricted_optimal = FALSE);efficiencies(C15_7v)

C15_8v=model_profit(h,price_input=t(hd[y15,7:9]),rts="vrs",dmu_eval=y15,dmu_ref=y8,restricted_optimal = FALSE);efficiencies(C15_8v)

C15_9v=model_profit(h,price_input=t(hd[y15,7:9]),rts="vrs",dmu_eval=y15,dmu_ref=y9,restricted_optimal = FALSE);efficiencies(C15_9v)

C15_10v=model_profit(h,price_input=t(hd[y15,7:9]),rts="vrs",dmu_eval=y15,dmu_ref=y10, restricted_optimal = FALSE);efficiencies(C15_10v)

C15_11v=model_profit(h,price_input=t(hd[y15,7:9]),rts="vrs",dmu_eval=y15,dmu_ref=y11, restricted_optimal = FALSE);efficiencies(C15_11v)

C15_12v=model_profit(h,price_input=t(hd[y15,7:9]),rts="vrs",dmu_eval=y15,dmu_ref=y12, restricted_optimal = FALSE);efficiencies(C15_12v)

C15_13v=model_profit(h,price_input=t(hd[y15,7:9]),rts="vrs",dmu_eval=y15,dmu_ref=y13, restricted_optimal = FALSE);efficiencies(C15_13v)

C15_14v=model_profit(h,price_input=t(hd[y15,7:9]),rts="vrs",dmu_eval=y15,dmu_ref=y14, restricted_optimal = FALSE);efficiencies(C15_14v)

C15_16v=model_profit(h,price_input=t(hd[y15,7:9]),rts="vrs",dmu_eval=y15,dmu_ref=y16, restricted_optimal = FALSE);efficiencies(C15_16v)

C15_17v=model_profit(h,price_input=t(hd[y15,7:9]),rts="vrs",dmu_eval=y15,dmu_ref=y17, restricted_optimal = FALSE);efficiencies(C15_17v)

C15_18v=model_profit(h,price_input=t(hd[y15,7:9]),rts="vrs",dmu_eval=y15,dmu_ref=y18, restricted_optimal = FALSE);efficiencies(C15_18v)

C15_19v=model_profit(h,price_input=t(hd[y15,7:9]),rts="vrs",dmu_eval=y15,dmu_ref=y19, restricted_optimal = FALSE);efficiencies(C15_19v)

C15_20v=model_profit(h,price_input=t(hd[y15,7:9]),rts="vrs",dmu_eval=y15,dmu_ref=y20, restricted_optimal = FALSE);efficiencies(C15_20v)

C15_21v=model_profit(h,price_input=t(hd[y15,7:9]),rts="vrs",dmu_eval=y15,dmu_ref=y21, restricted_optimal = FALSE);efficiencies(C15_21v)

C15_22v=model_profit(h,price_input=t(hd[y15,7:9]),rts="vrs",dmu_eval=y15,dmu_ref=y22, restricted_optimal = FALSE);efficiencies(C15_22v)

C15_23v=model_profit(h,price_input=t(hd[y15,7:9]),rts="vrs",dmu_eval=y15,dmu_ref=y23, restricted_optimal = FALSE);efficiencies(C15_23v)

C16_1v=model_profit(h,price_input=t(hd[y16,7:9]),rts="vrs",dmu_eval=y16,dmu_ref=y1,restricted_optimal = FALSE);efficiencies(C16_1v)#Cost Eff for yr16 rel to F1

C16_2v=model_profit(h,price_input=t(hd[y16,7:9]),rts="vrs",dmu_eval=y16,dmu_ref=y2,restricted_optimal = FALSE);efficiencies(C16_2v)

C16_3v=model_profit(h,price_input=t(hd[y16,7:9]),rts="vrs",dmu_eval=y16,dmu_ref=y3,restricted_optimal = FALSE);efficiencies(C16_3v)

C16_4v=model_profit(h,price_input=t(hd[y16,7:9]),rts="vrs",dmu_eval=y16,dmu_ref=y4,restricted_optimal = FALSE);efficiencies(C16_4v)

C16_5v=model_profit(h,price_input=t(hd[y16,7:9]),rts="vrs",dmu_eval=y16,dmu_ref=y5,restricted_optimal = FALSE);efficiencies(C16_5v)

C16_6v=model_profit(h,price_input=t(hd[y16,7:9]),rts="vrs",dmu_eval=y16,dmu_ref=y6,restricted_optimal = FALSE);efficiencies(C16_6v)

C16_7v=model_profit(h,price_input=t(hd[y16,7:9]),rts="vrs",dmu_eval=y16,dmu_ref=y7,restricted_optimal = FALSE);efficiencies(C16_7v)

C16_8v=model_profit(h,price_input=t(hd[y16,7:9]),rts="vrs",dmu_eval=y16,dmu_ref=y8,restricted_optimal = FALSE);efficiencies(C16_8v)

C16_9v=model_profit(h,price_input=t(hd[y16,7:9]),rts="vrs",dmu_eval=y16,dmu_ref=y9,restricted_optimal = FALSE);efficiencies(C16_9v)

C16_10v=model_profit(h,price_input=t(hd[y16,7:9]),rts="vrs",dmu_eval=y16,dmu_ref=y10, restricted_optimal = FALSE);efficiencies(C16_10v)

C16_11v=model_profit(h,price_input=t(hd[y16,7:9]),rts="vrs",dmu_eval=y16,dmu_ref=y11, restricted_optimal = FALSE);efficiencies(C16_11v)

C16_12v=model_profit(h,price_input=t(hd[y16,7:9]),rts="vrs",dmu_eval=y16,dmu_ref=y12, restricted_optimal = FALSE);efficiencies(C16_12v)

C16_13v=model_profit(h,price_input=t(hd[y16,7:9]),rts="vrs",dmu_eval=y16,dmu_ref=y13, restricted_optimal = FALSE);efficiencies(C16_13v)

C16_14v=model_profit(h,price_input=t(hd[y16,7:9]),rts="vrs",dmu_eval=y16,dmu_ref=y14, restricted_optimal = FALSE);efficiencies(C16_14v)

C16_15v=model_profit(h,price_input=t(hd[y16,7:9]),rts="vrs",dmu_eval=y16,dmu_ref=y15, restricted_optimal = FALSE);efficiencies(C16_15v)

C16_17v=model_profit(h,price_input=t(hd[y16,7:9]),rts="vrs",dmu_eval=y16,dmu_ref=y17, restricted_optimal = FALSE);efficiencies(C16_17v)

C16_18v=model_profit(h,price_input=t(hd[y16,7:9]),rts="vrs",dmu_eval=y16,dmu_ref=y18, restricted_optimal = FALSE);efficiencies(C16_18v)

C16_19v=model_profit(h,price_input=t(hd[y16,7:9]),rts="vrs",dmu_eval=y16,dmu_ref=y19, restricted_optimal = FALSE);efficiencies(C16_19v)

C16_20v=model_profit(h,price_input=t(hd[y16,7:9]),rts="vrs",dmu_eval=y16,dmu_ref=y20, restricted_optimal = FALSE);efficiencies(C16_20v)

C16_21v=model_profit(h,price_input=t(hd[y16,7:9]),rts="vrs",dmu_eval=y16,dmu_ref=y21, restricted_optimal = FALSE);efficiencies(C16_21v)

C16_22v=model_profit(h,price_input=t(hd[y16,7:9]),rts="vrs",dmu_eval=y16,dmu_ref=y22, restricted_optimal = FALSE);efficiencies(C16_22v)

C16_23v=model_profit(h,price_input=t(hd[y16,7:9]),rts="vrs",dmu_eval=y16,dmu_ref=y23, restricted_optimal = FALSE);efficiencies(C16_23v)

C17_1v=model_profit(h,price_input=t(hd[y17,7:9]),rts="vrs",dmu_eval=y17,dmu_ref=y1,restricted_optimal = FALSE);efficiencies(C17_1v)#Cost Eff for yr17 rel to F1

C17_2v=model_profit(h,price_input=t(hd[y17,7:9]),rts="vrs",dmu_eval=y17,dmu_ref=y2,restricted_optimal = FALSE);efficiencies(C17_2v)

C17_3v=model_profit(h,price_input=t(hd[y17,7:9]),rts="vrs",dmu_eval=y17,dmu_ref=y3,restricted_optimal = FALSE);efficiencies(C17_3v)

C17_4v=model_profit(h,price_input=t(hd[y17,7:9]),rts="vrs",dmu_eval=y17,dmu_ref=y4,restricted_optimal = FALSE);efficiencies(C17_4v)

C17_5v=model_profit(h,price_input=t(hd[y17,7:9]),rts="vrs",dmu_eval=y17,dmu_ref=y5,restricted_optimal = FALSE);efficiencies(C17_5v)

C17_6v=model_profit(h,price_input=t(hd[y17,7:9]),rts="vrs",dmu_eval=y17,dmu_ref=y6,restricted_optimal = FALSE);efficiencies(C17_6v)

C17_7v=model_profit(h,price_input=t(hd[y17,7:9]),rts="vrs",dmu_eval=y17,dmu_ref=y7,restricted_optimal = FALSE);efficiencies(C17_7v)

C17_8v=model_profit(h,price_input=t(hd[y17,7:9]),rts="vrs",dmu_eval=y17,dmu_ref=y8,restricted_optimal = FALSE);efficiencies(C17_8v)

C17_9v=model_profit(h,price_input=t(hd[y17,7:9]),rts="vrs",dmu_eval=y17,dmu_ref=y9,restricted_optimal = FALSE);efficiencies(C17_9v)

C17_10v=model_profit(h,price_input=t(hd[y17,7:9]),rts="vrs",dmu_eval=y17,dmu_ref=y10,restricted_optimal = FALSE);efficiencies(C17_10v)

C17_11v=model_profit(h,price_input=t(hd[y17,7:9]),rts="vrs",dmu_eval=y17,dmu_ref=y11,restricted_optimal = FALSE);efficiencies(C17_11v)

C17_12v=model_profit(h,price_input=t(hd[y17,7:9]),rts="vrs",dmu_eval=y17,dmu_ref=y12,restricted_optimal = FALSE);efficiencies(C17_12v)

C17_13v=model_profit(h,price_input=t(hd[y17,7:9]),rts="vrs",dmu_eval=y17,dmu_ref=y13,restricted_optimal = FALSE);efficiencies(C17_13v)

C17_14v=model_profit(h,price_input=t(hd[y17,7:9]),rts="vrs",dmu_eval=y17,dmu_ref=y14,restricted_optimal = FALSE);efficiencies(C17_14v)

C17_15v=model_profit(h,price_input=t(hd[y17,7:9]),rts="vrs",dmu_eval=y17,dmu_ref=y15,restricted_optimal = FALSE);efficiencies(C17_15v)

C17_16v=model_profit(h,price_input=t(hd[y17,7:9]),rts="vrs",dmu_eval=y17,dmu_ref=y16,restricted_optimal = FALSE);efficiencies(C17_16v)

C17_18v=model_profit(h,price_input=t(hd[y17,7:9]),rts="vrs",dmu_eval=y17,dmu_ref=y18,restricted_optimal = FALSE);efficiencies(C17_18v)

C17_19v=model_profit(h,price_input=t(hd[y17,7:9]),rts="vrs",dmu_eval=y17,dmu_ref=y19,restricted_optimal = FALSE);efficiencies(C17_19v)

C17_20v=model_profit(h,price_input=t(hd[y17,7:9]),rts="vrs",dmu_eval=y17,dmu_ref=y20,restricted_optimal = FALSE);efficiencies(C17_20v)

C17_21v=model_profit(h,price_input=t(hd[y17,7:9]),rts="vrs",dmu_eval=y17,dmu_ref=y21,

restricted_optimal = FALSE);efficiencies(C17_21v)

C17_22v=model_profit(h,price_input=t(hd[y17,7:9]),rts="vrs",dmu_eval=y17,dmu_ref=y22, restricted_optimal = FALSE);efficiencies(C17_22v)

C17_23v=model_profit(h,price_input=t(hd[y17,7:9]),rts="vrs",dmu_eval=y17,dmu_ref=y23, restricted_optimal = FALSE);efficiencies(C17_23v)

C18_1v=model_profit(h,price_input=t(hd[y18,7:9]),rts="vrs",dmu_eval=y18,dmu_ref=y1,restricted_optimal = FALSE);efficiencies(C18_1v)#Cost Eff for yr18 rel to F1

C18_2v=model_profit(h,price_input=t(hd[y18,7:9]),rts="vrs",dmu_eval=y18,dmu_ref=y2,restricted_optimal = FALSE);efficiencies(C18_2v)

C18_3v=model_profit(h,price_input=t(hd[y18,7:9]),rts="vrs",dmu_eval=y18,dmu_ref=y3,restricted_optimal = FALSE);efficiencies(C18_3v)

C18_4v=model_profit(h,price_input=t(hd[y18,7:9]),rts="vrs",dmu_eval=y18,dmu_ref=y4,restricted_optimal = FALSE);efficiencies(C18_4v)

C18_5v=model_profit(h,price_input=t(hd[y18,7:9]),rts="vrs",dmu_eval=y18,dmu_ref=y5,restricted_optimal = FALSE);efficiencies(C18_5v)

C18_6v=model_profit(h,price_input=t(hd[y18,7:9]),rts="vrs",dmu_eval=y18,dmu_ref=y6,restricted_optimal = FALSE);efficiencies(C18_6v)

C18_7v=model_profit(h,price_input=t(hd[y18,7:9]),rts="vrs",dmu_eval=y18,dmu_ref=y7,restricted_optimal = FALSE);efficiencies(C18_7v)

C18_8v=model_profit(h,price_input=t(hd[y18,7:9]),rts="vrs",dmu_eval=y18,dmu_ref=y8,restricted_optimal = FALSE);efficiencies(C18_8v)

