ADDIS ABABA UNIVERSITY
COLLEGE OF BUSINESS AND ECONOMICS
SCHOOL OF GRADUATE STUDIES

ANALYSIS OF THE EFFICIENCY OF INTEREST FREE BANKING WINDOWS AT DISTRICTS LEVEL: THE CASE OF DASHEN BANK SC

A Thesis Submitted to Addis Ababa University, College of Business and Economics, School of Graduate Studies, in Partial Fulfilment of the Requirements for the Degree of Master of Business Administration (MBA)

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ADDIS ABABA

Statement of Declaration

I, hereby, declare that this thesis entitled "**Analysis of the Efficiency of Interest Free Banking Windows at Districts level: The Case of Dashen Bank SC"** is submitted in partial fulfilment of the requirements for the award of the degree of Master of Business Administration with guidance and support of the thesis advisor. This study is my original work and it has never been presented for any degree or diploma program in this or any other university. All sources and materials used in this thesis have been appropriately acknowledged.

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Statement of Certification

This is to certify that the thesis prepared by Mesfin Bezu entitled **"Analysis of the Efficiency of Interest Free Banking Windows at Districts level: The Case of Dashen Bank SC"** submitted in partial fulfilment of the requirement for the award of the degree of Master in Business Administration complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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ACRONYMS AND ABBREVIATIONS

AE	Allocative Efficiency
ATMs	Automated Teller Machines
CSR	Constant Returns to Scale
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
EFFCH	Efficiency Change
EPS	Earnings Per Share
ETB	Ethiopian Birr
FDRE	Federal Democratic Republic of Ethiopia
FCY	Foreign Currency
GMM	Generalized Method of Moments
ICT	Information and Communication Technology
IFB	Interest Free Banking
IMF	International Monetary Fund
IRS	Increasing Returns to Scale
KPI	Key Performance Indicator
MPI	Malmquist Productivity Index
MSME	Micro, Small, and Medium Enterprises
NBE	National Bank of Ethiopia
OLS	Ordinary Least Squares
PECH	Pure Efficiency Change
POS	Point of Sale
ROA	Return on Assets
ROE	Return on Equity
SC	Share Company
SECH	Scale Efficiency Change
SFA	Stochastic Frontier Analysis
TC	Technological Change
TEC	Technical Efficiency Change
TECHCH	Technology change
TFP	Total Factor Productivity
TFPCH	Total Factor Productivity Change
VRS	Variable Returns to Scale

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ABSTRACT

This study evaluates the efficiency of Dashen Bank's District-level Interest-Free banking operations from July 2018 to June 2023 using the DEA-based Malmquist Productivity Index and a one-step system GMM dynamic data approach. Covering all 12 Districts, the research identifies trends in productivity, emphasizing the intermediary function of banks. The analysis, based on constant returns to scale, compares efficiency and productivity to establish performance benchmarks. Input variables included personnel expenses, operating expenses, and total deposits, while output variables comprised income from financing, advances and investments, service charges, and commissions. Findings indicate a modest average annual efficiency improvement of 0.2%, with significant disparities among Districts. Dire Dawa District led with a 0.6% improvement, while Adama District recorded the lowest efficiency. In terms of total factor productivity (TFP), West Addis Ababa District showed the highest positive change at 17.2%, whereas Adama District had the most significant decline at 20.9%. The study highlights the substantial impact of technological advancements on overall productivity. Districts leading in productivity, such as West Addis Ababa, Wolaita, and South Addis Ababa, demonstrated notable technological improvements of 17.2%, 15.6%, and 15.0%, respectively. The study also revealed that deposit and income growth positively influence district efficiency, while expense growth has a negative but insignificant impact. Strategic recommendations include continuous technology investment, operational efficiency enhancements, scale optimization, baseline efficiency standards, regular performance monitoring, staff development, strategic partnerships, enhanced deposit mobilization, revenue-generating activities, continuous improvement programs, and potential district reorganization to address disparities.

Keywords: *Interest Free Banking, Islamic Banking, Interest Free Banking Window, Islamic Window, Malmquist Productivity Index, Total Factor Productivity Change, Efficiency Change, Technology Change, Bank Performance, Dashen Bank*

CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

Islamic Banking is a system of banking that complies with the principles of Islamic law (Shari'ah). This system prohibits the payment or receipt of interest (riba) and emphasizes profit-sharing, risk-sharing, and ethical investment (Lewis & Algaoud, 2001). The global IFB sector has experienced significant growth over the past few decades, driven by an increasing demand for Shari'ah-compliant financial products. According to the Islamic Financial Services Board (2023), the assets of the Islamic banking sector reached USD 2.25 trillion by the end of 2022, reflecting its growing importance in the global financial system.

The Ethiopian banking sector has undergone significant transformations over the years, with a notable shift towards incorporating Islamic Banking. Islamic Banking is referred as Interest-Free Banking (IFB) as per National Bank of Ethiopia (NBE) directive SBB/51/2011. The regulatory environment in Ethiopia began accommodating IFB with the enactment of Proclamation No. 592/2008, which allowed the NBE to issue directives regulating non-interest-bearing financial services. Despite initial challenges, including the unsuccessful attempt to establish ZamZam Bank, Ethiopia's first full-fledged Islamic bank, the landscape has evolved to support IFB within conventional banking frameworks (Ali & Hailu, 2022).

Dashen Bank, one of the private banks in Ethiopia, launched its IFB services, branded as Sharik, on March 5, 2018. Dashen Bank coined its name from the highest peak in Ethiopia, mount Dashen. It was founded in September 1995 with an initial paid-up capital of ETB 14.9 Million Birr by eleven shareholders and veteran bankers. It has started its first operation on January 1, 1996 with eleven branches (Dashen Bank, 2023).

As per the Bank's annual report and audited financial statements for the fiscal year ended June 30, 2023, the Bank's capital has increased to ETB 9.34 Billion and its number of Branches has reached 835 excluding nine dedicated Forex Bureaus. As at June 30, 2023, the Bank's total assets have surged to ETB 144.64 Billion and its customer base has reached 5.3 million.

At the close of the fiscal year 2022/23, the bank has mobilized ETB 114.8 billion and extended loans and advances (including Interest-Free Financing) worth ETB 100.2 Billion. The Bank has generated a total revenue of ETB 17.9 billion and incurred a total expense of ETB 12.9 Billion. It has, thus, recorded a profit before tax of ETB 5.0 billion at the end of the fiscal year 2022/23.

Initially, Dashen Bank's Shari'ah Compliant service used to be provided through dedicated windows in conventional branches, eventually with the regulatory change that came in 2019, the Bank started rendering its interest-free banking services through full-fledged IFB Branches. As per the annual report issued for the fiscal year 2022/23, the bank is rendering the service through 784 windows of conventional branches and 67 dedicated full-fledged IFB branches.

The Bank has managed to attract 720,818 account holders in its Interest-Free banking business segment. It has achieved substantial progress in mobilizing resources from this business segment after the commercialization of the service. The IFB deposits stood at ETB 8.1 billion as per its audited financial statements for the period ending June 30, 2023. The report also indicated that the Bank has availed ETB 5.2 billion in the form of Interest-Free financing and investments to individuals, MSMEs, and corporate institutions engaged in various economic sectors. The Bank has achieved a relatively modest profit before tax of Birr 155.9 million birr from the IFB business segment.

Dashen Bank has concluded its 5th-year strategy plan that covered the fiscal year 2018/19 to 2022/23 and has been crafting another new five-year corporate strategy that sets the course for its growth (Dashen Bank, 2023). This is a good opportune moment to look back at the performance of its IFB window efficiency in the previous strategic period to draw important lessons and draft a new strategy to drive the success of the business segment.

Several techniques are commonly used to analyse bank efficiency, each with distinct advantages and applications. Despite the lack of a universally accepted method (Wheelock & Wilson, 1995), various studies have explored efficiency of Banks using prevalent models including traditional ratio models, parametric techniques like stochastic frontier analysis, and non-parametric techniques such as data envelopment analysis (Paradi & Zhu, 2013; Bayeh, Zeleke, & Belay, 2018).

Despite extensive research on bank efficiency, significant gaps remain, particularly in Ethiopia, concerning the efficiency of Islamic Banking, including Interest-Free Banking (IFB) windows and full-fledged branches at regional or district levels. Most studies concentrate on national assessments or individual branches, with limited regional analysis employing advanced methods such as Data Envelopment Analysis (DEA) and Malmquist Productivity Index (MPI).

This paper aims to analyse the relative efficiency and productivity change of Dashen Bank's District Interest-Free banking window performances over a period of five years (from 2018/19-2022/23) using Data Envelopment Analysis (DEA) based Malmquist productivity index(MPI).

1.2 Statement of the Problem

Branch expansion in banks can present challenges in terms of cost efficiency and profitability. Studies have shown that branch network expansion can have a negative impact on efficiency, especially when there is an increased distance between headquarters and branches (Bernini & Brighi, 2018). Bernini and Brighi (2018) further argue that branch expansion can lead to operational inefficiencies and create losses, which can adversely affect the profitability of the bank.

Hailu (2014) investigated whether branch expansion is favourable or not for Awash Bank (the first and largest private bank in Ethiopia) and found out that about 58% of the branches of the bank incurred loss. He further concluded that branch expansion may not help the bank increase its deposit mobilization as deposits and loans outstanding will continue to be concentrated in big branches and the bank should restrict its branch expansion, particularly in the face of growing inefficient branches. He further argues that the existing branches should be strengthened with new banking technologies rather than distributing resources everywhere in a way to expand branches which proved to be inefficient.

An internal review conducted by another private bank in Ethiopia, Wegagen Bank, revealed that many of its branches are underperforming in terms of targets and key performance indicators (KPIs) such as deposits, customer base, and foreign currency generation (Abebe, 2022). Dashen Bank is no exception; many of its districts and branches also fall short of major KPIs and other metrics.