C18_9v=model_profit(h,price_input=t(hd[y18,7:9]),rts="vrs",dmu_eval=y18,dmu_ref=y9,restricted_optimal = FALSE);efficiencies(C18_9v)

C18_10v=model_profit(h,price_input=t(hd[y18,7:9]),rts="vrs",dmu_eval=y18,dmu_ref=y10, restricted_optimal = FALSE);efficiencies(C18_10v)

C18_11v=model_profit(h,price_input=t(hd[y18,7:9]),rts="vrs",dmu_eval=y18,dmu_ref=y11, restricted_optimal = FALSE);efficiencies(C18_11v)

C18_12v=model_profit(h,price_input=t(hd[y18,7:9]),rts="vrs",dmu_eval=y18,dmu_ref=y12, restricted_optimal = FALSE);efficiencies(C18_12v)

C18_13v=model_profit(h,price_input=t(hd[y18,7:9]),rts="vrs",dmu_eval=y18,dmu_ref=y13, restricted_optimal = FALSE);efficiencies(C18_13v)

C18_14v=model_profit(h,price_input=t(hd[y18,7:9]),rts="vrs",dmu_eval=y18,dmu_ref=y14, restricted_optimal = FALSE);efficiencies(C18_14v)

C18_15v=model_profit(h,price_input=t(hd[y18,7:9]),rts="vrs",dmu_eval=y18,dmu_ref=y15, restricted_optimal = FALSE);efficiencies(C18_15v)

C18_16v=model_profit(h,price_input=t(hd[y18,7:9]),rts="vrs",dmu_eval=y18,dmu_ref=y16, restricted_optimal = FALSE);efficiencies(C18_16v)

C18_17v=model_profit(h,price_input=t(hd[y18,7:9]),rts="vrs",dmu_eval=y18,dmu_ref=y17, restricted_optimal = FALSE);efficiencies(C18_17v)

C18_19v=model_profit(h,price_input=t(hd[y18,7:9]),rts="vrs",dmu_eval=y18,dmu_ref=y19, restricted_optimal = FALSE);efficiencies(C18_19v)

C18_20v=model_profit(h,price_input=t(hd[y18,7:9]),rts="vrs",dmu_eval=y18,dmu_ref=y20, restricted_optimal = FALSE);efficiencies(C18_20v)

C18_21v=model_profit(h,price_input=t(hd[y18,7:9]),rts="vrs",dmu_eval=y18,dmu_ref=y21, restricted_optimal = FALSE);efficiencies(C18_21v)

C18_22v=model_profit(h,price_input=t(hd[y18,7:9]),rts="vrs",dmu_eval=y18,dmu_ref=y22, restricted_optimal = FALSE);efficiencies(C18_22v)

C18_23v=model_profit(h,price_input=t(hd[y18,7:9]),rts="vrs",dmu_eval=y18,dmu_ref=y23, restricted_optimal = FALSE);efficiencies(C18_23v)

C19_1v=model_profit(h,price_input=t(hd[y19,7:9]),rts="vrs",dmu_eval=y19,dmu_ref=y1,restricted_optimal = FALSE);efficiencies(C19_1v)#Cost Eff for yr19 rel to F1

C19_2v=model_profit(h,price_input=t(hd[y19,7:9]),rts="vrs",dmu_eval=y19,dmu_ref=y2,restricted_optimal = FALSE);efficiencies(C19_2v)

C19_3v=model_profit(h,price_input=t(hd[y19,7:9]),rts="vrs",dmu_eval=y19,dmu_ref=y3,restricted_optimal = FALSE);efficiencies(C19_3v)

C19_4v=model_profit(h,price_input=t(hd[y19,7:9]),rts="vrs",dmu_eval=y19,dmu_ref=y4,restricted_optimal = FALSE);efficiencies(C19_4v)

C19_5v=model_profit(h,price_input=t(hd[y19,7:9]),rts="vrs",dmu_eval=y19,dmu_ref=y5,restricted_optimal = FALSE);efficiencies(C19_5v)

C19_6v=model_profit(h,price_input=t(hd[y19,7:9]),rts="vrs",dmu_eval=y19,dmu_ref=y6,restricted_optimal = FALSE);efficiencies(C19_6v)

C19_7v=model_profit(h,price_input=t(hd[y19,7:9]),rts="vrs",dmu_eval=y19,dmu_ref=y7,restricted_optimal = FALSE);efficiencies(C19_7v)

C19_8v=model_profit(h,price_input=t(hd[y19,7:9]),rts="vrs",dmu_eval=y19,dmu_ref=y8,restricted_optimal = FALSE);efficiencies(C19_8v)

C19_9v=model_profit(h,price_input=t(hd[y19,7:9]),rts="vrs",dmu_eval=y19,dmu_ref=y9,restricted_optimal = FALSE);efficiencies(C19_9v)

C19_10v=model_profit(h,price_input=t(hd[y19,7:9]),rts="vrs",dmu_eval=y19,dmu_ref=y10, restricted_optimal = FALSE);efficiencies(C19_10v)

C19_11v=model_profit(h,price_input=t(hd[y19,7:9]),rts="vrs",dmu_eval=y19,dmu_ref=y11, restricted_optimal = FALSE);efficiencies(C19_11v)

C19_12v=model_profit(h,price_input=t(hd[y19,7:9]),rts="vrs",dmu_eval=y19,dmu_ref=y12, restricted_optimal = FALSE);efficiencies(C19_12v)

C19_13v=model_profit(h,price_input=t(hd[y19,7:9]),rts="vrs",dmu_eval=y19,dmu_ref=y13, restricted_optimal = FALSE);efficiencies(C19_13v)

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C19_14v=model_profit(h,price_input=t(hd[y19,7:9]),rts="vrs",dmu_eval=y19,dmu_ref=y14,
    restricted_optimal = FALSE);efficiencies(C19_14v)

C19_15v=model_profit(h,price_input=t(hd[y19,7:9]),rts="vrs",dmu_eval=y19,dmu_ref=y15,
    restricted_optimal = FALSE);efficiencies(C19_15v)

C19_16v=model_profit(h,price_input=t(hd[y19,7:9]),rts="vrs",dmu_eval=y19,dmu_ref=y16,
    restricted_optimal = FALSE);efficiencies(C19_16v)

C19_17v=model_profit(h,price_input=t(hd[y19,7:9]),rts="vrs",dmu_eval=y19,dmu_ref=y17,
    restricted_optimal = FALSE);efficiencies(C19_17v)

C19_18v=model_profit(h,price_input=t(hd[y19,7:9]),rts="vrs",dmu_eval=y19,dmu_ref=y18,
    restricted_optimal = FALSE);efficiencies(C19_18v)

C19_20v=model_profit(h,price_input=t(hd[y19,7:9]),rts="vrs",dmu_eval=y19,dmu_ref=y20,
    restricted_optimal = FALSE);efficiencies(C19_20v)

C19_21v=model_profit(h,price_input=t(hd[y19,7:9]),rts="vrs",dmu_eval=y19,dmu_ref=y21,
    restricted_optimal = FALSE);efficiencies(C19_21v)

C19_22v=model_profit(h,price_input=t(hd[y19,7:9]),rts="vrs",dmu_eval=y19,dmu_ref=y22,
    restricted_optimal = FALSE);efficiencies(C19_22v)

C19_23v=model_profit(h,price_input=t(hd[y19,7:9]),rts="vrs",dmu_eval=y19,dmu_ref=y23,
    restricted_optimal = FALSE);efficiencies(C19_23v)


C20_1v=model_profit(h,price_input=t(hd[y20,7:9]),rts="vrs",dmu_eval=y20,dmu_ref=y1,res
    tricted_optimal = FALSE);efficiencies(C20_1v)#Cost Eff for yr20 rel to F1

C20_2v=model_profit(h,price_input=t(hd[y20,7:9]),rts="vrs",dmu_eval=y20,dmu_ref=y2,res
    tricted_optimal = FALSE);efficiencies(C20_2v)

C20_3v=model_profit(h,price_input=t(hd[y20,7:9]),rts="vrs",dmu_eval=y20,dmu_ref=y3,res
    tricted_optimal = FALSE);efficiencies(C20_3v)

C20_4v=model_profit(h,price_input=t(hd[y20,7:9]),rts="vrs",dmu_eval=y20,dmu_ref=y4,res
    tricted_optimal = FALSE);efficiencies(C20_4v)

C20_5v=model_profit(h,price_input=t(hd[y20,7:9]),rts="vrs",dmu_eval=y20,dmu_ref=y5,res
    tricted_optimal = FALSE);efficiencies(C20_5v)

C20_6v=model_profit(h,price_input=t(hd[y20,7:9]),rts="vrs",dmu_eval=y20,dmu_ref=y6,res
    tricted_optimal = FALSE);efficiencies(C20_6v)

C20_7v=model_profit(h,price_input=t(hd[y20,7:9]),rts="vrs",dmu_eval=y20,dmu_ref=y7,res
    tricted_optimal = FALSE);efficiencies(C20_7v)

C20_8v=model_profit(h,price_input=t(hd[y20,7:9]),rts="vrs",dmu_eval=y20,dmu_ref=y8,res
    tricted_optimal = FALSE);efficiencies(C20_8v)

C20_9v=model_profit(h,price_input=t(hd[y20,7:9]),rts="vrs",dmu_eval=y20,dmu_ref=y9,res
    tricted_optimal = FALSE);efficiencies(C20_9v)

C20_10v=model_profit(h,price_input=t(hd[y20,7:9]),rts="vrs",dmu_eval=y20,dmu_ref=y10,
    restricted_optimal = FALSE);efficiencies(C20_10v)
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C20_11v=model_profit(h,price_input=t(hd[y20,7:9]),rts="vrs",dmu_eval=y20,dmu_ref=y11, restricted_optimal = FALSE);efficiencies(C20_11v)

C20_12v=model_profit(h,price_input=t(hd[y20,7:9]),rts="vrs",dmu_eval=y20,dmu_ref=y12, restricted_optimal = FALSE);efficiencies(C20_12v)

C20_13v=model_profit(h,price_input=t(hd[y20,7:9]),rts="vrs",dmu_eval=y20,dmu_ref=y13, restricted_optimal = FALSE);efficiencies(C20_13v)

C20_14v=model_profit(h,price_input=t(hd[y20,7:9]),rts="vrs",dmu_eval=y20,dmu_ref=y14, restricted_optimal = FALSE);efficiencies(C20_14v)

C20_15v=model_profit(h,price_input=t(hd[y20,7:9]),rts="vrs",dmu_eval=y20,dmu_ref=y15, restricted_optimal = FALSE);efficiencies(C20_15v)

C20_16v=model_profit(h,price_input=t(hd[y20,7:9]),rts="vrs",dmu_eval=y20,dmu_ref=y16, restricted_optimal = FALSE);efficiencies(C20_16v)

C20_17v=model_profit(h,price_input=t(hd[y20,7:9]),rts="vrs",dmu_eval=y20,dmu_ref=y17, restricted_optimal = FALSE);efficiencies(C20_17v)

C20_18v=model_profit(h,price_input=t(hd[y20,7:9]),rts="vrs",dmu_eval=y20,dmu_ref=y18, restricted_optimal = FALSE);efficiencies(C20_18v)

C20_19v=model_profit(h,price_input=t(hd[y20,7:9]),rts="vrs",dmu_eval=y20,dmu_ref=y19, restricted_optimal = FALSE);efficiencies(C20_19v)

C20_21v=model_profit(h,price_input=t(hd[y20,7:9]),rts="vrs",dmu_eval=y20,dmu_ref=y21, restricted_optimal = FALSE);efficiencies(C20_21v)

C20_22v=model_profit(h,price_input=t(hd[y20,7:9]),rts="vrs",dmu_eval=y20,dmu_ref=y22, restricted_optimal = FALSE);efficiencies(C20_22v)

C20_23v=model_profit(h,price_input=t(hd[y20,7:9]),rts="vrs",dmu_eval=y20,dmu_ref=y23, restricted_optimal = FALSE);efficiencies(C20_23v)

C21_1v=model_profit(h,price_input=t(hd[y21,7:9]),rts="vrs",dmu_eval=y21,dmu_ref=y1,restricted_optimal = FALSE);efficiencies(C21_1v)#Cost Eff for yr21 rel to F1

C21_2v=model_profit(h,price_input=t(hd[y21,7:9]),rts="vrs",dmu_eval=y21,dmu_ref=y2,restricted_optimal = FALSE);efficiencies(C21_2v)

C21_3v=model_profit(h,price_input=t(hd[y21,7:9]),rts="vrs",dmu_eval=y21,dmu_ref=y3,restricted_optimal = FALSE);efficiencies(C21_3v)

C21_4v=model_profit(h,price_input=t(hd[y21,7:9]),rts="vrs",dmu_eval=y21,dmu_ref=y4,restricted_optimal = FALSE);efficiencies(C21_4v)

C21_5v=model_profit(h,price_input=t(hd[y21,7:9]),rts="vrs",dmu_eval=y21,dmu_ref=y5,restricted_optimal = FALSE);efficiencies(C21_5v)

C21_6v=model_profit(h,price_input=t(hd[y21,7:9]),rts="vrs",dmu_eval=y21,dmu_ref=y6,restricted_optimal = FALSE);efficiencies(C21_6v)

C21_7v=model_profit(h,price_input=t(hd[y21,7:9]),rts="vrs",dmu_eval=y21,dmu_ref=y7,restricted_optimal = FALSE);efficiencies(C21_7v)

C21_8v=model_profit(h,price_input=t(hd[y21,7:9]),rts="vrs",dmu_eval=y21,dmu_ref=y8,restricted_optimal = FALSE);efficiencies(C21_8v)

C21_9v=model_profit(h,price_input=t(hd[y21,7:9]),rts="vrs",dmu_eval=y21,dmu_ref=y9,restricted_optimal = FALSE);efficiencies(C21_9v)

C21_10v=model_profit(h,price_input=t(hd[y21,7:9]),rts="vrs",dmu_eval=y21,dmu_ref=y10, restricted_optimal = FALSE);efficiencies(C21_10v)

C21_11v=model_profit(h,price_input=t(hd[y21,7:9]),rts="vrs",dmu_eval=y21,dmu_ref=y11, restricted_optimal = FALSE);efficiencies(C21_11v)

C21_12v=model_profit(h,price_input=t(hd[y21,7:9]),rts="vrs",dmu_eval=y21,dmu_ref=y12, restricted_optimal = FALSE);efficiencies(C21_12v)

C21_13v=model_profit(h,price_input=t(hd[y21,7:9]),rts="vrs",dmu_eval=y21,dmu_ref=y13, restricted_optimal = FALSE);efficiencies(C21_13v)

C21_14v=model_profit(h,price_input=t(hd[y21,7:9]),rts="vrs",dmu_eval=y21,dmu_ref=y14, restricted_optimal = FALSE);efficiencies(C21_14v)

C21_15v=model_profit(h,price_input=t(hd[y21,7:9]),rts="vrs",dmu_eval=y21,dmu_ref=y15, restricted_optimal = FALSE);efficiencies(C21_15v)

C21_16v=model_profit(h,price_input=t(hd[y21,7:9]),rts="vrs",dmu_eval=y21,dmu_ref=y16, restricted_optimal = FALSE);efficiencies(C21_16v)

C21_17v=model_profit(h,price_input=t(hd[y21,7:9]),rts="vrs",dmu_eval=y21,dmu_ref=y17, restricted_optimal = FALSE);efficiencies(C21_17v)

C21_18v=model_profit(h,price_input=t(hd[y21,7:9]),rts="vrs",dmu_eval=y21,dmu_ref=y18, restricted_optimal = FALSE);efficiencies(C21_18v)

C21_19v=model_profit(h,price_input=t(hd[y21,7:9]),rts="vrs",dmu_eval=y21,dmu_ref=y19, restricted_optimal = FALSE);efficiencies(C21_19v)

C21_20v=model_profit(h,price_input=t(hd[y21,7:9]),rts="vrs",dmu_eval=y21,dmu_ref=y20, restricted_optimal = FALSE);efficiencies(C21_20v)

C21_22v=model_profit(h,price_input=t(hd[y21,7:9]),rts="vrs",dmu_eval=y21,dmu_ref=y22, restricted_optimal = FALSE);efficiencies(C21_22v)

C21_23v=model_profit(h,price_input=t(hd[y21,7:9]),rts="vrs",dmu_eval=y21,dmu_ref=y23, restricted_optimal = FALSE);efficiencies(C21_23v)

C22_1v=model_profit(h,price_input=t(hd[y22,7:9]),rts="vrs",dmu_eval=y22,dmu_ref=y1,restricted_optimal = FALSE);efficiencies(C22_1v)#Cost Eff for yr22 rel to F1

C22_2v=model_profit(h,price_input=t(hd[y22,7:9]),rts="vrs",dmu_eval=y22,dmu_ref=y2,restricted_optimal = FALSE);efficiencies(C22_2v)

C22_3v=model_profit(h,price_input=t(hd[y22,7:9]),rts="vrs",dmu_eval=y22,dmu_ref=y3,restricted_optimal = FALSE);efficiencies(C22_3v)

C22_4v=model_profit(h,price_input=t(hd[y22,7:9]),rts="vrs",dmu_eval=y22,dmu_ref=y4,restricted_optimal = FALSE);efficiencies(C22_4v)

C22_5v=model_profit(h,price_input=t(hd[y22,7:9]),rts="vrs",dmu_eval=y22,dmu_ref=y5,restricted_optimal = FALSE);efficiencies(C22_5v)

C22_6v=model_profit(h,price_input=t(hd[y22,7:9]),rts="vrs",dmu_eval=y22,dmu_ref=y6,restricted_optimal = FALSE);efficiencies(C22_6v)

C22_7v=model_profit(h,price_input=t(hd[y22,7:9]),rts="vrs",dmu_eval=y22,dmu_ref=y7,restricted_optimal = FALSE);efficiencies(C22_7v)

C22_8v=model_profit(h,price_input=t(hd[y22,7:9]),rts="vrs",dmu_eval=y22,dmu_ref=y8,restricted_optimal = FALSE);efficiencies(C22_8v)

C22_9v=model_profit(h,price_input=t(hd[y22,7:9]),rts="vrs",dmu_eval=y22,dmu_ref=y9,restricted_optimal = FALSE);efficiencies(C22_9v)

C22_10v=model_profit(h,price_input=t(hd[y22,7:9]),rts="vrs",dmu_eval=y22,dmu_ref=y10, restricted_optimal = FALSE);efficiencies(C22_10v)

C22_11v=model_profit(h,price_input=t(hd[y22,7:9]),rts="vrs",dmu_eval=y22,dmu_ref=y11, restricted_optimal = FALSE);efficiencies(C22_11v)

C22_12v=model_profit(h,price_input=t(hd[y22,7:9]),rts="vrs",dmu_eval=y22,dmu_ref=y12, restricted_optimal = FALSE);efficiencies(C22_12v)

C22_13v=model_profit(h,price_input=t(hd[y22,7:9]),rts="vrs",dmu_eval=y22,dmu_ref=y13, restricted_optimal = FALSE);efficiencies(C22_13v)

C22_14v=model_profit(h,price_input=t(hd[y22,7:9]),rts="vrs",dmu_eval=y22,dmu_ref=y14, restricted_optimal = FALSE);efficiencies(C22_14v)

C22_15v=model_profit(h,price_input=t(hd[y22,7:9]),rts="vrs",dmu_eval=y22,dmu_ref=y15, restricted_optimal = FALSE);efficiencies(C22_15v)

C22_16v=model_profit(h,price_input=t(hd[y22,7:9]),rts="vrs",dmu_eval=y22,dmu_ref=y16, restricted_optimal = FALSE);efficiencies(C22_16v)

C22_17v=model_profit(h,price_input=t(hd[y22,7:9]),rts="vrs",dmu_eval=y22,dmu_ref=y17, restricted_optimal = FALSE);efficiencies(C22_17v)

C22_18v=model_profit(h,price_input=t(hd[y22,7:9]),rts="vrs",dmu_eval=y22,dmu_ref=y18, restricted_optimal = FALSE);efficiencies(C22_18v)

C22_19v=model_profit(h,price_input=t(hd[y22,7:9]),rts="vrs",dmu_eval=y22,dmu_ref=y19, restricted_optimal = FALSE);efficiencies(C22_19v)

C22_20v=model_profit(h,price_input=t(hd[y22,7:9]),rts="vrs",dmu_eval=y22,dmu_ref=y20, restricted_optimal = FALSE);efficiencies(C22_20v)

C22_21v=model_profit(h,price_input=t(hd[y22,7:9]),rts="vrs",dmu_eval=y22,dmu_ref=y21, restricted_optimal = FALSE);efficiencies(C22_21v)

C22_23v=model_profit(h,price_input=t(hd[y22,7:9]),rts="vrs",dmu_eval=y22,dmu_ref=y23, restricted_optimal = FALSE);efficiencies(C22_23v)

C23_1v=model_profit(h,price_input=t(hd[y23,7:9]),rts="vrs",dmu_eval=y23,dmu_ref=y1,restricted_optimal = FALSE);efficiencies(C23_1v)#Cost Eff for yr23 rel to F1

C23_2v=model_profit(h,price_input=t(hd[y23,7:9]),rts="vrs",dmu_eval=y23,dmu_ref=y2,restricted_optimal = FALSE);efficiencies(C23_2v)

C23_3v=model_profit(h,price_input=t(hd[y23,7:9]),rts="vrs",dmu_eval=y23,dmu_ref=y3,restricted_optimal = FALSE);efficiencies(C23_3v)

C23_4v=model_profit(h,price_input=t(hd[y23,7:9]),rts="vrs",dmu_eval=y23,dmu_ref=y4,restricted_optimal = FALSE);efficiencies(C23_4v)

C23_5v=model_profit(h,price_input=t(hd[y23,7:9]),rts="vrs",dmu_eval=y23,dmu_ref=y5,restricted_optimal = FALSE);efficiencies(C23_5v)

C23_6v=model_profit(h,price_input=t(hd[y23,7:9]),rts="vrs",dmu_eval=y23,dmu_ref=y6,restricted_optimal = FALSE);efficiencies(C23_6v)

C23_7v=model_profit(h,price_input=t(hd[y23,7:9]),rts="vrs",dmu_eval=y23,dmu_ref=y7,restricted_optimal = FALSE);efficiencies(C23_7v)

C23_8v=model_profit(h,price_input=t(hd[y23,7:9]),rts="vrs",dmu_eval=y23,dmu_ref=y8,restricted_optimal = FALSE);efficiencies(C23_8v)

C23_9v=model_profit(h,price_input=t(hd[y23,7:9]),rts="vrs",dmu_eval=y23,dmu_ref=y9,restricted_optimal = FALSE);efficiencies(C23_9v)

C23_10v=model_profit(h,price_input=t(hd[y23,7:9]),rts="vrs",dmu_eval=y23,dmu_ref=y10, restricted_optimal = FALSE);efficiencies(C23_10v)

C23_11v=model_profit(h,price_input=t(hd[y23,7:9]),rts="vrs",dmu_eval=y23,dmu_ref=y11, restricted_optimal = FALSE);efficiencies(C23_11v)

C23_12v=model_profit(h,price_input=t(hd[y23,7:9]),rts="vrs",dmu_eval=y23,dmu_ref=y12, restricted_optimal = FALSE);efficiencies(C23_12v)

C23_13v=model_profit(h,price_input=t(hd[y23,7:9]),rts="vrs",dmu_eval=y23,dmu_ref=y13, restricted_optimal = FALSE);efficiencies(C23_13v)

C23_14v=model_profit(h,price_input=t(hd[y23,7:9]),rts="vrs",dmu_eval=y23,dmu_ref=y14, restricted_optimal = FALSE);efficiencies(C23_14v)

C23_15v=model_profit(h,price_input=t(hd[y23,7:9]),rts="vrs",dmu_eval=y23,dmu_ref=y15, restricted_optimal = FALSE);efficiencies(C23_15v)

C23_16v=model_profit(h,price_input=t(hd[y23,7:9]),rts="vrs",dmu_eval=y23,dmu_ref=y16, restricted_optimal = FALSE);efficiencies(C23_16v)

C23_17v=model_profit(h,price_input=t(hd[y23,7:9]),rts="vrs",dmu_eval=y23,dmu_ref=y17, restricted_optimal = FALSE);efficiencies(C23_17v)

C23_18v=model_profit(h,price_input=t(hd[y23,7:9]),rts="vrs",dmu_eval=y23,dmu_ref=y18, restricted_optimal = FALSE);efficiencies(C23_18v)

C23_19v=model_profit(h,price_input=t(hd[y23,7:9]),rts="vrs",dmu_eval=y23,dmu_ref=y19, restricted_optimal = FALSE);efficiencies(C23_19v)

C23_20v=model_profit(h,price_input=t(hd[y23,7:9]),rts="vrs",dmu_eval=y23,dmu_ref=y20, restricted_optimal = FALSE);efficiencies(C23_20v)

C23_21v=model_profit(h,price_input=t(hd[y23,7:9]),rts="vrs",dmu_eval=y23,dmu_ref=y21,

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restricted_optimal = FALSE);efficiencies(C23_21v)