However, branch expansion can lead to more efficient lending and increased economic activity in economies with protected credit markets as seen in the case of public sector banks in India (Chakraborty, Javadekar & Ramacharan, 2021). This is due to greater credit market competition resulting from the branching of public sector banks and their lending practices towards poorly performing firms to stimulate economic activity.

It is, thus, important for banks to strike a balance between branch expansion and operational efficiency, and to consider the local economic impact and other market competition when expanding their branch networks.

Dashen Bank organized its strategic branch operations across 12 Districts based on various economic potential activities of regions across the country. This has fostered efficient allocation of resources, identification of the growth opportunities in each region so as to respond to the market dynamics, building personalized customer relationships to enhance customer satisfaction, and achieving its strategic objectives.

The Bank measures the performance of its Districts and branches under their domain across the major KPI of each business segment (Number of account holders, the volume of deposits and FCY mobilized and Loans and Financing availed, etc.) and various metrics (profitability, percentage of nonperforming loans/financings, percentage of active customers, etc.). The Bank uses such findings to make several strategic decisions including but not limited to new branch expansions at Districts, branch upgrading and downgrading, branch relocations, branch closure, resource allocation (both human and material), investment in technology, and human capital development. The Districts' operational efficiency is also continuously assessed and appropriate measures are taken to improve their effectiveness.

Though the Bank's internal measurement of performance based on defined KPIs and financial ratios gives insights into the performance of Districts and their branches under their domain, the techniques have limitations in distinguishing the efficient Districts from inefficient ones, identifying the determinants of factors causing the efficiency or inefficiency in Districts or branches. The bank needs to employ other tools on top of the already established measurements to make better-informed strategic decisions to achieve its objectives.

Various studies have been conducted globally to analyse the efficiency of both conventional and Islamic banks globally using parametric and non-parametric techniques like Stochastic frontier approach (SFA) and Data Envelopment Analysis (DEA), respectively (Ali & Hailu, 2022). Very few studies have been carried out to examine bank efficiency and productivity in the Ethiopian context (Abdu Kedir, 2006; Lelissa, 2014; Garamu, 2016; Lema, 2016; Lelissa & Mohammed, 2016; Yidersal, 2018; Ram & Mesfin, 2019; Muche, 2019; Berhe, 2021; Hailu, 2022; Ali & Hailu, 2022; Bayiley, 2022; Abebe, 2022).

Despite the availability of literature on the efficiency and productivity of banks and banks' branches of both conventional and Islamic banks (including Islamic Windows) globally and at the national level, there is no study conducted, to the knowledge of the researcher, on the efficiency of a Bank's Interest-Free Banking Window performance either at Branch or District level using a DEA-based Malmquist productivity index.

This study aims to give important insights into the relative efficiency and productivity of Dashen Bank Districts which are considered as Decision Making Units (DMU). It will also further help the bank to identify efficient and inefficient Districts and make appropriate strategic decisions to enable the Districts to achieve the required efficiency to achieve the overall objective of the bank. As the study will fill the gap in knowledge, it can be replicated by similar conventional banks offering Interest-Free Banking windows to get insights and adopt it to their environment. It may also motivate future research in the area for interested researches.

1.3 Research Question

The overarching research question of the study was to analyse the efficiency of Interest-Free Banking (IFB) windows in Dashen Bank across various districts from 2018/19 to 2022/23. The specific research questions included:

- What are the primary inputs and outputs utilized in measuring the efficiency of Interest-Free banking windows in general and the efficiency of individual Districts in particular?
- How can the trends in the efficiency of the Bank's Interest-Free banking windows among different Districts over specified periods be assessed?

- What are the principal causes of inefficiency in the Interest-Free banking windows at the District level?
- How can the performance of Interest-Free banking window in each District be ranked over the given periods?

1.4 Objective of the Study

1.4.1 General Objective

The primary objective of this study is to analyse the efficiency of Interest-Free banking windows in the Districts of Dashen Bank from 2018/19 to 2022/23.

1.4.2 Specific Objectives

The specific objectives are as follows:

- To identify the main inputs and outputs used in measuring the efficiency of Interest-Free banking windows in general and District efficiency in particular.
- To assess the trends in the efficiency of the Bank's Interest-Free banking windows across various Districts over specified periods.
- To identify the causes of inefficiency in Interest-Free banking window services and provide recommendations.
- To rank the performance of each District’s IFB Window over the given periods.

1.5 Significance of the Study

This study aims to provide a framework that could be used to measure the efficiency of Dashen Bank Districts’ interest-free Banking windows. The results of the study help the management and decision-makers to gain insights into the relative efficiency and productivity of Dashen Bank Districts and take remedial actions to increase the efficiency of the District’s IFB windows. It will also aid the management and policymakers in making informed strategic decisions regarding the bank’s IFB business and District operations. The learnings could also be replicated by similar financial institutions by incorporating factors deemed important to the respective institution.

The study will also be an addition to the existing body of knowledge in the study of interest-free banking windows. It will also serve as a foundation for further study into the subject by interested researches by modifying the input and output variables and employing similar or different techniques.

1.6 Limitation of the Study

The study used financial quantitative data obtained from the bank, which are further classified as inputs and outputs. However, the research has not considered additional data such as Interest-Free financing due to the current operating and service model of the IFB window service that has centralized functions of the bank's IFB financing and investment at Head Quarters.

The influence of environmental factors on the District's interest-free banking window efficiencies such as social, economic, and political were not considered in the study. Besides, performance factors suggested to be considered in the Islamic finance business were not considered, for example, Shari'ah related were not taken into account which could have complemented the study to be a holistic assessment of such value-based financial services.

1.7 Scope of the Study

The study encompasses a comprehensive analysis of the efficiency of Dashen Bank's Interest-Free Banking windows across all twelve districts. It spans a detailed examination of the operational performance and efficiency metrics within the specified fiscal years, from 2018/19 to 2022/23. This timeframe allows for the assessment of trends and variations in efficiency over a five-year period, providing a robust dataset for understanding the dynamics of Interest-Free Banking in different districts of Dashen Bank.

1.8 Organization of the Paper

This paper is organized into five chapters. The introduction to the research topic is covered in the first chapter. The second chapter laid the theoretical groundwork for this research by discussing concepts, principles, and existing literature on Islamic banking, efficiency, and its measurement in financial institutions (primarily banks). The proposed methodological approach and techniques employed for the study were articulated and justified in the third chapter. The analysis, discussion, and results were explained in detail in the fourth chapter. Finally, the summary, conclusion, and recommendations were presented in the fifth chapter.

CHAPTER TWO: LITERATURE REVIEW

2.1 Theoretical Literature Review – Islamic Banking

2.1.1 Overview of Islamic Banking

'Islamic banking' refers to a system of banking that is consistent with the principles of Shari'ah. It gives services to its customers free from interest, and the giving and taking of interest is prohibited in all transactions. Islam bans Muslims from taking or giving interest (the Arabic term for which is *riba*), and this prohibition makes an Islamic banking system differ fundamentally from a conventional banking system (Lewis & Algaoud, 2001). However, Islam is not the only religion where the prohibition of riba exists. Other religions like Christianity and Judaism have similar restrictions which are basically similar to the concept of riba in Islam in that they all prohibit the act of charging rent for the use of money (Abdul-Rahman, 2010). The practice of interest has also been condemned by foremost thinkers in human history like Aristotle who dwelt on the "barren" nature of money and vehemently condemned the institution of interest which he described as the "birth of money from money" (Ahmad,1994).

According to Shari'ah, Islamic banks are obliged to engage in "ethical investment" that contributes to the good of society. They are not also allowed to invest or deal with customers who are engaged in businesses that provide goods or services considered Haram. These include business activities that contain elements of uncertainty or gambling, dealing with alcoholic beverages and pork meat, etc. (Lewis & Algaoud, 2001).

Profit-sharing arrangements such as Mudaraba and Musharaka, which are the main features of Islamic banks, almost certainly pre-date the genesis of Islam. However, following the spread of the religion of Islam, interest-based financial transactions were forbidden and all finance had to be conducted on a profit-sharing basis. These practices were prevalent in the subsequent periods among Muslims in their dealings. Experimental attempts with Islamic banking were made, though unsuccessful, in Malaya and Pakistan in the 1940s and 1950s respectively (Lewis & Algaoud, 2001, p. 5).

The first Islamic banking experiment started in Egypt around the early 1960s as a micro-lending finance operation/project in Zefta/Mit Ghamr, a small village in the Nile Delta of Egypt. It was started by Dr. Ahmad Al Naggar who was a young German-educated Egyptian (Abdul-Rahman, 2010). This initiative led to the development of other nine banks. The project was closed in the second half of 1967 after staying for more than four years. These banks, which neither charged nor paid interest, invested mostly by engaging in trade and industry, directly or in partnership with others, and shared the profits with their depositors, yet were functioning essentially as saving investment institutions rather than as full commercial banks.

The first Islamic institution was Nasser Social Bank (Egypt) which was created as an interest-free commercial bank in 1971 (Lewis & Algaoud, 2001). Then after, another private interest-free bank, the Dubai Islamic Bank, was also set up in 1975 by a group of Muslim businessmen from several countries followed by two more private banks that were founded in 1977 under the name of Faisal Islamic Bank in Egypt and the Sudan. In the same year, the Kuwaiti government set up the Kuwait Finance House (Abdul Gafoor, 1995). Islamic banking has also steadily moved into an increasing number of conventional financial systems. It is expanding not only in nations with majority Muslim populations but also in other countries where Muslims are a minority, such as the United Kingdom or Japan (Solé, 2007). Concentrated in Malaysia and Gulf Cooperation Council countries, Islamic finance has expanded throughout the Middle East, Indonesia, the United Kingdom, North Africa, and, more recently, in some Sub-Saharan African countries (Gelbard, Hussain, Maino, Mu, & Yehoue, 2014).