C23_22v=model_profit(h,price_input=t(hd[y23,7:9]),rts="vrs",dmu_eval=y23,dmu_ref=y22,
    restricted_optimal = FALSE);efficiencies(C23_22v)


writexl::write_xlsx(round(data.frame("C1_1v"=efficiencies(C1_1v),"C1_2v"=efficiencies(C1_2v),"C1_3v"=efficiencies(C1_3v),"C1_4v"=efficiencies(C1_4v),"C1_5v"=efficiencies(C1_5v),"C1_6v"=efficiencies(C1_6v),"C1_7v"=efficiencies(C1_7v),"C1_8v"=efficiencies(C1_8v),"C1_9v"=efficiencies(C1_9v),"C1_10v"=efficiencies(C1_10v),"C1_11v"=efficiencies(C1_11v),"C1_12v"=efficiencies(C1_12v),"C1_13v"=efficiencies(C1_13v),"C1_14v"=efficiencies(C1_14v),"C1_15v"=efficiencies(C1_15v),"C1_16v"=efficiencies(C1_16v),"C1_17v"=efficiencies(C1_17v),"C1_18v"=efficiencies(C1_18v),"C1_19v"=efficiencies(C1_19v),"C1_20v"=efficiencies(C1_20v),"C1_21v"=efficiencies(C1_21v),"C1_22v"=efficiencies(C1_22v),"C1_23v"=efficiencies(C1_23v)),3),path="C:/Users/DELL E7450/Documents/costeff1.xlsx")

writexl::write_xlsx(round(data.frame("C2_1v"=efficiencies(C2_1v),"C2_2v"=efficiencies(C2_2v),"C2_3v"=efficiencies(C2_3v),"C2_4v"=efficiencies(C2_4v),"C2_5v"=efficiencies(C2_5v),"C2_6v"=efficiencies(C2_6v),"C2_7v"=efficiencies(C2_7v),"C2_8v"=efficiencies(C2_8v),"C2_9v"=efficiencies(C2_9v),"C2_10v"=efficiencies(C2_10v),"C2_11v"=efficiencies(C2_11v),"C2_12v"=efficiencies(C2_12v),"C2_13v"=efficiencies(C2_13v),"C2_14v"=efficiencies(C2_14v),"C2_15v"=efficiencies(C2_15v),"C2_16v"=efficiencies(C2_16v),"C2_17v"=efficiencies(C2_17v),"C2_18v"=efficiencies(C2_18v),"C2_19v"=efficiencies(C2_19v),"C2_20v"=efficiencies(C2_20v),"C2_21v"=efficiencies(C2_21v),"C2_22v"=efficiencies(C2_22v),"C2_23v"=efficiencies(C2_23v)),3),path="C:/Users/DELL E7450/Documents/costeff2.xlsx")

writexl::write_xlsx(round(data.frame("C3_1v"=efficiencies(C3_1v),"C3_2v"=efficiencies(C3_2v),"C3_3v"=efficiencies(C3_3v),"C3_4v"=efficiencies(C3_4v),"C3_5v"=efficiencies(C3_5v),"C3_6v"=efficiencies(C3_6v),"C3_7v"=efficiencies(C3_7v),"C3_8v"=efficiencies(C3_8v),"C3_9v"=efficiencies(C3_9v),"C3_10v"=efficiencies(C3_10v),"C3_11v"=efficiencies(C3_11v),"C3_12v"=efficiencies(C3_12v),"C3_13v"=efficiencies(C3_13v),"C3_14v"=efficiencies(C3_14v),"C3_15v"=efficiencies(C3_15v),"C3_16v"=efficiencies(C3_16v),"C3_17v"=efficiencies(C3_17v),"C3_18v"=efficiencies(C3_18v),"C3_19v"=efficiencies(C3_19v),"C3_20v"=efficiencies(C3_20v),"C3_21v"=efficiencies(C3_21v),"C3_22v"=efficiencies(C3_22v),"C3_23v"=efficiencies(C3_23v)),3),path="C:/Users/DELL E7450/Documents/costeff3.xlsx")

writexl::write_xlsx(round(data.frame("C4_1v"=efficiencies(C4_1v),"C4_2v"=efficiencies(C4_2v),"C4_3v"=efficiencies(C4_3v),"C4_4v"=efficiencies(C4_4v),"C4_5v"=efficiencies(C4_5v),"C4_6v"=efficiencies(C4_6v),"C4_7v"=efficiencies(C4_7v),"C4_8v"=efficiencies(C4_8v),"C4_9v"=efficiencies(C4_9v),"C4_10v"=efficiencies(C4_10v),"C4_11v"=efficiencies(C4_11v),"C4_12v"=efficiencies(C4_12v),"C4_13v"=efficiencies(C4_13v),"C4_14v"=efficiencies(C4_14v),"C4_15v"=efficiencies(C4_15v),"C4_16v"=efficiencies(C4_16v),"C4_17v"=efficiencies(C4_17v),"C4_18v"=efficiencies(C4_18v),"C4_19v"=efficiencies(C4_19v),"C4_20v"=efficiencies(C4_20v),"C4_21v"=efficiencies(C4_21v),"C4_22v"=efficiencies(C4_22v),"C4_23v"=efficiencies(C4_23v)),3),path="C:/Users/DELL E7450/Documents/costeff4.xlsx")

writexl::write_xlsx(round(data.frame("C5_1v"=efficiencies(C5_1v),"C5_2v"=efficiencies(C5_2v),"C5_3v"=efficiencies(C5_3v),"C5_4v"=efficiencies(C5_4v),"C5_5v"=efficiencies(
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C5_5v),"C5_6v"=efficiencies(C5_6v),"C5_7v"=efficiencies(C5_7v),"C5_8v"=efficiencies(C5_8v),"C5_9v"=efficiencies(C5_9v),"C5_10v"=efficiencies(C5_10v),"C5_11v"=efficiencies(C5_11v),"C5_12v"=efficiencies(C5_12v),"C5_13v"=efficiencies(C5_13v),"C5_14v"=efficiencies(C5_14v),"C5_15v"=efficiencies(C5_15v),"C5_16v"=efficiencies(C5_16v),"C5_17v"=efficiencies(C5_17v),"C5_18v"=efficiencies(C5_18v),"C5_19v"=efficiencies(C5_19v),"C5_20v"=efficiencies(C5_20v),"C5_21v"=efficiencies(C5_21v),"C5_22v"=efficiencies(C5_22v),"C5_23v"=efficiencies(C5_23v)),3),path="C:/Users/DELL E7450/Documents/costeff5.xlsx")

writexl::write_xlsx(round(data.frame("C6_1v"=efficiencies(C6_1v),"C6_2v"=efficiencies(C6_2v),"C6_3v"=efficiencies(C6_3v),"C6_4v"=efficiencies(C6_4v),"C6_5v"=efficiencies(C6_5v),"C6_6v"=efficiencies(C6_6v),"C6_7v"=efficiencies(C6_7v),"C6_8v"=efficiencies(C6_8v),"C6_9v"=efficiencies(C6_9v),"C6_10v"=efficiencies(C6_10v),"C6_11v"=efficiencies(C6_11v),"C6_12v"=efficiencies(C6_12v),"C6_13v"=efficiencies(C6_13v),"C6_14v"=efficiencies(C6_14v),"C6_15v"=efficiencies(C6_15v),"C6_16v"=efficiencies(C6_16v),"C6_17v"=efficiencies(C6_17v),"C6_18v"=efficiencies(C6_18v),"C6_19v"=efficiencies(C6_19v),"C6_20v"=efficiencies(C6_20v),"C6_21v"=efficiencies(C6_21v),"C6_22v"=efficiencies(C6_22v),"C6_23v"=efficiencies(C6_23v)),3),path="C:/Users/DELL E7450/Documents/costeff6.xlsx")

writexl::write_xlsx(round(data.frame("C7_1v"=efficiencies(C7_1v),"C7_2v"=efficiencies(C7_2v),"C7_3v"=efficiencies(C7_3v),"C7_4v"=efficiencies(C7_4v),"C7_5v"=efficiencies(C7_5v),"C7_6v"=efficiencies(C7_6v),"C7_7v"=efficiencies(C7_7v),"C7_8v"=efficiencies(C7_8v),"C7_9v"=efficiencies(C7_9v),"C7_10v"=efficiencies(C7_10v),"C7_11v"=efficiencies(C7_11v),"C7_12v"=efficiencies(C7_12v),"C7_13v"=efficiencies(C7_13v),"C7_14v"=efficiencies(C7_14v),"C7_15v"=efficiencies(C7_15v),"C7_16v"=efficiencies(C7_16v),"C7_17v"=efficiencies(C7_17v),"C7_18v"=efficiencies(C7_18v),"C7_19v"=efficiencies(C7_19v),"C7_20v"=efficiencies(C7_20v),"C7_21v"=efficiencies(C7_21v),"C7_22v"=efficiencies(C7_22v),"C7_23v"=efficiencies(C7_23v)),3),path="C:/Users/DELL E7450/Documents/costeff7.xlsx")

writexl::write_xlsx(round(data.frame("C8_1v"=efficiencies(C8_1v),"C8_2v"=efficiencies(C8_2v),"C8_3v"=efficiencies(C8_3v),"C8_4v"=efficiencies(C8_4v),"C8_5v"=efficiencies(C8_5v),"C8_6v"=efficiencies(C8_6v),"C8_7v"=efficiencies(C8_7v),"C8_8v"=efficiencies(C8_8v),"C8_9v"=efficiencies(C8_9v),"C8_10v"=efficiencies(C8_10v),"C8_11v"=efficiencies(C8_11v),"C8_12v"=efficiencies(C8_12v),"C8_13v"=efficiencies(C8_13v),"C8_14v"=efficiencies(C8_14v),"C8_15v"=efficiencies(C8_15v),"C8_16v"=efficiencies(C8_16v),"C8_17v"=efficiencies(C8_17v),"C8_18v"=efficiencies(C8_18v),"C8_19v"=efficiencies(C8_19v),"C8_20v"=efficiencies(C8_20v),"C8_21v"=efficiencies(C8_21v),"C8_22v"=efficiencies(C8_22v),"C8_23v"=efficiencies(C8_23v)),3),path="C:/Users/DELL E7450/Documents/costeff8.xlsx")

writexl::write_xlsx(round(data.frame("C9_1v"=efficiencies(C9_1v),"C9_2v"=efficiencies(C9_2v),"C9_3v"=efficiencies(C9_3v),"C9_4v"=efficiencies(C9_4v),"C9_5v"=efficiencies(C9_5v),"C9_6v"=efficiencies(C9_6v),"C9_7v"=efficiencies(C9_7v),"C9_8v"=efficiencies(C9_8v),"C9_9v"=efficiencies(C9_9v),"C9_10v"=efficiencies(C9_10v),"C9_11v"=efficiencies(C9_11v),"C9_12v"=efficiencies(C9_12v),"C9_13v"=efficiencies(C9_13v),"C9_14v"=efficiencies(C9_14v),"C9_15v"=efficiencies(C9_15v),"C9_16v"=efficiencies(C9_16v),"C9_17v"=efficiencies(C9_17v),"C9_18v"=efficiencies(C9_18v),"C9_19v"=efficiencies(C9_19v),"C9_20v"=efficiencies(C9_20v),"C9_21v"=efficiencies(C9_21v),"C9_22v"=efficiencies(C9_22v),"C9_23v"=efficiencies(C9_23v)),3),path="C:/Users/DELL E7450/Documents/costeff9.xlsx")

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writexl::write_xlsx(round(data.frame("C10_1v"=efficiencies(C10_1v),"C10_2v"=efficiencies(C10_2v),"C10_3v"=efficiencies(C10_3v),"C10_4v"=efficiencies(C10_4v),"C10_5v"=efficiencies(C10_5v),"C10_6v"=efficiencies(C10_6v),"C10_7v"=efficiencies(C10_7v),"C10_8v"=efficiencies(C10_8v),"C10_9v"=efficiencies(C10_9v),"C10_10v"=efficiencies(C10_10v),"C10_11v"=efficiencies(C10_11v),"C10_12v"=efficiencies(C10_12v),"C10_13v"=efficiencies(C10_13v),"C10_14v"=efficiencies(C10_14v),"C10_15v"=efficiencies(C10_15v),"C10_16v"=efficiencies(C10_16v),"C10_17v"=efficiencies(C10_17v),"C10_18v"=efficiencies(C10_18v),"C10_19v"=efficiencies(C10_19v),"C10_20v"=efficiencies(C10_20v),"C10_21v"=efficiencies(C10_21v),"C10_22v"=efficiencies(C10_22v),"C10_23v"=efficiencies(C10_23v)),3),path="C:/Users/DELL E7450/Documents/costeff10.xlsx")

writexl::write_xlsx(round(data.frame("C11_1v"=efficiencies(C11_1v),"C11_2v"=efficiencies(C11_2v),"C11_3v"=efficiencies(C11_3v),"C11_4v"=efficiencies(C11_4v),"C11_5v"=efficiencies(C11_5v),"C11_6v"=efficiencies(C11_6v),"C11_7v"=efficiencies(C11_7v),"C11_8v"=efficiencies(C11_8v),"C11_9v"=efficiencies(C11_9v),"C11_10v"=efficiencies(C11_10v),"C11_11v"=efficiencies(C11_11v),"C11_12v"=efficiencies(C11_12v),"C11_13v"=efficiencies(C11_13v),"C11_14v"=efficiencies(C11_14v),"C11_15v"=efficiencies(C11_15v),"C11_16v"=efficiencies(C11_16v),"C11_17v"=efficiencies(C11_17v),"C11_18v"=efficiencies(C11_18v),"C11_19v"=efficiencies(C11_19v),"C11_20v"=efficiencies(C11_20v),"C11_21v"=efficiencies(C11_21v),"C11_22v"=efficiencies(C11_22v),"C11_23v"=efficiencies(C11_23v)),3),path="C:/Users/DELL E7450/Documents/costeff11.xlsx")

writexl::write_xlsx(round(data.frame("C12_1v"=efficiencies(C12_1v),"C12_2v"=efficiencies(C12_2v),"C12_3v"=efficiencies(C12_3v),"C12_4v"=efficiencies(C12_4v),"C12_5v"=efficiencies(C12_5v),"C12_6v"=efficiencies(C12_6v),"C12_7v"=efficiencies(C12_7v),"C12_8v"=efficiencies(C12_8v),"C12_9v"=efficiencies(C12_9v),"C12_10v"=efficiencies(C12_10v),"C12_11v"=efficiencies(C12_11v),"C12_12v"=efficiencies(C12_12v),"C12_13v"=efficiencies(C12_13v),"C12_14v"=efficiencies(C12_14v),"C12_15v"=efficiencies(C12_15v),"C12_16v"=efficiencies(C12_16v),"C12_17v"=efficiencies(C12_17v),"C12_18v"=efficiencies(C12_18v),"C12_19v"=efficiencies(C12_19v),"C12_20v"=efficiencies(C12_20v),"C12_21v"=efficiencies(C12_21v),"C12_22v"=efficiencies(C12_22v),"C12_23v"=efficiencies(C12_23v)),3),path="C:/Users/DELL E7450/Documents/costeff12.xlsx")