The Islamic finance industry, particularly the Islamic banking sector, has experienced significant growth in the last decades. According to Islamic Financial Services Board (2023) "The Islamic banking segment retained its dominance in terms of asset size of USD 2.25 trillion as of the end of 2022 (2021: USD 2.10 trillion) accounting for 69.3% of the value of global Islamic Financial Services Assets (IFSI assets) (2021: 68.7%). In 2022, the segment recorded a 6.9% y-o-y growth in assets".

This growth is driven by factors such as the increasing acceptance of Islamic banking globally, the perception of higher moral standards and avoidance of unethical activities, and the growing demand for halal products and services (Hu,2023; Higuchi,2022). The growth of the Islamic finance industry, particularly Islamic banking, is driven by both religious and practical motivations, making it an important alternative to conventional finance. But others argue that the growth in Islamic banking and finance appears to be a secular phenomenon (GIFR,2023).

2.1.2 Fundamental Principles of Islamic Banking

Islamic banking is guided by fundamental principles derived from Islamic law, also known as Sharia or Islamic Shari'ah. These principles ensure that financial activities and transactions are conducted in accordance with Islamic ethics. The key principles of Islamic banking include:

Prohibition of Riba (Usury/Interest)

The prohibition of riba is central to Islamic financial ethics and law. Islam prohibits the earning or payment of interest because it is considered exploitative and unjust. All transactions and contracts must be free from elements of riba. The word riba literally means, "increase" or "excess" and the prohibition of riba or usury or interest in financial transactions implies that there is no reward for time preference alone. Reward, returns, or benefits must always accompany liability or Risk (Obaidullah, 2005).

The Implication of the prohibition of riba is to discourage the time value of money as it is applied in the conventional banking sense. Under the Islamic financial system, money is merely a medium of exchange and not a factor of production independently. In order to earn a return, human labour is required in addition to money. Therefore, there is no fixed return for capital. However, capitalists can participate in business under profit and loss sharing with or without participation in the management of the project or entity (Hanif, 2014).

Risk and Profit-and-Loss Sharing

Islamic finance endorses risk sharing as the preferred organizational structure for all economic activities (Askari, Iqbal, Krichne & Mirakhor, 2012). It also encourages profit-and-loss sharing between the provider of funds (investor) and the user of funds (entrepreneur). This is in contrast to conventional banking where interest is fixed and unrelated to the actual performance of the investment. Islamic Banking contracts/products like Mudarabah and Musharaka are types of partnerships that involve profit and loss sharing. In Mudarabah, one party provides the funds, and the other manages the investment, while in Musharaka, both parties contribute capital and share profits and losses. This profit-sharing mechanism is believed to encourage people to become partners and work together rather than enter into a creditor-debtor relationship (Shanmugam & Zahari, 2009).

Asset-Backed Financing

Islamic banking promotes asset-backed financing to ensure that financial transactions are linked to tangible assets or services. This linkage between the financial and real sectors is created as Islamic Financial Institutions cannot extend credit facilities without having support from the real sector. Financing is either made through sharing risk and reward arrangements or must be asset-backed (Hanif, 2014). This helps in minimizing speculative activities and ensures that investments are tied to real economic activities. To avoid money earning more money, all Islamic financial transactions are linked to a real asset and there is an exchange of goods and services, making them less risky (Habib, 2018).

Avoidance of Uncertainty (Gharar) and Speculation (Maysir)

Gharar means taking excessive risk or having unnecessary uncertainty in a contract. Islam requires all aspects of the transaction or contract to be transparent and known to all parties, thus significantly reducing conflict (Habib, 2018). Maysir refers to easily available wealth or acquisition of wealth by chance, whether or not it deprives the other’s right (Ayub, 2007). Transactions involving excessive uncertainty (Gharar) and speculative elements (Maysir) are discouraged. This is to promote fair and transparent dealings and to avoid exploitation or unfair advantage.

Ethical and Social Responsibility

Shari’ah, Islamic religious law, forms the foundation of Islamic finance. Shari’ah promotes equality and fairness in society by emphasizing moral, social, ethical, and religious factors (Shanmugam & Zahari, 2009). As Islamic banking adheres to moral and ethical guidelines derived from Shari’ah principles, it emphasizes ethical and socially responsible investments. Transactions and investments should align with Islamic values, and activities that involve harm or unethical practices are prohibited. Activities involving alcohol, gambling, pork, and other prohibited items are avoided (Shanmugam & Zahari, 2009). The payment of Zakat (obligatory almsgiving) is also encouraged, and Islamic banks often contribute a portion of their profits to charitable causes.

2.1.3 Comparison of Islamic and Conventional Banking

Islamic banking and conventional banking represent two distinct paradigms in the global financial landscape. However, they are similar in their establishments as both are licensed by central banks as commercial entities to be involved in collecting deposits from the surplus units in society and applying the funds to borrowers, entrepreneurs, or deficit units (CISI, 2015). Both Islamic and conventional banks provide financial services such as deposits, loans, and investment products to their customers. Islamic banks, like conventional banks, are also primarily in existence in the banking business to make profits, not losses (Aburime, 2008).

Rooted in Islamic principles, Islamic banking operates on the basis of Sharia, prohibiting interest (riba) and emphasizing ethical and socially responsible financial transactions. In contrast, conventional banking adheres to interest-based transactions as a cornerstone of its revenue model. Table 2.1.3-1 below portrays the differences between Islamic banking and conventional banking, shedding light on their operational principles, risk management, and societal implications.

Table 2.1.3 - 1 Comparison of Islamic and Conventional Banking

Characteristic	Islamic Banking System	Conventional Banking System (interest-based)
Business framework	Functions and operating modes are based on *Shari'ah*, and Islamic banks must ensure that all business activities are in compliance with *Shari'ah* requirements.	Functions and operating modes are based on secular principles, not religious laws or guidelines.
Interest charging	Financing is not interest (*riba*) oriented and should be based on risk-and-reward sharing.	Financing is interest oriented, and a fixed or variable interest rate is charged for the use of money.
Interest on deposits	Account holders do not receive interest (*riba*) but may share risk and rewards of investments made by the Islamic bank.	Depositors receive interest and a guarantee of principal repayment.
Risk sharing in equity financing	Islamic banks offer equity financing with risk sharing for a project or venture. Losses are shared on the basis of the equity participation, whereas profit is shared on the basis of a pre-agreed ratio.	Risk sharing is not generally offered but is available through venture capital firms and investment banks, which may also participate in management.
Restrictions	Islamic banks are allowed to participate only in economic activities that are *Shari'ah* compliant. For example, banks cannot finance a business that involves selling pork or alcohol.	Conventional banks may finance any lawful product or service.
***Zakat* (religious tax)**	One of the functions of the Islamic banks is to collect and distribute *zakat*.	Conventional banks do not collect any religious tax.

Penalty on default	Islamic banks are not allowed to charge penalties for their enrichment. They may, however, allow imposition of default or late payment penalties on the grounds that these penalties discourage late payments or defaults, which impose administrative costs on banks for processing and collecting the amount owed. Penalties may be donated to a charity or used to offset collection costs.	Conventional banks normally charge additional money (compound interest) in case of late payments or defaults.
Avoidance of *Gharar*	Transactions with elements of gambling or speculation are discouraged or forbidden.	Speculative investments are allowed.
Customer relationships	The status of an Islamic bank in relation to its clients is that of partner and investor.	The status of a conventional bank in relation to its clients is one of creditor and debtor.
***Shari'ah* supervisory board**	Each Islamic bank must have a supervisory board to ensure that all its business activities are in line with *Shari'ah* requirements.	Conventional banks have no such requirement.
Statutory requirements	An Islamic bank must be in compliance with the statutory requirements of the central bank of the country in which it operates and also with *Shari'ah* guidelines.	A conventional bank must be in compliance with the statutory requirements of the central bank of the country in which it operates and in some places, the banking laws of state or other localities.

Source: (Shanmugam & Zahari, 2009)

2.1.4 Models of Islamic Banking Implementation

Islamic banking can be implemented in various ways within the financial industry. The three major models are Islamic banking windows, full-fledged Islamic banks, and Islamic banking subsidiaries. Each country uses different structures and approaches in implementing each or all models of Islamic banking (Aman, 2019). Sole (2007) has discussed the main stages through which a country is likely to pass through as its Islamic banking industry develops. He has drawn the experience of several countries which have introduced Islamic banking over a period of time.

The various models and their respective advantages and disadvantages are explained below. It is, however, important to note that the disadvantages mentioned below are not inherent flaws in the concept of Islamic banking but rather considerations related to the specific implementation models.

Islamic Banking Windows:

An Islamic banking window, also known as an "Islamic Window", is a department or division setup by a conventional financial institution that offers Islamic products and services to customers who prefer Islamic finance over conventional finance (GIFR, 2014). In many countries, the development of Islamic banking was initially based on the opening of Islamic "windows' by conventional banks (Salikhova, 2016). Islamic windows operate as a "Bank within a Bank". This is due to the fact that when a conventional bank opens an Islamic window, to a large degree, it is in fact establishing a separate entity from the rest of the bank. (Sole, 2007)

There are a number of advantages and disadvantages associated with this type of Islamic banking model. According to GIFR (2014), the primary rationale for any regulator to allow the Islamic window model is cost efficiency and profitability. This type of Islamic banking model is cost-effective for conventional banks to introduce Islamic banking services without establishing a separate entity. This allows customers to choose between conventional and Islamic services within the same institution.

The windows operate within the existing structure of the conventional bank and provide Shari'ah-compliant financial products and services alongside conventional ones. Another advantage to a conventional bank opening an Islamic window is it will supplement the existing business of the conventional bank through servicing its existing customers or it can target new customers without cannibalization (GIFR, 2014). Sole (2007) further argues that such banks could also take advantage of their existing branch network to open Islamic windows, through which they will reach potential new clientele.