writexl::write_xlsx(round(data.frame("C13_1v"=efficiencies(C13_1v),"C13_2v"=efficiencies(C13_2v),"C13_3v"=efficiencies(C13_3v),"C13_4v"=efficiencies(C13_4v),"C13_5v"=efficiencies(C13_5v),"C13_6v"=efficiencies(C13_6v),"C13_7v"=efficiencies(C13_7v),"C13_8v"=efficiencies(C13_8v),"C13_9v"=efficiencies(C13_9v),"C13_10v"=efficiencies(C13_10v),"C13_11v"=efficiencies(C13_11v),"C13_12v"=efficiencies(C13_12v),"C13_13v"=efficiencies(C13_13v),"C13_14v"=efficiencies(C13_14v),"C13_15v"=efficiencies(C13_15v),"C13_16v"=efficiencies(C13_16v),"C13_17v"=efficiencies(C13_17v),"C13_18v"=efficiencies(C13_18v),"C13_19v"=efficiencies(C13_19v),"C13_20v"=efficiencies(C13_20v),"C13_21v"=efficiencies(C13_21v),"C13_22v"=efficiencies(C13_22v),"C13_23v"=efficiencies(C13_23v)),3),path="C:/Users/DELL E7450/Documents/costeff13.xlsx")

writexl::write_xlsx(round(data.frame("C14_1v"=efficiencies(C14_1v),"C14_2v"=efficiencies(C14_2v),"C14_3v"=efficiencies(C14_3v),"C14_4v"=efficiencies(C14_4v),"C14_5v"=efficiencies(C14_5v),"C14_6v"=efficiencies(C14_6v),"C14_7v"=efficiencies(C14_7v),"C14_8v"=efficiencies(C14_8v),"C14_9v"=efficiencies(C14_9v),"C14_10v"=efficiencie
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s(C14_10v),"C14_11v"=efficiencies(C14_11v),"C14_12v"=efficiencies(C14_12v),"C14_13v"=efficiencies(C14_13v),"C14_14v"=efficiencies(C14_14v),"C14_15v"=efficiencies(C14_15v),"C14_16v"=efficiencies(C14_16v),"C14_17v"=efficiencies(C14_17v),"C14_18v"=efficiencies(C14_18v),"C14_19v"=efficiencies(C14_19v),"C14_20v"=efficiencies(C14_20v),"C14_21v"=efficiencies(C14_21v),"C14_22v"=efficiencies(C14_22v),"C14_23v"=efficiencies(C14_23v)),3),path="C:/Users/DELL E7450/Documents/costeff14.xlsx")

writexl::write_xlsx(round(data.frame("C15_1v"=efficiencies(C15_1v),"C15_2v"=efficiencies(C15_2v),"C15_3v"=efficiencies(C15_3v),"C15_4v"=efficiencies(C15_4v),"C15_5v"=efficiencies(C15_5v),"C15_6v"=efficiencies(C15_6v),"C15_7v"=efficiencies(C15_7v),"C15_8v"=efficiencies(C15_8v),"C15_9v"=efficiencies(C15_9v),"C15_10v"=efficiencies(C15_10v),"C15_11v"=efficiencies(C15_11v),"C15_12v"=efficiencies(C15_12v),"C15_13v"=efficiencies(C15_13v),"C15_14v"=efficiencies(C15_14v),"C15_15v"=efficiencies(C15_15v),"C15_16v"=efficiencies(C15_16v),"C15_17v"=efficiencies(C15_17v),"C15_18v"=efficiencies(C15_18v),"C15_19v"=efficiencies(C15_19v),"C15_20v"=efficiencies(C15_20v),"C15_21v"=efficiencies(C15_21v),"C15_22v"=efficiencies(C15_22v),"C15_23v"=efficiencies(C15_23v)),3),path="C:/Users/DELL E7450/Documents/costeff15.xlsx")

writexl::write_xlsx(round(data.frame("C16_1v"=efficiencies(C16_1v),"C16_2v"=efficiencies(C16_2v),"C16_3v"=efficiencies(C16_3v),"C16_4v"=efficiencies(C16_4v),"C16_5v"=efficiencies(C16_5v),"C16_6v"=efficiencies(C16_6v),"C16_7v"=efficiencies(C16_7v),"C16_8v"=efficiencies(C16_8v),"C16_9v"=efficiencies(C16_9v),"C16_10v"=efficiencies(C16_10v),"C16_11v"=efficiencies(C16_11v),"C16_12v"=efficiencies(C16_12v),"C16_13v"=efficiencies(C16_13v),"C16_14v"=efficiencies(C16_14v),"C16_15v"=efficiencies(C16_15v),"C16_16v"=efficiencies(C16_16v),"C16_17v"=efficiencies(C16_17v),"C16_18v"=efficiencies(C16_18v),"C16_19v"=efficiencies(C16_19v),"C16_20v"=efficiencies(C16_20v),"C16_21v"=efficiencies(C16_21v),"C16_22v"=efficiencies(C16_22v),"C16_23v"=efficiencies(C16_23v)),3),path="C:/Users/DELL E7450/Documents/costeff16.xlsx")

writexl::write_xlsx(round(data.frame("C17_1v"=efficiencies(C17_1v),"C17_2v"=efficiencies(C17_2v),"C17_3v"=efficiencies(C17_3v),"C17_4v"=efficiencies(C17_4v),"C17_5v"=efficiencies(C17_5v),"C17_6v"=efficiencies(C17_6v),"C17_7v"=efficiencies(C17_7v),"C17_8v"=efficiencies(C17_8v),"C17_9v"=efficiencies(C17_9v),"C17_10v"=efficiencies(C17_10v),"C17_11v"=efficiencies(C17_11v),"C17_12v"=efficiencies(C17_12v),"C17_13v"=efficiencies(C17_13v),"C17_14v"=efficiencies(C17_14v),"C17_15v"=efficiencies(C17_15v),"C17_16v"=efficiencies(C17_16v),"C17_17v"=efficiencies(C17_17v),"C17_18v"=efficiencies(C17_18v),"C17_19v"=efficiencies(C17_19v),"C17_20v"=efficiencies(C17_20v),"C17_21v"=efficiencies(C17_21v),"C17_22v"=efficiencies(C17_22v),"C17_23v"=efficiencies(C17_23v)),3),path="C:/Users/DELL E7450/Documents/costeff17.xlsx")

writexl::write_xlsx(round(data.frame("C18_1v"=efficiencies(C18_1v),"C18_2v"=efficiencies(C18_2v),"C18_3v"=efficiencies(C18_3v),"C18_4v"=efficiencies(C18_4v),"C18_5v"=efficiencies(C18_5v),"C18_6v"=efficiencies(C18_6v),"C18_7v"=efficiencies(C18_7v),"C18_8v"=efficiencies(C18_8v),"C18_9v"=efficiencies(C18_9v),"C18_10v"=efficiencies(C18_10v),"C18_11v"=efficiencies(C18_11v),"C18_12v"=efficiencies(C18_12v),"C18_13v"=efficiencies(C18_13v),"C18_14v"=efficiencies(C18_14v),"C18_15v"=efficiencies(C18_15v),"C18_16v"=efficiencies(C18_16v),"C18_17v"=efficiencies(C18_17v),"C18_18v"=efficiencies(C18_18v),"C18_19v"=efficiencies(C18_19v),"C18_20v"=efficienc
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ies(C18_20v),"C18_21v"=efficiencies(C18_21v),"C18_22v"=efficiencies(C18_22v),"C18_23v"=efficiencies(C18_23v)),3),path="C:/Users/DELL E7450/Documents/costeff18.xlsx")

writexl::write_xlsx(round(data.frame("C19_1v"=efficiencies(C19_1v),"C19_2v"=efficiencies(C19_2v),"C19_3v"=efficiencies(C19_3v),"C19_4v"=efficiencies(C19_4v),"C19_5v"=efficiencies(C19_5v),"C19_6v"=efficiencies(C19_6v),"C19_7v"=efficiencies(C19_7v),"C19_8v"=efficiencies(C19_8v),"C19_9v"=efficiencies(C19_9v),"C19_10v"=efficiencies(C19_10v),"C19_11v"=efficiencies(C19_11v),"C19_12v"=efficiencies(C19_12v),"C19_13v"=efficiencies(C19_13v),"C19_14v"=efficiencies(C19_14v),"C19_15v"=efficiencies(C19_15v),"C19_16v"=efficiencies(C19_16v),"C19_17v"=efficiencies(C19_17v),"C19_18v"=efficiencies(C19_18v),"C19_19v"=efficiencies(C19_19v),"C19_20v"=efficiencies(C19_20v),"C19_21v"=efficiencies(C19_21v),"C19_22v"=efficiencies(C19_22v),"C19_23v"=efficiencies(C19_23v)),3),path="C:/Users/DELL E7450/Documents/costeff19.xlsx")

writexl::write_xlsx(round(data.frame("C20_1v"=efficiencies(C20_1v),"C20_2v"=efficiencies(C20_2v),"C20_3v"=efficiencies(C20_3v),"C20_4v"=efficiencies(C20_4v),"C20_5v"=efficiencies(C20_5v),"C20_6v"=efficiencies(C20_6v),"C20_7v"=efficiencies(C20_7v),"C20_8v"=efficiencies(C20_8v),"C20_9v"=efficiencies(C20_9v),"C20_10v"=efficiencies(C20_10v),"C20_11v"=efficiencies(C20_11v),"C20_12v"=efficiencies(C20_12v),"C20_13v"=efficiencies(C20_13v),"C20_14v"=efficiencies(C20_14v),"C20_15v"=efficiencies(C20_15v),"C20_16v"=efficiencies(C20_16v),"C20_17v"=efficiencies(C20_17v),"C20_18v"=efficiencies(C20_18v),"C20_19v"=efficiencies(C20_19v),"C20_20v"=efficiencies(C20_20v),"C20_21v"=efficiencies(C20_21v),"C20_22v"=efficiencies(C20_22v),"C20_23v"=efficiencies(C20_23v)),3),path="C:/Users/DELL E7450/Documents/costeff20.xlsx")

writexl::write_xlsx(round(data.frame("C21_1v"=efficiencies(C21_1v),"C21_2v"=efficiencies(C21_2v),"C21_3v"=efficiencies(C21_3v),"C21_4v"=efficiencies(C21_4v),"C21_5v"=efficiencies(C21_5v),"C21_6v"=efficiencies(C21_6v),"C21_7v"=efficiencies(C21_7v),"C21_8v"=efficiencies(C21_8v),"C21_9v"=efficiencies(C21_9v),"C21_10v"=efficiencies(C21_10v),"C21_11v"=efficiencies(C21_11v),"C21_12v"=efficiencies(C21_12v),"C21_13v"=efficiencies(C21_13v),"C21_14v"=efficiencies(C21_14v),"C21_15v"=efficiencies(C21_15v),"C21_16v"=efficiencies(C21_16v),"C21_17v"=efficiencies(C21_17v),"C21_18v"=efficiencies(C21_18v),"C21_19v"=efficiencies(C21_19v),"C21_20v"=efficiencies(C21_20v),"C21_21v"=efficiencies(C21_21v),"C21_22v"=efficiencies(C21_22v),"C21_23v"=efficiencies(C21_23v)),3),path="C:/Users/DELL E7450/Documents/costeff21.xlsx")

writexl::write_xlsx(round(data.frame("C22_1v"=efficiencies(C22_1v),"C22_2v"=efficiencies(C22_2v),"C22_3v"=efficiencies(C22_3v),"C22_4v"=efficiencies(C22_4v),"C22_5v"=efficiencies(C22_5v),"C22_6v"=efficiencies(C22_6v),"C22_7v"=efficiencies(C22_7v),"C22_8v"=efficiencies(C22_8v),"C22_9v"=efficiencies(C22_9v),"C22_10v"=efficiencies(C22_10v),"C22_11v"=efficiencies(C22_11v),"C22_12v"=efficiencies(C22_12v),"C22_13v"=efficiencies(C22_13v),"C22_14v"=efficiencies(C22_14v),"C22_15v"=efficiencies(C22_15v),"C22_16v"=efficiencies(C22_16v),"C22_17v"=efficiencies(C22_17v),"C22_18v"=efficiencies(C22_18v),"C22_19v"=efficiencies(C22_19v),"C22_20v"=efficiencies(C22_20v),"C22_21v"=efficiencies(C22_21v),"C22_22v"=efficiencies(C22_22v),"C22_23v"=efficiencies(C22_23v)),3),path="C:/Users/DELL E7450/Documents/costeff22.xlsx")

writexl::write_xlsx(round(data.frame("C23_1v"=efficiencies(C23_1v),"C23_2v"=efficiencies(C23_2v),"C23_3v"=efficiencies(C23_3v),"C23_4v"=efficiencies(C23_4v),"C23_5v"=efficiencies(C23_5v),"C23_6v"=efficiencies(C23_6v),"C23_7v"=efficiencies(C23_7v),"C23_8v"=efficiencies(C23_8v),"C23_9v"=efficiencies(C23_9v),"C23_10v"=efficiencies(C23_10v),"C23_11v"=efficiencies(C23_11v),"C23_12v"=efficiencies(C23_12v),"C23_13v"=efficiencies(C23_13v),"C23_14v"=efficiencies(C23_14v),"C23_15v"=efficiencies(C23_15v),"C23_16v"=efficiencies(C23_16v),"C23_17v"=efficiencies(C23_17v),"C23_18v"=efficiencies(C23_18v),"C23_19v"=efficiencies(C23_19v),"C23_20v"=efficiencies(C23_20v),"C23_21v"=efficiencies(C23_21v),"C23_22v"=efficiencies(C23_22v),"C23_23v"=efficiencies(C23_23v)),3),path="C:/Users/DELL E7450/Documents/costeff23.xlsx")

#CALCULATING MALMQUIST PRODUCTIVITY INDEX

#Fare et al (1994)

#calculated in Excel

#CALCULATING COST MALMQUIST PRODUCTIVITY INDEX

#Maniadakis & Thanassoulis (2004)