When conventional banks participate in Islamic banking, they also bring the benefits of their size, banking experience, and specialized knowledge to the market (Habib, 2018). Given their wide branch networks, conventional banks could offer Islamic products to larger segments of the population (Sole, 2007). The growth of the Islamic banking industry would not have been possible without the involvement of conventional banks offering the service through Islamic windows. The banks have also created positive competition in the markets where they operate. Fully-fledged Islamic banks would not have the pressure to be more efficient, diversify their products and services, and deliver quality services, if there was no competition from the Islamic windows of conventional banks (GIFR, 2014).

Apart from the various benefits of Islamic Windows, there is a lot of criticism towards the model from various stakeholders. Some Scholars even believe that it is not a permissible model as the very nature of the incorporation and statutes of the banks themselves is not in compliance with Shari'ah (Yaquby, 1999). However, it is also worth mentioning that there are quite many scholars who permit this type of model as long as the Shari'ah conditions laid down for the establishment and operations of Islamic windows are met.

When a conventional bank also offers Islamic banking via an Islamic finance window or through a separate branch, there is a major concern about the possible mixing of funds sourced from non-Shariah-compliant sources with the funds of the Islamic banking operations, potentially compromising the Sharia compliance of the overall operations. Customers may, sometimes, find it challenging to distinguish between conventional and Islamic banking services within the same institution, leading to confusion about the nature and principles of the services they are availing. On this issue, for example, Qatar Central Bank asked all Islamic finance windows in the country to close in 2011 (Habib, 2018).

Another area where Islamic windows are criticized is the lack of commitment of the conventional financial institution to implement the principles of Shari'ah and the absence of a clear strategy for the business. It advised that stakeholders of the conventional bank should have clarity on the strategy they are adopting when they set up an Islamic window and their executive and senior management running the bank should take ownership to deliver the window model and become successful (GIFR, 2014). It is also recommended that all involved in the management and operation of the business should be trained (Yaquby, 1999).

Full-Fledged Islamic Banks:

Full-fledged Islamic banks are standalone financial institutions that operate exclusively on Islamic principles. These banks are established with the sole purpose of providing Sharia-compliant financial services, including banking, investment, and other related activities. A full-fledged Bank is more promoted and dominates the market in some Muslim-majority countries (Aman, 2019).

Running a full-fledged bank has a lot of advantages. It allows for a comprehensive and specialized focus on Islamic finance. Full-fledged Islamic banks operate based on an independent management system, specifically raised capital, and specially designed products, and use different risk management, accounting, and auditing procedures (Aman, 2019). This will give such banks opportunities to offer a complete range of Islamic banking products and services. Unlike Islamic windows, such banks are not prone to issues like segregation of funds due to their manner of incorporation.

However, full-fledged Islamic banks are known to have higher operational costs which emanate from having no or little control over the cost allocation model, which is one major benefit Islamic windows can have over full-fledged Islamic banks. These banks also suffer operational inefficiencies, lack of product and service diversification, poor quality, higher cost-to-income ratios, weaker risk assessment systems, concentration on few sectors, etc., though, in the wake of major global financial crisis, the banks were shielded due to the prohibition of partaking in highly speculative products such as derivatives and multiple securitizations (GIFR, 2014).

Full-fledged Islamic banks may face stiff competition from conventional banks, especially in markets where conventional banking dominates. This competition can pose challenges for market share and profitability.

Establishing a full-fledged Islamic bank requires a specialized understanding of Islamic finance. In regions where expertise is limited, recruiting qualified personnel may be a challenge.

Islamic Banking Subsidiaries:

An Islamic Subsidiary model is defined as a dedicated division or unit established under the conventional parent bank to offer Islamic banking products (Aman, 2019). These subsidiaries operate independently, with their own management, boards of directors, policies, and strategies. They provide Islamic banking services via a separate legal entity specifically set up. The subsidiary may also have its own dedicated distribution channel or use that of the parent company (Habib, 2018).

The subsidiary Islamic banking model is another popular approach used by conventional banks to offer Shariah-compliant financial products and services as it provides an opportunity for conventional banks to enter new markets and expand their customer base. According to Iqbal and Molyneux (2005), the tremendous growth of Islamic banks has prompted global financial institutions to develop products and services that are Shari'ah compliant in order to tap the potential of Muslim finance. This expansion into Islamic finance allows conventional banks to access new sources of revenue and strengthen their position in the financial services industry.

The model has also gained popularity in response to the growing demand for Shariah-compliant financial products and services in some jurisdictions. According to Hasan and Dridi (2011), the subsidiary Islamic banking model has been successful in countries such as Malaysia, Bahrain, and the United Arab Emirates, where there is a high demand for Shariah-compliant financial products and services.

The Subsidiary like the Window model is also practiced than the Full-fledged Islamic banks in many non-Muslim majority of nations (Aman, 2019). Such a model provides the benefits of both conventional and Islamic banking services under the same corporate umbrella. It allows the parent bank to diversify its offerings and cater to a broader customer base. It also helps to maintain a degree of separation to ensure compliance with Islamic principles.

While the Islamic subsidiary model shares a common ownership structure with the parent bank, they maintain a separate identity and operations focused on Islamic finance. This model is different from the window system as its capital and management teams are fully segregated. However, establishing and maintaining a separate Islamic banking subsidiary involves additional costs, including regulatory compliance, operational expenses, and marketing efforts. It may strain the overall financial resources of the parent bank.

There is no much criticism towards the model as it will not face any issue of commingling of funds with the conventional bank like the Islamic window model. However, in the end, the owner bank is a conventional one that also offers interest-bearing products. Another concern raised about the subsidiary model is the sustainability of the model and its reliance on the support of conventional banks. El-Gamal (2006) argues that the subsidiary Islamic banking model may not be sustainable in the long run, as it relies on the infrastructure and capabilities of conventional banks. This reliance may limit the ability of Islamic subsidiaries to fully develop their own Islamic finance infrastructure and products.

2.1.5 Interest-Free Banking in Ethiopia

History of Banking in Ethiopia

The history of banking in Ethiopia dates back to 1905 when an agreement was reached between Minilik II of Ethiopia and Mr. Mac Gillivray, representative of the British-owned National Bank of Egypt. This led to the establishment of the first bank in Ethiopia, Bank of Abyssinia (It has no association with the Bank that is operational today except for sharing the name) which was inaugurated on February 15, 1906. The bank was totally managed by the National Bank of Egypt and had the role of a central bank as well as that of a commercial bank (Pankhurst, 1963).

The banking sector in Ethiopia has undergone significant changes after the first bank went operational over a century ago. Ethiopia's modern banking sector's evolution and development can be categorized into three distinct periods based on the different political and economic structure forms the country was governed; The 'Imperial period' (1905 to 1974), 'Socialist State' (1974 to 1991) and 'Post reform period' (1991 to date) (Geda, 2006; Abate & Kaur, 2023). Each period has its own characteristics but the third ear (the Post Reform Period), marked a new era in the Ethiopian banking sector. Proclamation No. 84/1994 paved the floor for the emergence of private banking institutions (Geda, 2006).

Emergence of Interest-Free Banking in Ethiopia

The current banking business proclamation (Proclamation No. 592/2008 of FDRE) in Ethiopia was entered into force on the 25th day of August 2008. This proclamation contained an article that laid the foundation for the authorization of Islamic or Interest-Free Banking in Ethiopia. Article 22-2 of the Proclamation states "The National Bank may issue a directive to regulate banking businesses related to noninterest-bearing deposit mobilization and fund utilization".

Subsequently, many interested individuals applied to establish the first full-fledged Islamic Bank in Ethiopia. Notably, a bank named ZamZam Bank S.C., offered shares to the public to establish such a bank. It was able to raise 137 million Birr in paid-up capital, surpassing the minimum requirements set to form a bank, and 337 million Birr in subscribed capital from 6,800 shareholders. It had its first General Assembly meeting in April 2011 (ZamZam Bank, 2012). However, with the introduction of the directive SBB/51/2011 by the National Bank of Ethiopia that entered in to force on the 1st day of October 2011, the bank is forced to liquidate and disburse back the raised capital to its shareholders. This is due to the absence of provisions that allow the formation of full-fledged Islamic banks.

The National Bank of Ethiopia Directive SBB/51/2011, however, allowed the business of Interest-Free Banking and gave the green light for existing and or future conventional banks to offer

"Interest-Free Banking Windows". The concise directive gave operational definitions to "Islamic Banking" and "Islamic Banking Window". It has also laid down regulatory and supervisory requirements as well as other requirements and conditions to setup an Islamic Window in conventional Banks.

The National Bank of Ethiopia (NBE) defines Islamic Banking as "Interest-Free Banking". "Interest-free Banking Business", in the Ethiopian context, is referred to as "a banking business in which mobilizing or advancing funds is undertaken in a manner consistent with Islamic finance principles and mode of operation that avoids receiving or paying interest". Islamic Banking is named differently in other jurisdictions. "Interest-Free Banking Window", which is globally known as the "Islamic Window", is referred to as "a unit within a conventional bank exclusively offering interest-free banking services".

Bank of Oromia S.C. was a pioneer in introducing an Interest-Free Banking window in its conventional banking establishment after securing the first license on September 16, 2013. Commercial Bank of Ethiopia, the state-owned commercial bank, became the second bank to launch the service on October 28, 2013 (Aman, 2019). Dashen Bank became the 10th commercial bank to launch an interest-free window. The service was started on March 5, 2018 (Dashen Bank, 2023). At the end of June 30, 2023, there were 17 Conventional Banks offering IFB Window Services.

In response to strong public demand, the Ethiopian government amended the Banking Business Proclamation No. 592/2008 on September 9, 2019, under Proclamation No. 1159/2019 to include provisions that allow the establishment of an Interest-Free Bank. Subsequently, ZamZam Bank was established in 2020 as the first full-fledged Islamic Bank (Interest-Free Bank) following the coming into force of NBE Directive SBB/72/2019 on June 18, 2019 (ZamZam Bank, 2023). The number of full-fledged Banks has grown to four at the end of the June 30, 2023

2.2 Theoretical Literature Review –Measurement of Bank Efficiency

2.2.1 Efficiency: Concepts and Definition

The concept of efficiency is intrinsically grounded in microeconomic theory, particularly within the frameworks of consumer theory and producer theory. Consumer theory aims at the maximization of utility or satisfaction from an individual's perspective, whereas producer theory focuses on the maximization of profit or the minimization of costs from the producer's standpoint (Ascarya & Yumanita, 2008).

The concept of efficiency as a broad performance measure for all types of organizations was initially established in the early writings of Edgeworth (1881) and Pareto (1927) and was empirically implemented in Shephard's book (1953). In economics, efficiency is defined as the optimum potential ratio between the output and input of a product development process, indicating the best distribution of available resources to achieve maximum potential. According to Drucker (1963), efficiency is defined as an organization's ability to produce its result with the smallest amount of input. In other words, efficiency is the measure of effectiveness that results in the least amount of wasted time, effort, and expertise.

The terms efficiency and effectiveness are used to describe an entity's performance, but according to Jouadi & Zorgui (2014), efficiency summarizes the idea of producing in the best way possible, which means that efficiency is focused on the use of minimum inputs to produce the best output, or in other words, the optimized use of resources to generate the best products at the lowest costs. Efficiency in management can be defined as the study of the firm's optimal use of internal elements.

The concept of effectiveness, by contrast, encapsulates the attainment of objectives and the yield of outputs without considering the methods or the efficient utilization of resources. Generally, effectiveness pertains to the capability of an individual, group, or system to achieve designated goals using the resources at hand (Rahimpour Golroudbary, El Wali, & Kraslawski, 2019). In the context of banking, effectiveness signifies the institution's ability to establish and meet its goals and objectives, while efficiency denotes the capacity to generate outputs with minimal resources or inputs, essentially reflecting the ratio of outputs to inputs (Akhtaruzzaman, Boubaker, & Sensoy, 2021).

Economic units aim to maximize profit by efficiently combining various inputs. Firms strive to optimize output from a limited set of inputs within the constraints of their technological capabilities. A firm is defined as an organizational entity involved in the production and distribution of goods or services, with a focus on achieving economic efficiency. According to Ascarya and Yumanita (2008), the concept of the production frontier is crucial in producer theory.

This frontier illustrates the relationship between inputs and outputs in the production process, indicating the maximum output achievable for each input level given the current technology. Ascarya and Yumanita (2008) further contend that operating on the production frontier signifies that a firm is achieving technical efficiency by optimally utilizing its resources to produce the highest possible output.

Efficiency entails the production of the appropriate goods or services at the right quality and cost. It denotes a firm's capability to effectively utilize its resources to generate output of a specified quality. Farrell (1957) defines a firm's efficiency as its ability to maximize output from a given set of inputs. Scholars have conceptualized efficiency in various ways, often describing it as the amount of time, effort, or money expended on an intended activity or purpose, emphasizing the ability to achieve a specific outcome with minimal waste. Efficiency assesses how closely a production unit approaches its production potential frontier, optimally combining inputs to produce a unit of output (Sickles & Zelenyuk, 2019).

2.2.2 Efficiency Classification

Efficiency is a concept that assesses the extent to which resources are effectively utilized to achieve a specific goal or outcome. Efficiency can be measured using two approaches: Input oriented vs. output-oriented measures; the input-oriented approach measures the amount of input that should be proportionally reduced without changing the output produced while the output-oriented approach measures the amount of output quantities that shall be proportionally expanded without altering the input quantities used (Coelli, 1996).

In economics and business contexts, efficiency can be divided into various categories. As outlined by Coelli (1996), and originally proposed by Farrell (1957), a firm's efficiency is composed of two key components: technical efficiency (TE) and allocative efficiency (AE). These components are combined to provide a comprehensive measure of total economic efficiency.

Technical Efficiency

Technical efficiency is described by Emrouznejad and Cabanda, (2015) as a firm's ability to obtain optimal output from given inputs. Technical efficiency is achieved by avoiding resource waste and creating as many outputs as inputs allow (output-oriented measure) or by utilizing as little input as the production target permits (input-oriented measure). This efficiency is determined by comparing observed and optimal values of production, costs, income, profit, or other metrics constrained by appropriate quantities and prices. Technical efficiency can be compared to an idealistic production frontier isoquant in terms of deviation (Tahir et al., 2009). In practice, technical efficiency is measured on a scale of 0 to 1, with 1 indicating the most efficient unit and 0 indicating growing inefficiency relative to competitors (Yidersal, 2018).

Technical efficiency is described by Emrouznejad, & Cabanda, (2015) as a firm's ability to obtain optimal output from given inputs. Technical efficiency is mainly concerned with the physical relationship between the levels of inputs and outputs; it necessitates inputs and outputs that are free of charge (Bauer, Berger, Ferrier, & Humphrey, 1998). The most popular efficiency metric, technical efficiency, represents a company's capacity to get the most output from a given set of inputs.

Coelli (1996) identified that many studies decomposed Technical Efficiency into Scale efficiency and the other to Pure Technical Efficiency. Pure technical efficiency represents the ability of a Decision Making Unit (DMU) to produce the maximum amount of output from a given set of inputs, given the current state of technology. It reflects how well a DMU utilizes its inputs to generate outputs without any inefficiencies in the production process. Scale efficiency, on the other hand, captures the extent to which a DMU operates at an optimal scale of production. It indicates whether a DMU is operating at an efficient scale, taking into account economies or diseconomies of scale (Coelli, 1996).

Coelli (1996) further argues that the decomposition of efficiency into pure technical efficiency and scale efficiency allows for a more detailed analysis of the sources of inefficiency within a production process. By distinguishing between these two components, decision-makers can identify whether inefficiencies arise from suboptimal scale of operations or technical inefficiencies in the production process.

Allocative Efficiency

Allocative Efficiency is also termed Price Efficiency in the works of Farrell (1957). The notion that asset prices reflect all available information by all market players is known as price efficiency (Phan et al., 2019). According to price efficiency theory, markets are efficient because all essential information that influences valuations is publicly available. Price efficiency ensures that resources are allocated to their most valued uses. When prices are accurate reflections of value, they signal to producers and consumers how resources should be distributed to maximize overall economic welfare.

Allocative efficiency or price efficiency refers to the ability of a firm to choose the optimal combination of inputs given input prices (Farrell, 1957). Allocative efficiency measures the skills in achieving the best combination of inputs by taking into account their relative prices or producing the right mix of outputs given the set of prices (Kumbhaker and Lovell, 2000). It reflects the capability of a firm to utilize input in optimal proportion, given their respective prices and the production technology.

Allocative efficiency occurs when goods and services are distributed optimally, taking into consideration consumer preferences. At an output level where the Price equals the Marginal Cost of production, a more accurate definition of allocative efficiency can be found. This is due to the fact that the price consumers are ready to pay is equal to the marginal utility they receive (Wang, Li, & Chen, 2020). As a result, the optimal distribution occurs when the good's marginal usefulness matches its marginal cost.

Economic Efficiency

Economic efficiency, a cornerstone concept in economics, is essential for understanding how resources are allocated to maximize welfare and productivity within an economy (Fried, Lovell, & Schmidt, 2008).

Economic efficiency, also known as overall efficiency (Farrell, 1957), is a concept that combines technical efficiency and allocative efficiency to assess the ability of a business entity to operate optimally in terms of resource utilization and output production within a given economic environment.

Economic efficiency represents the ability of a firm to minimize production costs while producing a certain level of output within the constraints of technology and market prices. Achieving economic efficiency means striking the right balance between maximizing output with a given set of inputs (technical efficiency) and optimizing input allocation based on prices (allocative efficiency) (Ascarya & Yumanita, 2008). Economic efficiency or overall efficiency is a comprehensive measure that considers both the technical and allocative aspects of a firm’s operations. It reflects the company's ability to operate at an optimal level by efficiently utilizing resources, minimizing costs, and maximizing output in line with market conditions and technological constraints.

2.2.3 Measurement of Bank Efficiency

In the financial system and the economy, banks are the most important financial entities. As a result, enabling economic growth and avoiding financial crises requires an efficient and stable banking system. The banking sector's efficiency is critical for boosting both access to financial services and the banking sector's stability as a component of the financial system. According to (Alexakis, Izzeldin, Johnes, & Pappas, 2019; Lee, Kim, & Park, 2021; Zhang & Vigne, 2021), banks are critical to the smooth operation of payment systems, and their efficiency is linked to increased economic production.

The concept of bank efficiency has garnered significant attention in academic literature, particularly within the context of performance evaluation of financial institutions. Bank efficiency refers to the ability of a bank to maximize outputs from given sets of inputs, or conversely, to minimize input usage while producing a certain level of outputs (Berger & Mester, 1997). Bank efficiency, according to Ofori-Sasu (2019), is the best level of output achieved without changing the amount of input. A bank's efficiency relates to its ability to provide service with the fewest resources possible or to provide the most products and services with the fewest inputs (Zainal, Nassir, Kamarudin, & Law, 2020).

According to Cortelezzi and Ferrari (2022), there are three primary reasons why it is essential to investigate the effectiveness of Islamic banks. Firstly, enhancing cost efficiency boosts profitability and improves the chances of survival in competitive and unregulated markets. This is particularly important as Islamic banks compete directly with conventional banks. Secondly, a bank's overall operational efficiency significantly influences consumers' interest in the costs and nature of its services, as well as potential new offerings. Lastly, understanding efficiency issues is crucial for legislators to formulate regulations that impact the banking sector as a whole.