#calculated in Excel

#CALCULATING GLOBAL MALMQUSIT PRODUCTIVITY INDEX USING DeaR

#Pastor & Lovell (2005)

ge1v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y1,dmu_ref=yg);efficiencies(ge1v)#Tec Eff for yr1 rel to GF, column for year is not included in data for cal

ge2v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y2,dmu_ref=yg);efficiencies(ge2v)#Tec Eff for yr2 rel to GF

ge3v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y3,dmu_ref=yg);efficiencies(ge3v)#Tec Eff for yr3 rel to GF

ge4v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y4,dmu_ref=yg);efficiencies(ge4v)#Tec Eff for yr4 rel to GF

```
ge5v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y5,dmu_ref=yg);efficiencies(ge5v)#Tec Eff for yr5 rel to GF

ge6v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y6,dmu_ref=yg);efficiencies(ge6v)#Tec Eff for yr6 rel to GF

ge7v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y7,dmu_ref=yg);efficiencies(ge7v)#Tec Eff for yr7 rel to GF

ge8v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y8,dmu_ref=yg);efficiencies(ge8v)#Tec Eff for yr8 rel to GF

ge9v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y9,dmu_ref=yg);efficiencies(ge9v)#Tec Eff for yr9 rel to GF

ge10v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y10,dmu_ref=yg);efficiencies(ge10v)#Tec Eff for yr10 rel to
    GF

ge11v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y11,dmu_ref=yg);efficiencies(ge11v)#Tec Eff for yr11 rel to
    GF

ge12v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y12,dmu_ref=yg);efficiencies(ge12v)#Tec Eff for yr12 rel to
    GF

ge13v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y13,dmu_ref=yg);efficiencies(ge13v)#Tec Eff for yr13 rel to
    GF

ge14v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y14,dmu_ref=yg);efficiencies(ge14v)#Tec Eff for yr14 rel to
    GF

ge15v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y15,dmu_ref=yg);efficiencies(ge15v)#Tec Eff for yr15 rel to
    GF

ge16v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y16,dmu_ref=yg);efficiencies(ge16v)#Tec Eff for yr16 rel to
    GF

ge17v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y17,dmu_ref=yg);efficiencies(ge17v)#Tec Eff for yr17 rel to
    GF

ge18v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y18,dmu_ref=yg);efficiencies(ge18v)#Tec Eff for yr18 rel to
    GF

ge19v=model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=y19,dmu_ref=yg);efficiencies(ge19v)#Tec Eff for yr19 rel to
    GF

ge20v=model_basic(h,orientation
```

```
="io",rts="vrs",dmu_eval=y20,dmu_ref=yg);efficiencies(ge20v)#Tec Eff for yr20 rel to GF

ge21v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y21,dmu_ref=yg);efficiencies(ge21v)#Tec Eff for yr21 rel to GF

ge22v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y22,dmu_ref=yg);efficiencies(ge22v)#Tec Eff for yr22 rel to GF

ge23v=model_basic(h,orientation ="io",rts="vrs",dmu_eval=y23,dmu_ref=yg);efficiencies(ge23v)#Tec Eff for yr23 rel to GF


gm_pl12v=mean(efficiencies(ge1v))/mean(efficiencies(ge2v))
gm_pl23v=mean(efficiencies(ge2v))/mean(efficiencies(ge3v))
gm_pl34v=mean(efficiencies(ge3v))/mean(efficiencies(ge4v))
gm_pl45v=mean(efficiencies(ge4v))/mean(efficiencies(ge5v))
gm_pl56v=mean(efficiencies(ge5v))/mean(efficiencies(ge6v))
gm_pl67v=mean(efficiencies(ge6v))/mean(efficiencies(ge7v))
gm_pl78v=mean(efficiencies(ge7v))/mean(efficiencies(ge8v))
gm_pl89v=mean(efficiencies(ge8v))/mean(efficiencies(ge9v))
gm_pl910v=mean(efficiencies(ge9v))/mean(efficiencies(ge10v))
gm_pl1011v=mean(efficiencies(ge10v))/mean(efficiencies(ge11v))
gm_pl1112v=mean(efficiencies(ge11v))/mean(efficiencies(ge12v))
gm_pl1213v=mean(efficiencies(ge12v))/mean(efficiencies(ge13v))
gm_pl1314v=mean(efficiencies(ge13v))/mean(efficiencies(ge14v))
gm_pl1415v=mean(efficiencies(ge14v))/mean(efficiencies(ge15v))
gm_pl1516v=mean(efficiencies(ge15v))/mean(efficiencies(ge16v))
gm_pl1617v=mean(efficiencies(ge16v))/mean(efficiencies(ge17v))
gm_pl1718v=mean(efficiencies(ge17v))/mean(efficiencies(ge18v))
gm_pl1819v=mean(efficiencies(ge18v))/mean(efficiencies(ge19v))
gm_pl1920v=mean(efficiencies(ge19v))/mean(efficiencies(ge20v))
gm_pl2021v=mean(efficiencies(ge20v))/mean(efficiencies(ge21v))
gm_pl2122v=mean(efficiencies(ge21v))/mean(efficiencies(ge22v))
gm_pl2223v=mean(efficiencies(ge22v))/mean(efficiencies(ge23v))
```

```
writexl::write_xlsx(data.frame(gm_pl12v,gm_pl23v,gm_pl34v,gm_pl45v,gm_pl56v,gm_pl67
    v,gm_pl78v,gm_pl89v,gm_pl910v,gm_pl1011v,gm_pl1112v,gm_pl1213v,gm_pl1314v,g
    m_pl1415v,gm_pl1516v,

    gm_pl1617v,gm_pl1718v,gm_pl1819v,gm_pl1920v,gm_pl2021v,gm_pl2122v,gm_pl222
    3v),path="C:/Users/DELL E7450/Documents/my_gm_pl.xlsx")

#Asmild & Tam (2007)

#Global Technical Index

TI1v<-model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=yg,dmu_ref=y1);efficiencies(TI1v)#Eff for all yrs rel to
    F1,column for year is not included in cal

TI2v<-model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=yg,dmu_ref=y2);efficiencies(TI2v)#Eff for all yrs rel to
    F2,column for year is not included in cal

TI3v<-model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=yg,dmu_ref=y3);efficiencies(TI3v)#Eff for all yrs rel to
    F3,column for year is not included in cal

TI4v<-model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=yg,dmu_ref=y4);efficiencies(TI4v)#Eff for all yrs rel to
    F4,column for year is not included in cal

TI5v<-model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=yg,dmu_ref=y5);efficiencies(TI5v)

TI6v<-model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=yg,dmu_ref=y6);efficiencies(TI6v)

TI7v<-model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=yg,dmu_ref=y7);efficiencies(TI7v)

TI8v<-model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=yg,dmu_ref=y8);efficiencies(TI8v)

TI9v<-model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=yg,dmu_ref=y9);efficiencies(TI9v)

TI10v<-model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=yg,dmu_ref=y10);efficiencies(TI10v)

TI11v<-model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=yg,dmu_ref=y11);efficiencies(TI11v)

TI12v<-model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=yg,dmu_ref=y12);efficiencies(TI12v)
```

```
TI13v<-model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=yg,dmu_ref=y13);efficiencies(TI13v)
TI14v<-model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=yg,dmu_ref=y14);efficiencies(TI14v)
TI15v<-model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=yg,dmu_ref=y15);efficiencies(TI15v)
TI16v<-model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=yg,dmu_ref=y16);efficiencies(TI16v)
TI17v<-model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=yg,dmu_ref=y17);efficiencies(TI17v)
TI18v<-model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=yg,dmu_ref=y18);efficiencies(TI18v)
TI19v<-model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=yg,dmu_ref=y19);efficiencies(TI19v)
TI20v<-model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=yg,dmu_ref=y20);efficiencies(TI20v)
TI21v<-model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=yg,dmu_ref=y21);efficiencies(TI21v)
TI22v<-model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=yg,dmu_ref=y22);efficiencies(TI22v)
TI23v<-model_basic(h,orientation
    ="io",rts="vrs",dmu_eval=yg,dmu_ref=y23);efficiencies(TI23v)


writexl::write_xlsx(data.frame(hd[,1],"TI1v"=efficiencies(TI1v),"TI2v"=efficiencies(TI2v),"
    TI3v"=efficiencies(TI3v),"TI4v"=efficiencies(TI4v),"TI5v"=efficiencies(TI5v),"TI6v"=
    efficiencies(TI6v),

    "TI7v"=efficiencies(TI7v),"TI8v"=efficiencies(TI8v),"TI9v"=efficiencies(TI9v),"TI10v"
    =efficiencies(TI10v),"TI11v"=efficiencies(TI11v),"TI12v"=efficiencies(TI12v),

    "TI13v"=efficiencies(TI13v),"TI14v"=efficiencies(TI14v),"TI15v"=efficiencies(TI15v),
    "TI16v"=efficiencies(TI16v),"TI17v"=efficiencies(TI17v),"TI18v"=efficiencies(TI18v),

    "TI19v"=efficiencies(TI19v),"TI20v"=efficiencies(TI20v),"TI21v"=efficiencies(TI21v),
    "TI22v"=efficiencies(TI22v),"TI23v"=efficiencies(TI23v)),path="C:/Users/DELL
    E7450/Documents/my_gfs.xlsx")


#Global Efficiency Change
gec12v=exp(mean(log(efficiencies(E2_2v))))/exp(mean(log(efficiencies(E1_1v)))) #Global
    Eff yr1 to yr2
```

```
gec23v=exp(mean(log(efficiencies(E3_3v))))/exp(mean(log(efficiencies(E2_2v)))) #Global
    Eff yr2 to yr3
gec34v=exp(mean(log(efficiencies(E4_4v))))/exp(mean(log(efficiencies(E3_3v)))) #Global
    Eff yr3 to yr4
gec45v=exp(mean(log(efficiencies(E5_5v))))/exp(mean(log(efficiencies(E4_4v))))
gec56v=exp(mean(log(efficiencies(E6_6v))))/exp(mean(log(efficiencies(E5_5v))))
gec67v=exp(mean(log(efficiencies(E7_7v))))/exp(mean(log(efficiencies(E6_6v))))
gec78v=exp(mean(log(efficiencies(E8_8v))))/exp(mean(log(efficiencies(E7_7v))))
gec89v=exp(mean(log(efficiencies(E9_9v))))/exp(mean(log(efficiencies(E8_8v))))
gec910v=exp(mean(log(efficiencies(E10_10v))))/exp(mean(log(efficiencies(E9_9v))))
gec1011v=exp(mean(log(efficiencies(E11_11v))))/exp(mean(log(efficiencies(E10_10v))))
gec1112v=exp(mean(log(efficiencies(E12_12v))))/exp(mean(log(efficiencies(E11_11v))))
gec1213v=exp(mean(log(efficiencies(E13_13v))))/exp(mean(log(efficiencies(E12_12v))))
gec1314v=exp(mean(log(efficiencies(E14_14v))))/exp(mean(log(efficiencies(E13_13v))))
gec1415v=exp(mean(log(efficiencies(E15_15v))))/exp(mean(log(efficiencies(E14_14v))))
gec1516v=exp(mean(log(efficiencies(E16_16v))))/exp(mean(log(efficiencies(E15_15v))))
gec1617v=exp(mean(log(efficiencies(E17_17v))))/exp(mean(log(efficiencies(E16_16v))))
gec1718v=exp(mean(log(efficiencies(E18_18v))))/exp(mean(log(efficiencies(E17_17v))))
gec1819v=exp(mean(log(efficiencies(E19_19v))))/exp(mean(log(efficiencies(E18_18v))))
gec1920v=exp(mean(log(efficiencies(E20_20v))))/exp(mean(log(efficiencies(E19_19v))))
gec2021v=exp(mean(log(efficiencies(E21_21v))))/exp(mean(log(efficiencies(E20_20v))))
gec2122v=exp(mean(log(efficiencies(E22_22v))))/exp(mean(log(efficiencies(E21_21v))))
gec2223v=exp(mean(log(efficiencies(E23_23v))))/exp(mean(log(efficiencies(E22_22v))))

writexl::write_xlsx(data.frame(gec12v,gec23v,gec34v,gec45v,gec56v,gec67v,gec78v,gec89v,g
    ec910v,gec1011v,gec1112v,gec1213v,gec1314v,gec1415v,gec1516v,

    gec1617v,gec1718v,gec1819v,gec1920v,gec2021v,gec2122v,gec2223v),path="C:/Users/
    DELL E7450/Documents/my_gec.xlsx")

#Global Frontier Shift
#Calculated in Excel

#Global Malmquist Index
```