2.2.4 Bank Efficiency Analysis Techniques/Approaches

Several techniques are commonly used to analyse bank efficiency. Each method has its unique advantages and applications, making them prevalent in academic and industry research. Banks operate in diverse environments, vary in size, and offer different services, assessing their relative efficiency is inherently complex. Nonetheless, various methodologies exist for evaluating bank efficiency, though no universally accepted method prevails (Wheelock & Wilson, 1995). The literature identifies several prevalent models for this purpose, including traditional ratio models, parametric techniques such as stochastic frontier analysis, and non-parametric techniques like data envelopment analysis (Paradi & Zhu, 2013; Bayeh, Zeleke, & Belay, 2018).

Below are the most frequently used approaches in the literature for measuring bank efficiency.

Data Envelopment Analysis (DEA)

Data Envelopment Analysis (DEA) is extensively used due to its non-parametric nature, which does not require a specific functional form for the production function. DEA employs linear programming to measure the relative efficiency of Decision Making Units (DMUs) by comparing multiple input and output variables. It identifies efficient banks/units (on the efficiency frontier) and measures the inefficiency of others relative to this benchmark. DEA is particularly effective in assessing the performance of DMUs that use multiple inputs to produce multiple outputs. The method benchmarks DMUs, identifies potential improvements, indicates sources of inefficiency, and provides a comprehensive evaluation across various dimensions (Charnes, Cooper, & Rhodes, 1978; Banker, Charnes, & Cooper, 1984).

Stochastic Frontier Analysis (SFA)

The Stochastic Frontier Approach (SFA) estimates a frontier production function and measures inefficiency as the deviation from this frontier. It is widely used in cross-country efficiency comparisons and regulatory impact assessments. SFA is favoured for its ability to separate inefficiency from random noise, providing a more accurate measure of inefficiency. It is a regression-based parametric technique utilized to assess efficiency by analysing the deviations between actual and predicted costs of banks. This method employs a single output and one or multiple input variables, operating under the assumption that discrepancies from the predicted costs can be attributed to random error and inefficiency. SFA presumes that most decision-making units (DMUs) are either very close to the efficiency frontier or on it. It is termed "parametric" because it necessitates the specification of a functional form and the establishment of distributional assumptions for both the inefficiency and noise terms. One of the strengths of SFA is its ability to naturally handle noise in the data, making it a robust method for efficiency analysis (Strange, O'Leary, & Mackay, 2021; Kumbhakar & Lovell, 2003; Bogetoft & Otto, 2011).

Financial Ratios Analysis

Financial ratios are widely used due to their simplicity and direct connection to financial performance metrics. Ratios such as Return on Assets (ROA), Return on Equity (ROE), earnings per share (EPS), and the cost-to-income ratio are used to assess profitability, efficiency, and liquidity. Banks' financial statements are used to measure the rations. While these measures are popular due to their simplicity and ease of calculation, they may sometimes lead to misleading conclusions as bank efficiency is a multifaceted and complex phenomenon (DeYoung, 1997). The limitation of these ratios lies in their inability to capture the broader aspects of bank performance and efficiency, such as risk management, market conditions, and operational efficiencies, which are critical for a comprehensive evaluation.

Simple Regression Analysis

Simple regression analysis is another commonly used method in the literature for analysing bank efficiency. It involves estimating the relationship between a dependent variable (e.g., bank efficiency) and one or more independent variables (e.g., bank size, capital adequacy, asset quality). This method is straightforward and provides insights into how specific factors impact bank efficiency. Simple Regression Analysis employs ordinary least squares (OLS) regression to establish relationships between variables and estimate production or cost functions, thereby measuring relative efficiency among firms. The residuals of the estimated regression are interpreted as a measure of inefficiency (Sarafidis, 2002, as cited in Abdu Kedir, 2006). However, this approach has limitations as it considers the error term solely as a measure of inefficiency, overlooking potential causes such as measurement error, environmental factors, or other influences that could affect the output. Consequently, the coefficients derived from this model may be biased and inconsistent (Abdu Kedir, 2006).

Malmquist Productivity Index

The Malmquist index is popular for measuring productivity changes over time, providing insights into both efficiency and technological progress. This index is often used in longitudinal studies to assess productivity trends and shifts in efficiency. The Malmquist Productivity Index (MPI) is a tool developed by Malmquist (1953) and subsequently expanded upon by various researchers (Caves, Christensen, & Diewert, 1982; Färe, Grifell-Tatjé, Grosskopf, & Knox, 1997; Homayouni, Alavi, & Gharakhani, 2021) to measure productivity and technical change in production technology.

The MPI is interpreted as follows:

- **Greater than unity (>1)**: Indicates an improvement in productivity and technology.
- **Equal to unity (=1)**: Implies that productivity and technology remain constant.
- **Less than unity (<1)**: Signifies a decline in productivity and technology.

This index is valuable in various fields for assessing how production efficiency and technological advancements evolve over time.

These methods are widely used in the literature because they provide robust and diverse insights into bank efficiency. Researchers often combine multiple approaches to gain a comprehensive understanding of efficiency determinants and performance trends in the banking sector.

2.2.6 Data Envelope Analysis (DEA) Overview

Data Envelopment Analysis (DEA) is a mathematical programming technique widely applied for evaluating the performance of similar units, such as hospitals, schools, banks, and other entities. DEA is a relatively recent, data-oriented approach for assessing the performance of peer entities known as Decision Making Units (DMUs), which transform multiple inputs into multiple outputs. The concept of a DMU is highly flexible and can be applied to various contexts.

DEA was formally introduced by Charnes, et al. in 1978, though its theoretical foundations can be traced back to Farrell's seminal work in 1957 and Debreu's introduction of the "coefficient of resource utilization" in the early 1950s. The first practical application of DEA was in the agricultural sector, where Farrell applied it to data from 48 U.S. states, using four inputs and two outputs. However, the term DEA was not yet coined; it was first applied in the education sector during the analysis of the Program Follow Through in the late 1970s.

Since its inception, DEA has been employed to assess efficiency across numerous fields, including healthcare (Wilson & Zhu, 2012), county jails (Seiford & Zhu, 2002), courts (Schneider, 2005), and universities (Bougnol & Dula, 2010). It has also been extended to sectors such as public transit (Chiu & Chen, 2011), mining (Chen & Cook, 2010), hotels (Pestana & Dieke, 2007), and banking (Emrouznejad & Anouze, 2010).

DEA is grounded in linear programming and was initially developed for performance measurement. It effectively assesses the relative performance of firms using identical inputs to produce identical outputs. The principles of DEA were first outlined by Farrell (1957), and the method gained substantial attention following the publication by Charnes et al. (1978). Comprehensive introductions and materials on DEA are available in Norman and Stoker (1991) and Cooper, Seiford, & Tone (2000).

DEA has not only provided new insights into previously evaluated activities and entities but has also highlighted sources of inefficiency in profitable firms, thereby identifying better benchmarks. For example, DEA studies have revealed inefficiencies in firms previously considered benchmarks based on profitability alone. This methodology has also facilitated the revaluation of studies on the efficiency of different organizational forms, such as stock versus mutual insurance companies, and the efficiency of pre- and post-merger activities in banks (Norman & Stoker, 1991).

Since its formal introduction in 1978, DEA has been recognized as a robust and user-friendly methodology for modelling operational processes and evaluating performance. This recognition has led to various developments, including the creation of DEA spreadsheet models for performance evaluation and benchmarking (Zhu, 2002). DEA's empirical orientation and the minimal a priori assumptions required make it suitable for numerous studies involving efficient frontier estimation across governmental, non-profit, regulated, and private sectors. For instance, DEA has been utilized to guide the relocation of government agencies in Japan, as discussed by Takamura and Tone (2003).

2.2.7 Malmquist Productivity Index (MPI)

The Malmquist Productivity Index (MPI) is a widely utilized measure in productivity analysis, designed to evaluate changes in total factor productivity (TFP) over time. Introduced by Caves, Christensen, and Diewert in 1982 and named after the Swedish Economist J. L. Malmquist, the MPI has become a cornerstone in productivity studies (Fried et al., 2008).

The MPI is grounded in the concept of the distance function, which quantifies the distance between a firm's observed input-output ratio and the best-practice frontier. By comparing the distance function across two time periods, the MPI captures productivity changes attributable to technological progress, efficiency improvements, or other influencing factors (Fried et al., 2008).

MPI measures productivity change in Data Envelopment Analysis (DEA). The index represents the total factor productivity (TFP) growth of a Decision Making Unit (DMU), which is considered as an entity that transforms inputs into outputs. The MPI reflects both progress and regress in productivity, as well as changes in frontier technology between two time periods. This allows firms to compare productivity changes over time and identify low-performing units from high-performing ones. The MPI measures productivity change and can be decomposed into five components that are useful for assessing a firm's performance; Efficiency Changes, Pure Efficiency Changes, Scale Efficiency Changes, Technological Changes, and Total Factor Productivity Changes (Abebe, 2022).

Calculation of the MPI involves taking the geometric mean of two components: technical efficiency change (TEC) and technological change (TC). The TEC component reflects variations in firms' relative efficiency over time, whereas the TC component indicates shifts in the production frontier due to technological advancements. A key advantage of the MPI is its ability to decompose productivity changes into efficiency and technological components, thus providing insights into the sources of productivity growth or decline. By separately analysing the TEC and TC components, researchers can pinpoint areas for improvement and develop strategies to enhance overall productivity (Fried et al., 2008).

The MPI has been applied across various industries and sectors to assess productivity trends, benchmark performance, and inform policy decisions. Tracking changes in TFP using the MPI enables organizations and policymakers to monitor productivity dynamics, identify best practices, and drive continuous improvement initiatives (Fried et al., 2008).