#Calculated in Excel

#CALCULATING GLOBAL COST MALMQUIST PRODUCTIVITY INDEX

#Tohidi et al (2012)

```
gce1v=model_profit(h,price_input=t(hd[y1,7:9]),rts="vrs",dmu_eval=y1,dmu_ref=yg,restricted_optimal = FALSE);efficiencies(gce1v)#Global Cost Eff for yr1 rel to GF
gce2v=model_profit(h,price_input=t(hd[y2,7:9]),rts="vrs",dmu_eval=y2,dmu_ref=yg,restricted_optimal = FALSE);efficiencies(gce2v)
gce3v=model_profit(h,price_input=t(hd[y3,7:9]),rts="vrs",dmu_eval=y3,dmu_ref=yg,restricted_optimal = FALSE);efficiencies(gce3v)
gce4v=model_profit(h,price_input=t(hd[y4,7:9]),rts="vrs",dmu_eval=y4,dmu_ref=yg,restricted_optimal = FALSE);efficiencies(gce4v)
gce5v=model_profit(h,price_input=t(hd[y5,7:9]),rts="vrs",dmu_eval=y5,dmu_ref=yg,restricted_optimal = FALSE);efficiencies(gce5v)
gce6v=model_profit(h,price_input=t(hd[y6,7:9]),rts="vrs",dmu_eval=y6,dmu_ref=yg,restricted_optimal = FALSE);efficiencies(gce6v)
gce7v=model_profit(h,price_input=t(hd[y7,7:9]),rts="vrs",dmu_eval=y7,dmu_ref=yg,restricted_optimal = FALSE);efficiencies(gce7v)
gce8v=model_profit(h,price_input=t(hd[y8,7:9]),rts="vrs",dmu_eval=y8,dmu_ref=yg,restricted_optimal = FALSE);efficiencies(gce8v)
gce9v=model_profit(h,price_input=t(hd[y9,7:9]),rts="vrs",dmu_eval=y9,dmu_ref=yg,restricted_optimal = FALSE);efficiencies(gce9v)
gce10v=model_profit(h,price_input=t(hd[y10,7:9]),rts="vrs",dmu_eval=y10,dmu_ref=yg,restricted_optimal = FALSE);efficiencies(gce10v)
gce11v=model_profit(h,price_input=t(hd[y11,7:9]),rts="vrs",dmu_eval=y11,dmu_ref=yg,restricted_optimal = FALSE);efficiencies(gce11v)
gce12v=model_profit(h,price_input=t(hd[y12,7:9]),rts="vrs",dmu_eval=y12,dmu_ref=yg,restricted_optimal = FALSE);efficiencies(gce12v)
gce13v=model_profit(h,price_input=t(hd[y13,7:9]),rts="vrs",dmu_eval=y13,dmu_ref=yg,restricted_optimal = FALSE);efficiencies(gce13v)
gce14v=model_profit(h,price_input=t(hd[y14,7:9]),rts="vrs",dmu_eval=y14,dmu_ref=yg,restricted_optimal = FALSE);efficiencies(gce14v)
gce15v=model_profit(h,price_input=t(hd[y15,7:9]),rts="vrs",dmu_eval=y15,dmu_ref=yg,restricted_optimal = FALSE);efficiencies(gce15v)
gce16v=model_profit(h,price_input=t(hd[y16,7:9]),rts="vrs",dmu_eval=y16,dmu_ref=yg,restricted_optimal = FALSE);efficiencies(gce16v)
gce17v=model_profit(h,price_input=t(hd[y17,7:9]),rts="vrs",dmu_eval=y17,dmu_ref=yg,restricted_optimal = FALSE);efficiencies(gce17v)
```

gce18v=model_profit(h,price_input=t(hd[y18,7:9]),rts="vrs",dmu_eval=y18,dmu_ref=yg,restricted_optimal = FALSE);efficiencies(gce18v)

gce19v=model_profit(h,price_input=t(hd[y19,7:9]),rts="vrs",dmu_eval=y19,dmu_ref=yg,restricted_optimal = FALSE);efficiencies(gce19v)

gce20v=model_profit(h,price_input=t(hd[y20,7:9]),rts="vrs",dmu_eval=y20,dmu_ref=yg,restricted_optimal = FALSE);efficiencies(gce20v)

gce21v=model_profit(h,price_input=t(hd[y21,7:9]),rts="vrs",dmu_eval=y21,dmu_ref=yg,restricted_optimal = FALSE);efficiencies(gce21v)

gce22v=model_profit(h,price_input=t(hd[y22,7:9]),rts="vrs",dmu_eval=y22,dmu_ref=yg,restricted_optimal = FALSE);efficiencies(gce22v)

gce23v=model_profit(h,price_input=t(hd[y23,7:9]),rts="vrs",dmu_eval=y23,dmu_ref=yg,restricted_optimal = FALSE);efficiencies(gce23v)

gcm_t12v=mean(efficiencies(gce1v))/mean(efficiencies(gce2v))

gcm_t23v=mean(efficiencies(gce2v))/mean(efficiencies(gce3v))

gcm_t34v=mean(efficiencies(gce3v))/mean(efficiencies(gce4v))

gcm_t45v=mean(efficiencies(gce4v))/mean(efficiencies(gce5v))

gcm_t56v=mean(efficiencies(gce5v))/mean(efficiencies(gce6v))

gcm_t67v=mean(efficiencies(gce6v))/mean(efficiencies(gce7v))

gcm_t78v=mean(efficiencies(gce7v))/mean(efficiencies(gce8v))

gcm_t89v=mean(efficiencies(gce8v))/mean(efficiencies(gce9v))

gcm_t910v=mean(efficiencies(gce9v))/mean(efficiencies(gce10v))

gcm_t1011v=mean(efficiencies(gce10v))/mean(efficiencies(gce11v))

gcm_t1112v=mean(efficiencies(gce11v))/mean(efficiencies(gce12v))

gcm_t1213v=mean(efficiencies(gce12v))/mean(efficiencies(gce13v))

gcm_t1314v=mean(efficiencies(gce13v))/mean(efficiencies(gce14v))

gcm_t1415v=mean(efficiencies(gce14v))/mean(efficiencies(gce15v))

gcm_t1516v=mean(efficiencies(gce15v))/mean(efficiencies(gce16v))

gcm_t1617v=mean(efficiencies(gce16v))/mean(efficiencies(gce17v))

gcm_t1718v=mean(efficiencies(gce17v))/mean(efficiencies(gce18v))

gcm_t1819v=mean(efficiencies(gce18v))/mean(efficiencies(gce19v))

gcm_t1920v=mean(efficiencies(gce19v))/mean(efficiencies(gce20v))

gcm_t2021v=mean(efficiencies(gce20v))/mean(efficiencies(gce21v))

gcm_t2122v=mean(efficiencies(gce21v))/mean(efficiencies(gce22v))

```
gcm_t2223v=mean(efficiencies(gce22v))/mean(efficiencies(gce23v))

writexl::write_xlsx(data.frame(gcm_t12v,gcm_t23v,gcm_t34v,gcm_t45v,gcm_t56v,gcm_t67v
    ,gcm_t78v,gcm_t89v,gcm_t910v,gcm_t1011v,gcm_t1112v,gcm_t1213v,gcm_t1314v,gc
    m_t1415v,gcm_t1516v,

    gcm_t1617v,gcm_t1718v,gcm_t1819v,gcm_t1920v,gcm_t2021v,gcm_t2122v,gcm_t2223
    v),path="C:/Users/DELL E7450/Documents/my_gcm_t.xlsx")

#PROPOSED MODEL (2024)-Working Paper

#Global Cost Technical Index

CTI1v=model_profit(h,price_input=t(hd[yg,7:9]),rts="vrs",dmu_eval=yg,dmu_ref=y1,restrict
    ed_optimal = FALSE);efficiencies(CTI1v)

CTI2v=model_profit(h,price_input=t(hd[yg,7:9]),rts="vrs",dmu_eval=yg,dmu_ref=y2,restrict
    ed_optimal = FALSE);efficiencies(CTI2v)

CTI3v=model_profit(h,price_input=t(hd[yg,7:9]),rts="vrs",dmu_eval=yg,dmu_ref=y3,restrict
    ed_optimal = FALSE);efficiencies(CTI3v)

CTI4v=model_profit(h,price_input=t(hd[yg,7:9]),rts="vrs",dmu_eval=yg,dmu_ref=y4,restrict
    ed_optimal = FALSE);efficiencies(CTI4v)

CTI5v=model_profit(h,price_input=t(hd[yg,7:9]),rts="vrs",dmu_eval=yg,dmu_ref=y5,restrict
    ed_optimal = FALSE);efficiencies(CTI5v)

CTI6v=model_profit(h,price_input=t(hd[yg,7:9]),rts="vrs",dmu_eval=yg,dmu_ref=y6,restrict
    ed_optimal = FALSE);efficiencies(CTI6v)

CTI7v=model_profit(h,price_input=t(hd[yg,7:9]),rts="vrs",dmu_eval=yg,dmu_ref=y7,restrict
    ed_optimal = FALSE);efficiencies(CTI7v)

CTI8v=model_profit(h,price_input=t(hd[yg,7:9]),rts="vrs",dmu_eval=yg,dmu_ref=y8,restrict
    ed_optimal = FALSE);efficiencies(CTI8v)

CTI9v=model_profit(h,price_input=t(hd[yg,7:9]),rts="vrs",dmu_eval=yg,dmu_ref=y9,restrict
    ed_optimal = FALSE);efficiencies(CTI9v)

CTI10v=model_profit(h,price_input=t(hd[yg,7:9]),rts="vrs",dmu_eval=yg,dmu_ref=y10,restr
    icted_optimal = FALSE);efficiencies(CTI10v)

CTI11v=model_profit(h,price_input=t(hd[yg,7:9]),rts="vrs",dmu_eval=yg,dmu_ref=y11,restr
    icted_optimal = FALSE);efficiencies(CTI11v)

CTI12v=model_profit(h,price_input=t(hd[yg,7:9]),rts="vrs",dmu_eval=yg,dmu_ref=y12,restr
    icted_optimal = FALSE);efficiencies(CTI12v)

CTI13v=model_profit(h,price_input=t(hd[yg,7:9]),rts="vrs",dmu_eval=yg,dmu_ref=y13,restr
    icted_optimal = FALSE);efficiencies(CTI13v)
```

```
CTI14v=model_profit(h,price_input=t(hd[yg,7:9]),rts="vrs",dmu_eval=yg,dmu_ref=y14,restr
    icted_optimal = FALSE);efficiencies(CTI14v)
CTI15v=model_profit(h,price_input=t(hd[yg,7:9]),rts="vrs",dmu_eval=yg,dmu_ref=y15,restr
    icted_optimal = FALSE);efficiencies(CTI15v)
CTI16v=model_profit(h,price_input=t(hd[yg,7:9]),rts="vrs",dmu_eval=yg,dmu_ref=y16,restr
    icted_optimal = FALSE);efficiencies(CTI16v)
CTI17v=model_profit(h,price_input=t(hd[yg,7:9]),rts="vrs",dmu_eval=yg,dmu_ref=y17,restr
    icted_optimal = FALSE);efficiencies(CTI17v)
CTI18v=model_profit(h,price_input=t(hd[yg,7:9]),rts="vrs",dmu_eval=yg,dmu_ref=y18,restr
    icted_optimal = FALSE);efficiencies(CTI18v)
CTI19v=model_profit(h,price_input=t(hd[yg,7:9]),rts="vrs",dmu_eval=yg,dmu_ref=y19,restr
    icted_optimal = FALSE);efficiencies(CTI19v)
CTI20v=model_profit(h,price_input=t(hd[yg,7:9]),rts="vrs",dmu_eval=yg,dmu_ref=y20,restr
    icted_optimal = FALSE);efficiencies(CTI20v)
CTI21v=model_profit(h,price_input=t(hd[yg,7:9]),rts="vrs",dmu_eval=yg,dmu_ref=y21,restr
    icted_optimal = FALSE);efficiencies(CTI21v)
CTI22v=model_profit(h,price_input=t(hd[yg,7:9]),rts="vrs",dmu_eval=yg,dmu_ref=y22,restr
    icted_optimal = FALSE);efficiencies(CTI22v)
CTI23v=model_profit(h,price_input=t(hd[yg,7:9]),rts="vrs",dmu_eval=yg,dmu_ref=y23,restr
    icted_optimal = FALSE);efficiencies(CTI23v)


writexl::write_xlsx(data.frame(hd[,1],"CTI1v"=efficiencies(CTI1v),"CTI2v"=efficiencies(CT
    I2v),"CTI3v"=efficiencies(CTI3v),"CTI4v"=efficiencies(CTI4v),"CTI5v"=efficiencies(
    CTI5v),"CTI6v"=efficiencies(CTI6v),

    "CTI7v"=efficiencies(CTI7v),"CTI8v"=efficiencies(CTI8v),"CTI9v"=efficiencies(CTI9
    v),"CTI10v"=efficiencies(CTI10v),"CTI11v"=efficiencies(CTI11v),"CTI12v"=efficienci
    es(CTI12v),

    "CTI13v"=efficiencies(CTI13v),"CTI14v"=efficiencies(CTI14v),"CTI15v"=efficiencies
    (CTI15v),"CTI16v"=efficiencies(CTI16v),"CTI17v"=efficiencies(CTI17v),"CTI18v"=ef
    ficiencies(CTI18v),

    "CTI19v"=efficiencies(CTI19v),"CTI20v"=efficiencies(CTI20v),"CTI21v"=efficiencies
    (CTI21v),"CTI22v"=efficiencies(CTI22v),"CTI23v"=efficiencies(CTI23v)),path="C:/Us
    ers/DELL E7450/Documents/my_gcfs.xlsx")


#Global Cost Efficiency Change

gcec12v=exp(mean(log(efficiencies(C2_2v))))/exp(mean(log(efficiencies(C1_1v)))) #Global
    Cost Eff yr1 to yr2
```

```
gcec23v=exp(mean(log(efficiencies(C3_3v))))/exp(mean(log(efficiencies(C2_2v)))) #Global
    Cost Eff yr2 to yr3
gcec34v=exp(mean(log(efficiencies(C4_4v))))/exp(mean(log(efficiencies(C3_3v)))) #Global
    Cost Eff yr3 to yr4
gcec45v=exp(mean(log(efficiencies(C5_5v))))/exp(mean(log(efficiencies(C4_4v))))
gcec56v=exp(mean(log(efficiencies(C6_6v))))/exp(mean(log(efficiencies(C5_5v))))
gcec67v=exp(mean(log(efficiencies(C7_7v))))/exp(mean(log(efficiencies(C6_6v))))
gcec78v=exp(mean(log(efficiencies(C8_8v))))/exp(mean(log(efficiencies(C7_7v))))
gcec89v=exp(mean(log(efficiencies(C9_9v))))/exp(mean(log(efficiencies(C8_8v))))
gcec910v=exp(mean(log(efficiencies(C10_10v))))/exp(mean(log(efficiencies(C9_9v))))
gcec1011v=exp(mean(log(efficiencies(C11_11v))))/exp(mean(log(efficiencies(C10_10v))))
gcec1112v=exp(mean(log(efficiencies(C12_12v))))/exp(mean(log(efficiencies(C11_11v))))
gcec1213v=exp(mean(log(efficiencies(C13_13v))))/exp(mean(log(efficiencies(C12_12v))))
gcec1314v=exp(mean(log(efficiencies(C14_14v))))/exp(mean(log(efficiencies(C13_13v))))
gcec1415v=exp(mean(log(efficiencies(C15_15v))))/exp(mean(log(efficiencies(C14_14v))))
gcec1516v=exp(mean(log(efficiencies(C16_16v))))/exp(mean(log(efficiencies(C15_15v))))
gcec1617v=exp(mean(log(efficiencies(C17_17v))))/exp(mean(log(efficiencies(C16_16v))))
gcec1718v=exp(mean(log(efficiencies(C18_18v))))/exp(mean(log(efficiencies(C17_17v))))
gcec1819v=exp(mean(log(efficiencies(C19_19v))))/exp(mean(log(efficiencies(C18_18v))))
gcec1920v=exp(mean(log(efficiencies(C20_20v))))/exp(mean(log(efficiencies(C19_19v))))
gcec2021v=exp(mean(log(efficiencies(C21_21v))))/exp(mean(log(efficiencies(C20_20v))))
gcec2122v=exp(mean(log(efficiencies(C22_22v))))/exp(mean(log(efficiencies(C21_21v))))
gcec2223v=exp(mean(log(efficiencies(C23_23v))))/exp(mean(log(efficiencies(C22_22v))))

writexl::write_xlsx(data.frame(gcec12v,gcec23v,gcec34v,gcec45v,gcec56v,gcec67v,gcec78v,
    gcec89v,gcec910v,gcec1011v,gcec1112v,gcec1213v,gcec1314v,gcec1415v,gcec1516v,

    gcec1617v,gcec1718v,gcec1819v,gcec1920v,gcec2021v,gcec2122v,gcec2223v),path="C
    :/Users/DELL E7450/Documents/my_gcec.xlsx")

#Global Cost Frontier Shift
#Calculated in Excel
#Global Cost Malmquist Index
#Calculated in Excel
```