2.2.8 Criteria for choosing Inputs and Outputs in DEA Model

Despite its widespread use, Data Envelopment Analysis (DEA) is not without limitations. The choice of inputs and outputs, the selection of DMUs, and the treatment of outliers can significantly influence the results of DEA analysis. Researchers must carefully consider these factors to ensure the robustness and reliability of DEA efficiency scores (Fried et al., 2008). Although this step is crucial in applying DEA, it is frequently overlooked (Wagner and Shimshak, 2007; Wanke, Barros, & Emrouznejad, 2016; Zimková, 2014; Luo, Wang, & Zhang, 2012). Since efficiency is defined as the difference between input and output levels and their corresponding optimal values (Wheelock & Wilson, 1995), unreliable efficiency estimates can result from models that omit key inputs and outputs. Therefore, selecting appropriate input and output variables is perhaps the most critical aspect of using DEA to measure the relative efficiency of any DMU.

The selection of inputs and outputs for the DEA model depends on how researchers view banks: either as producers or as intermediaries (Favero & Papi, 1995; Drake, Hall, & Simper, 2009). These perspectives highlight the different functions and roles that banks play in the economy:

Production Approach

The production approach views banks as financial institutions engaged in the production of financial services. The production approach describes banking activities as the production of services to depositors and borrowers using all available factors such as labour and physical capital (Ascarya & Yumanita, 2008). According to Benston (1965), banks are considered service providers for customers, generating loans and deposit accounts. In this framework, the number of loans and accounts produced and/or serviced are regarded as outputs, while physical variables such as labour, capital, and materials are treated as inputs. However, Bayiley (2022) highlights that critics of this approach argue that the cost criteria are ineffective in differentiating financial inputs from financial outputs.

Intermediation Approach

The intermediation approach views banks as financial intermediaries that facilitate the flow of funds between savers and borrowers. Banks collect deposits from savers and provide loans to borrowers, earning a profit from the interest rate spread. In this approach, banks act as intermediaries that channel funds from surplus units (savers) to deficit units (borrowers) in the economy (Ascarya & Yumanita, 2008). Sealey and Lindley (1977) also highlight that the primary function of banks is to collect funds from depositors and other sources and convert them into loans and other profitable assets using physical capital and labour. From this perspective, banks' outputs include loans, while inputs encompass various costs associated with these funds, such as interest expenses, labour, capital costs, and operational costs.

According to Ascarya and Yumanita (2008), the production approach can be effectively applied to the study of efficiency in Islamic banking, as this approach considers an Islamic bank as a general business unit. However, they argue that this perspective may be overly general, thereby failing to capture the unique essence of Islamic banking. Conversely, the intermediation approach is also suitable for Islamic banking, as it views Islamic banks as intermediary institutions (Ascarya & Yumanita, 2008).

Nevertheless, Ascarya and Yumanita (2008) advise that input and output variables should be selected carefully to accurately reflect the true essence of Islamic banking. The input and output variables chosen by Sufian (2006) are among the closest to the characteristics of Islamic banking, although some modifications may be necessary to make them more representative.

2.2.9 Empirical Research on Bank Efficiency using DEA-MPI

Among other techniques of Bank efficiency measures such as stochastic frontier approaches and financial ratio analysis, data envelopment analysis is the most widely used technique as discussed below. Extensive empirical research has applied DEA and MPI to measure bank efficiency across different contexts and regions. The following are selected empirical researches at international and national levels.

Empirical Research – At International Level

Sherman and Gold (1985) conducted a seminal study applying Data Envelopment Analysis (DEA) to assess the operational efficiency of financial institutions, focusing on 14 branches of a U.S. savings bank. This pioneering research marked the first known use of DEA in banking. The study employed DEA, a non-parametric linear programming method, to estimate production frontiers and evaluate the relative efficiency of decision-making units (DMUs). Inputs included labour, office space, and supply costs, while outputs were the number of transaction types processed. The findings revealed that only 6 out of the 14 branches were relatively efficient, highlighting the inadequacy of traditional performance metrics like profitability and transaction costs in capturing branch operations' complexity. Inefficiencies were attributed to ineffective management, inappropriate branch size, liquidity constraints, and diseconomies of scale. Subsequent studies using DEA in banking, such as Parkan (1987) and Drake and Howcroft (1994), similarly identified diverse sources of inefficiency and emphasized the need for comprehensive input-output analysis.

Parkan (1987) extended the application of DEA to assess the efficiency of 35 branches of a prominent Canadian commercial bank, building on earlier work by Sherman and Gold (1985). Parkan used DEA to analyse operational efficiency, incorporating a broader range of inputs and outputs than previous studies. The inputs included total authorized fund transfer, annual rent, quality ranking of customer service, space expenses related to telephone and stationary supplies, number of online terminals, and ranking of marketing activities, while the outputs comprised the number of transactions, commercial account openings, number of loan applications, customer service survey ratings, and number of corrections. The study found that 11 out of 35 branches were relatively efficient, with inefficiencies primarily stemming from operational techniques, highlighting the need for refining operational strategies to enhance overall efficiency. Subsequent studies, such as those by Oral and Yolalan (1990) and Drake and Hall (2003), have also focused on operational strategies as key determinants of efficiency, suggesting a common trend across different banking contexts.

Although the data used was limited to a single year, potentially leading to unreliable results, Giokas, Doumpos, & Zopounidis, (1990) analysed the efficiency of branches of the Commercial Bank of Greece for the year 1987 using Data Envelopment Analysis (DEA), providing insights into the Greek banking sector. The study evaluated the relative efficiency of bank branches based on inputs such as labour, monetary value of supplies, office space, and computer terminals, with the output being the number of transactions. The analysis revealed that 9 out of 20 branches achieved maximum efficiency, while the remaining 11 were inefficient. The authors emphasized the importance of discussing DEA results with management to consider branch-specific characteristics. Similar findings on the importance of managerial insights were observed in studies like Abebe (2022) and Sherman and Gold (1985).

Oral and Yolalan (1990) conducted an empirical investigation to compute the operating efficiencies of 20 branches of a major Turkish commercial bank, utilizing the concepts and principles of Data Envelopment Analysis (DEA). The researchers employed the number of personnel, terminals, credit applications, and commercial and savings accounts as inputs while considering the use of time on general services, credits, savings accounts, and foreign exchange as outputs. Their findings indicated that DEA not only complements traditionally implemented financial ratios but also serves as an effective bank management tool for reallocating resources between branches to achieve higher efficiencies. Additionally, they observed that the service-efficient branches were also the most profitable, suggesting a relationship between service efficiency and profitability. This relationship between service efficiency and profitability was also observed in subsequent studies (e.g., Drake and Howcroft 1994; Noulas and Glavelim 2007).

The study by Berger et al. (1992) is pivotal in evaluating banking efficiency and productivity amid regulatory changes, focusing on the Norwegian banking system. Using the Malmquist Productivity Index (MPI), which breaks down productivity changes into efficiency and technological advancements, the authors assessed deregulation's impact over a specific period by analysing pre- and post-deregulation data. Inputs included labour, capital, and operational expenses, while outputs encompassed loan volumes, deposit volumes, and financial services. The study found a notable decline in productivity before deregulation due to regulatory constraints, but a significant improvement post-deregulation driven by efficiency gains and technological advancements. These findings align with similar studies by Drake and Hall (2003) on Japanese banks, Worthington (1999) on credit unions, and Sufian (2007) on Malaysian Islamic banks, all highlighting deregulation's positive long-term effects. Despite these insights, gaps remain, such as the need for longitudinal analysis, comparative studies across countries, and more detailed input-output analysis to fully understand deregulation's impacts.

Drake and Howcroft (1994) also investigated the relative efficiency of 190 branches of a UK clearing bank using Data Envelopment Analysis (DEA). They considered the number of interview rooms and ATMs, floor area, staff grades, and stationery costs as inputs, while the outputs included the size of till transactions, lending products, deposit products, automated transfers, clearing items, ancillary business, and insurance business. The results revealed that only 83 branches were efficient. The study found that the size of the branches, in terms of the number of staff, was positively correlated with higher efficiency scores and scale efficiency. Additionally, factors such as location, age, competitive environment, and the existence of economies of scale were identified as determinants of branch efficiency levels. Similar determinants of efficiency were highlighted in studies like Sherman and Gold (1985) and Parkan (1987).

Worthington (1999) used non-parametric frontier analysis employing Malmquist DEA to investigate productivity growth in credit unions, particularly following deregulation. The study focused on measuring productivity changes by examining technological progress and efficiency improvements over time. Utilizing various inputs such as labour, capital, and operational expenses, and outputs including loan volumes, deposit volumes, and financial services, the analysis provided a comprehensive view of productivity dynamics. The findings indicated significant technological progress in most credit unions post-deregulation, driven primarily by improvements in technical efficiency and innovation adoption. This progress was attributed to the increased competitive pressures and operational flexibility resulting from deregulation, which incentivized credit unions to enhance their operational practices and integrate new technologies. Similar observations on the positive impact of deregulation were made by Berger et al. (1992), who studied the Norwegian banking system, and Drake and Hall (2003), who analysed the Japanese banking sector. These studies collectively reinforce the notion that deregulation, while initially disruptive, often leads to long-term productivity gains through enhanced efficiency and technological advancements in the financial sector.

Drake and Hall (2003) employed Data Envelopment Analysis (DEA) to examine technical and scale efficiency within the Japanese banking sector. Their analysis utilized a recent cross-sectional sample, encompassing individual banks, bank types, and bank size groups. The study revealed significant size-efficiency relationships concerning both technical and scale efficiency. The researchers emphasized the importance of accounting for the exogenous effect of problem loans, particularly for smaller regional banks.

Sufian (2007) conducted a study on the efficiency of the Islamic banking industry in Malaysia, comparing the performance of foreign and domestic banks, Using Data Envelopment Analysis (DEA), a non-parametric method, the study assessed the relative efficiency of banks by analysing inputs such as labour, capital, and operational expenses, and outputs like loan volumes, deposit volumes, and financial services. The findings revealed that foreign Islamic banks were generally more efficient than domestic ones, attributed to better management practices, advanced technological adoption, and economies of scale. Conversely, domestic banks showed lower efficiency due to less optimal resource allocation and weaker management. These results underscore the critical role of effective management and technological integration in achieving higher efficiency. The study aligns with similar research by Berger et al. (1992) and Worthington (1999), emphasizing the importance of technological advancements and managerial efficiency in bank performance. Sufian's study contributes valuable insights into the Islamic banking sector in Malaysia, highlighting distinct challenges and advantages faced by foreign and domestic banks. However, it lacks consideration of external factors such as regulatory environment and market conditions.