Appendix 2: R Codes for Descriptive Analysis

```
###DATA ANALYSIS###
ins=read.delim("clipboard")
str(ins)
is.na(ins)
(colMeans(is.na(ins)))*100
library(psych)
library(skimr)
describe(ins)
skimr::skim(ins)
attach(ins)
###Description of Data by Time###
describeBy(ins,Year)
X1Year=aov(X1~Year);summary(X1Year)
X2Year=aov(X2~Year);summary(X2Year)
X3Year=aov(X3~Year);summary(X3Year)
Y1Year=aov(Y1~Year);summary(Y1Year)
Y2Year=aov(Y2~Year);summary(Y2Year)
W1Year=aov(W1~Year);summary(W1Year)
W2Year=aov(W2~Year);summary(W2Year)
W3Year=aov(W3~Year);summary(W3Year)

#correlation
library(Hmisc)
rcorr(as.matrix(round(cor(ins[sapply(ins,is.numeric)]),2)))

###RETURNS TO SCALE###
p=read.delim("clipboard") ##Loading the Dataset
names(p)
options(max.print=999999)
X0<-cbind(p$X1[1:495],p$X2[1:495],p$X3[1:495])
Y0<-cbind(p$Y1[1:495],p$Y2[1:495])
```

```
ID0=p$dmu[1:495]

##Loading all Required Packages
require(Benchmarking)
require(stats)
require(KernSmooth)
require(MASS)
require(psych)
require(abind)
require(RcmdrMisc)

###Test of hypothesis in DEA model
# Null hypothesis is that technology is CRS and the alternative is VRS
# Bogetoft and Otto (2011) pages 183--185.
X0=matrix(cbind(p$X1,p$X2,p$X3),nrow=3)##Matrix of inputs
Y0=matrix(cbind(p$Y1,p$Y2),nrow=2)##Matrix of Outputs

ec <- dea(t(X0),t(Y0),RTS=3)
Ec <- eff(ec)
ev <- dea(t(X0),t(Y0),RTS=1)
Ev <- eff(ev)

# The test statistic; (Bogetoft & Otto, 2011, equation 6.1)
S1 <- (sum(Ec/Ev))/495 #mean of ratios

# To calculate CRS and VRS efficiency in the same bootstrap replicas
# we reset the random number generator before each call of the
# function dea.boot.

# To get the an initial value for the random number generating process
# we save its state (seed)
save.seed <- sample.int(1e9,1)
```

```
# The bootstrap and calculate CRS and VRS under the assumption that
# the true technology is CRS (the null hypothesis) and such that the
# results corresponds to the case where CRS and VRS are calculated for
# the same reference set of firms; to make this happen we set the
# random number generator to the same state before the calls.
set.seed(save.seed) #save record for other works
nrep=2000 #no of bootstrap replications
bc <- dea.boot(t(X0),t(Y0), nrep, RTS="crs")
head(bc)
set.seed(save.seed)
bv <- dea.boot(t(X0),t(Y0), nrep, RTS="vrs", XREF=t(X0),YREF=t(Y0), EREF=ec$eff)

# Calculate the statistic for each bootstrap replica
bs1 <- colSums(((bc$boot)/(bv$boot))/495)
# The critical value for the test (default size \code{alpha} of test is 1%)
critValue(bs1, alpha=.05)
critValue(bs1, alpha=.01)
S1
# Accept the hypothesis at 1% level?
critValue(bs1, alpha=.05) <= S1
critValue(bs1, alpha=.01) <= S1

# The probability of observing a smaller value of S when the
# hypothesis is true; the p--value.
typeIerror(S1, bs1)

# Accept the hypothesis at size level 1%?
typeIerror(S1,bs1) >= .05 #false means reject Ho at 5%
typeIerror(S1, bs1) >= .01 #True means accept Ho @ 1%- Means that the Ho it is not
    significant at 1%
```

```
# The test statistic; (Bogetoft & Otto, 2011, equation 6.1)
S2 <- sum(Ec)/sum(Ev)#ratio of means

# To calculate CRS and VRS efficiency in the same bootstrap replicas
# we reset the random number generator before each call of the
# function dea.boot.

# To get the an initial value for the random number generating process
# we save its state (seed)
save.seed <- sample.int(1e9,1)

# The bootstrap and calculate CRS and VRS under the assumption that
# the true technology is CRS (the null hypothesis) and such that the
# results corresponds to the case where CRS and VRS are calculated for
# the same reference set of firms; to make this happen we set the
# random number generator to the same state before the calls.
set.seed(save.seed) #save record for other works
nrep=2000 #no of bootstrap replications
bc <- dea.boot(t(X0),t(Y0), nrep, RTS="crs")
head(bc)
set.seed(save.seed)
bv <- dea.boot(t(X0),t(Y0), nrep, RTS="vrs", XREF=t(X0),YREF=t(Y0), EREF=ec$eff)

# Calculate the statistic for each bootstrap replica
bs2 <- colSums(bc$boot)/colSums(bv$boot)
# The critical value for the test (default size \code{alpha} of test is 1%)
critValue(bs2, alpha=.05)
critValue(bs2, alpha=.01)
S2
# Accept the hypothesis at 1% level?
critValue(bs2, alpha=.05) <= S2
critValue(bs2, alpha=.01) <= S2
```

```
# The probability of observing a smaller value of S when the
# hypothesis is true; the p--value.
typeIerror(S2, bs2)
# Accept the hypothesis at size level 1%?
typeIerror(S2, bs2) >= .05 #false means reject Ho at 5%
typeIerror(S2, bs2) >= .01 #True means accept Ho @ 1%- Means that the Ho it is not
    significant at 1%

# The test statistic; (Bogetoft & Otto, 2011, equation 6.1)
S3 <- (sum((Ec/Ev)-1))/495 #mean of ratios minus 1

# To calculate CRS and VRS efficiency in the same bootstrap replicas
# we reset the random number generator before each call of the
# function dea.boot.
# To get the an initial value for the random number generating process
# we save its state (seed)
save.seed <- sample.int(1e9,1)

# The bootstrap and calculate CRS and VRS under the assumption that
# the true technology is CRS (the null hypothesis) and such that the
# results corresponds to the case where CRS and VRS are calculated for
# the same reference set of firms; to make this happen we set the
# random number generator to the same state before the calls.
set.seed(save.seed) #save record for other works
nrep=2000 #no of bootstrap replications
bc <- dea.boot(t(X0),t(Y0), nrep, RTS="crs")
head(bc)
set.seed(save.seed)
bv <- dea.boot(t(X0),t(Y0), nrep, RTS="vrs", XREF=t(X0),YREF=t(Y0), EREF=ec$eff)

# Calculate the statistic for each bootstrap replica
bs3 <- (colSums((bc$boot)/(bv$boot))/495)
```

```
# The critical value for the test (default size \code{alpha} of test is 1%)
critValue(bs3, alpha=.05)
critValue(bs3, alpha=.01)
S3
# Accept the hypothesis at 1% level?
critValue(bs3, alpha=.05) <= S3
critValue(bs3, alpha=.01) <= S3

# The probability of observing a smaller value of S when the
# hypothesis is true; the p--value.
typeIerror(abs(S3), bs3)
# Accept the hypothesis at size level 1%?
typeIerror(abs(S3), bs3) >= .05 #false means reject Ho at 5%
typeIerror(abs(S3), bs3) >= .01 #True means accept Ho @ 1%- Means that the Ho it is not significant at 1%


###PLOTS
vp=read.delim("clipboard") #imports the compiled Global Productivity scores from excel
vp$Component <- as.factor(vp$Component) #Converts the variable dose from a numeric to a factor variable
attach(vp)
library(ggplot2)
ggplot(vp, aes(x=Component, y= CP, fill=Component)) + geom_violin(trim=TRUE) + geom_boxplot(width=0.1, fill="gold") + labs(x="Component of GCMI", y = "Component Scores") #Change color by groups


###Statistical Tests of Differences in Productivity Measurement Types##Null Hypothesis-the population mean/median of all the group are equal, Alternate Hypothesis- atleast one population mean/median is different from the others#
vp1=read.delim("clipboard")
attach(vp1)
kruskal.test(Type~MI) #non-parametric test of differences of MI between Type (KruskalWallistest)
```

```
data <- data.frame(
  Type = c(1.104, 1.097, 1.16, 0.869, 1.029, 0.875, 0.939, 1.286, 0.993, 0.955,
           1.105, 1.038, 1.048, 1.108, 0.924, 0.929, 1.015, 1.084, 0.982, 0.951,
           1.025, 0.899, 1.116, 1.075, 0.886, 1.113, 1.079, 1.075, 1.007, 0.756,
           0.993, 1.014, 0.926, 0.916, 0.901, 0.948, 1.096, 0.965, 1.152, 0.794,
           0.932, 0.949, 0.852, 1.035, 0.932, 1.020, 1.026, 0.952, 0.972, 0.937,
           0.927, 0.967, 0.963, 0.895, 1.279, 0.855, 1.077, 0.903, 0.804, 0.919,
           0.984, 1.043, 0.723, 0.880, 0.863, 0.867),
  MI = factor(c(rep("CPI", 22), rep("GCMT", 22), rep("GCMI", 22)))
)

# Verify the data structure
str(data)

# Run ANOVA
MIType <- aov(Type ~ MI, data=data)

# Get ANOVA summary
summary(MIType)
data_wide <- data.frame(
  CPI = data$Type[data$MI == "CPI"],
  GCMT = data$Type[data$MI == "GCMT"],
  GCMI = data$Type[data$MI == "GCMI"]
)

# Function to calculate Cohen's d for paired data
cohens_d_paired <- function(x, y) {
  d <- (mean(x) - mean(y)) / sd(x - y)
  return(d)
}

# 1. Paired t-test: CPI vs GCMI
```

```
t_test_cpi_gcmi <- t.test(data_wide$CPI, data_wide$GCMI, paired = TRUE)
d_cpi_gcmi <- cohens_d_paired(data_wide$CPI, data_wide$GCMI)

# 2. Paired t-test: GCMT vs GCMI
t_test_gcmt_gcmi <- t.test(data_wide$GCMT, data_wide$GCMI, paired = TRUE)
d_gcmt_gcmi <- cohens_d_paired(data_wide$GCMT, data_wide$GCMI)

# Print results
cat("Paired t-test Results:\n\n")

# CPI vs GCMI
cat("2. CPI vs GCMI:\n")
cat("Mean difference:", round(mean(data_wide$CPI - data_wide$GCMI), 4), "\n")
cat("t-value:", round(t_test_cpi_gcmi$statistic, 4), "\n")
cat("degrees of freedom:", t_test_cpi_gcmi$parameter, "\n")
cat("p-value:", round(t_test_cpi_gcmi$p.value, 4), "\n")
cat("95% CI:", round(t_test_cpi_gcmi$conf.int[1], 4), "to",
   round(t_test_cpi_gcmi$conf.int[2], 4), "\n")
cat("Cohen's d:", round(d_cpi_gcmi, 4), "\n\n")

# GCMT vs GCMI
cat("3. GCMT vs GCMI:\n")
cat("Mean difference:", round(mean(data_wide$GCMT - data_wide$GCMI), 4), "\n")
cat("t-value:", round(t_test_gcmt_gcmi$statistic, 4), "\n")
cat("degrees of freedom:", t_test_gcmt_gcmi$parameter, "\n")
cat("p-value:", round(t_test_gcmt_gcmi$p.value, 4), "\n")
cat("95% CI:", round(t_test_gcmt_gcmi$conf.int[1], 4), "to",
   round(t_test_gcmt_gcmi$conf.int[2], 4), "\n")
cat("Cohen's d:", round(d_gcmt_gcmi, 4), "\n\n")
```