Noulas and Glavelim (2007) conducted an efficiency assessment of 28 branches of a major Greek commercial bank using Data Envelopment Analysis (DEA). The study aimed to evaluate both operational and profitability efficiency, utilizing inputs such as labour costs, capital expenditures, operating expenses, and the number of employees, while outputs included loan volumes, deposit volumes, the number of transactions, and revenue from banking services. The findings revealed significant variations in efficiency among the branches, indicating room for improvement. Profitability efficiency was generally higher than operational efficiency, suggesting that while some branches were effective at generating profits, they were less efficient in overall operations. This aligns with previous studies like Oral and Yolalan (1990) and Drake and Howcroft (1994), which also highlighted the relationship between service efficiency and profitability. The study emphasizes the need for future research to explore the factors driving these differences in efficiency more thoroughly.

Ascarya and Yumanita (2008) conducted a comparative study on the efficiency of Islamic banks in Malaysia and Indonesia. Utilizing Data Envelopment Analysis (DEA), the research aimed to assess and compare the operational efficiency of Islamic banks in these two countries. The study considered inputs such as labour, capital, and operational expenses, and outputs like loan volumes, deposit volumes, and other financial services. The findings indicated significant differences in efficiency levels between the two countries, with Malaysian Islamic banks generally outperforming their Indonesian counterparts. The study attributed these differences to varying regulatory environments, levels of technological adoption, and management practices. Comparative literature, such as Sufian (2007) and Alexakis et al. (2019), also highlights the impact of regulatory frameworks and operational practices on bank efficiency. Ascarya and Yumanita's research identified a need for improved regulatory support and technological integration in Indonesian Islamic banks.

Zarinkamar and Alam-Tabriz (2014) conducted an efficiency assessment of branches of a major Iranian bank using Data Envelopment Analysis (DEA). The study aimed to measure the relative efficiency of the bank's branches by analysing various inputs and outputs. Inputs included labour, operational costs, and capital, while outputs consisted of loan volumes, deposit volumes, and other financial services provided. The findings revealed significant disparities in efficiency levels among the branches, indicating substantial potential for improvement. This study underscores the importance of identifying and addressing inefficiencies to enhance overall branch performance. It aligns with similar research, such as Noulas and Glavelim (2007), which also emphasized the role of DEA in pinpointing operational inefficiencies. The study highlights the need for continuous efficiency monitoring and suggests future research should incorporate additional factors such as customer satisfaction and technological advancements to provide a more comprehensive efficiency assessment.

Mehmet and Kale (2014) conducted an empirical study analysing the efficiency of bank branches. Using Data Envelopment Analysis (DEA), the study evaluated the relative efficiency of various bank branches. The inputs considered included labour, operational expenses, and capital investments, while the outputs were loan volumes, deposit volumes, and revenue from banking services. The analysis revealed significant discrepancies in efficiency among the branches, indicating areas for potential improvement. The study underscores the importance of optimizing resource allocation and management practices to enhance branch performance. This aligns with findings from similar studies such as Zarinkamar and Alam-Tabriz (2014), which also utilized DEA to identify inefficiencies in bank operations. Mehmet and Kale's research emphasizes the need for continuous efficiency evaluation and suggests incorporating additional factors like technological advancements and customer satisfaction in future assessments to provide a more comprehensive evaluation of bank branch efficiency.

Stoica, Mehdian, & Sargu, (2015) conducted a study on bank efficiency measurement using Data Envelopment Analysis (DEA). The study evaluated the efficiency of 24 banks by analysing various inputs and outputs to determine their relative performance. Inputs included labour costs, capital investments, and operational expenses, while outputs consisted of loan volumes, deposit volumes, and financial services provided. The findings revealed substantial variability in efficiency levels among the banks, with some banks operating at optimal efficiency and others showing significant inefficiencies. The study highlighted the importance of effective management practices and resource allocation in achieving high efficiency. Stoica et al. (2015) emphasize the need for continuous monitoring and improvement of bank operations to enhance overall performance. The study suggests future research should consider incorporating technological advancements and market conditions to provide a more comprehensive analysis of bank efficiency.

Kisielewska, Guzovska, Nellis, and Zarzecki (2015) conducted a study on the performance of the largest commercial banks in Poland using Data Envelopment Analysis (DEA), published in the International Journal of Business Performance Management. The study evaluated the efficiency of the top 10 Polish banks, which represent about 80% of the sector's total assets, during the period from 1995 to 2003. Inputs included labour costs, capital expenditures, and operational expenses, while outputs comprised loan volumes, deposit volumes, and other financial services. The findings indicated that the cost efficiency of these banks varied significantly, with some operating at optimal efficiency and others showing considerable inefficiencies. The research emphasized the importance of continuous efficiency monitoring and the adoption of best practices in management to enhance performance. The study also suggested the potential benefits of incorporating technological advancements and adapting to market conditions to improve bank efficiency over time.

Stewart, Matousek, Nguyen, and Nguyen (2016) conducted a study on the efficiency of Vietnamese banks from 1999 to 2009. The study used unique data samples to compare the performance of large, very large, small, and medium-sized banks using Data Envelopment Analysis (DEA). The findings indicated that large and very large banks exhibited greater efficiency compared to their smaller counterparts, with small banks demonstrating the lowest efficiency scores. The results highlight the significant disparities in efficiency within the Vietnamese banking sector and suggest that size and scale play crucial roles in bank efficiency. This study provides valuable insights into the factors influencing bank performance in Vietnam and underscores the importance of strategic management and operational optimization for improving efficiency in smaller banks.

Emrouznejad and Yang (2018) conducted a comprehensive survey and analysis of DEA applications. The literature review compiled over 10,000 research articles on DEA from 1978 to 2016, illustrating the extensive use of DEA across various fields. The review highlighted the diversity of DEA applications, particularly emphasizing its significance in the banking sector. DEA has been utilized for country-wide bank analyses, bank branch efficiency assessments, cross-national banking comparisons, evaluations of bank merger efficiencies, and branch deployment strategies. This extensive survey underscores DEA's versatility and its critical role in optimizing efficiency and performance in numerous industries.

Alexakis et al. (2019) conducted a comparative study on the performance and productivity of Islamic and conventional banks during the global financial crisis. The study utilized a combination of Data Envelopment Analysis (DEA) and the Malmquist Productivity Index (MPI) to assess and compare the efficiency and productivity changes of both banking types. Inputs included labour, capital, and operational expenses, while outputs comprised loan volumes, deposit volumes, and financial services provided by the banks. The findings indicated that Islamic banks exhibited more resilience during the financial crisis, maintaining higher efficiency and productivity levels compared to conventional banks. The study also found that the unique operational and ethical principles of Islamic banking contributed to their stability. Comparative literature, such as Sufian (2007) and Berger et al. (1992), also highlights the differential impacts of economic shocks on various banking systems, emphasizing the robustness of Islamic banks under financial stress. However, the study by Alexakis et al. pointed out the need for more granular data to understand the specific mechanisms driving efficiency in Islamic versus conventional banks.

Agrawal (2021) conducted an in-depth study on the efficiency of the Indian banking industry. The research employed Data Envelopment Analysis (DEA) to perform an integrated benchmarking analysis, aiming to evaluate and compare the efficiency of various banks in India. Inputs for the DEA model included labour, capital, and operational expenses, while outputs encompassed loan volumes, deposit volumes, and other financial services provided by the banks. The study revealed a wide range of efficiency scores, indicating that while some banks operated at optimal efficiency, others had significant room for improvement. Agrawal's work highlighted key factors influencing bank efficiency, such as management practices, technological adoption, and scale of operations. This study's findings are in line with other efficiency studies in banking, such as those by Drake and Hall (2003) and Sufian (2007), which also emphasized the importance of technological advancements and managerial strategies in enhancing efficiency.

Xie et al. (2021) evaluated the performance of Chinese commercial banks using the Malmquist Productivity Index (MPI). The study aimed to measure productivity changes over time, attributing gains to efficiency improvements and technological advancements. Utilizing inputs like labour, capital, and operational expenses, and outputs such as loan and deposit volumes, the findings showed that productivity improvements were primarily driven by technological advancements rather than efficiency changes. This aligns with Berger et al. (1992) and Worthington (1999), which also emphasized technological impacts on productivity. However, the study did not consider external factors like regulatory changes and market conditions.

Empirical Research in Ethiopia

Abdu Kedir (2006) conducted a comprehensive analysis of the technical efficiency of the Ethiopian banking sector, published in the Journal of African Economies. This study utilized Data Envelopment Analysis (DEA) to evaluate the performance of Ethiopian banks, focusing on how effectively banks transform inputs into outputs. The inputs considered included labour, capital, and operational expenses, while outputs comprised loan volumes, deposit volumes, and other financial services. The study found significant variations in efficiency levels across different banks, with some banks demonstrating high technical efficiency while others lagged behind. Comparative literature, such as studies by Lelissa (2014) and Garamu (2016), also noted similar inefficiencies in the Ethiopian banking context, emphasizing the role of management practices and scale efficiency. Kedir's findings highlighted the need for improved management strategies and better resource allocation to enhance overall efficiency. However, the study's reliance on cross-sectional data limited its ability to capture long-term efficiency trends

Lelissa (2014) conducted an analysis of efficiency within the Ethiopian Banking System from 2008 to 2012, utilizing Data Envelopment Analysis (DEA). The study revealed that while the industry's efficiency level was modest, the technical and scale efficiency of banks exhibited both inter and intra-group variations across different ownership and size categories.

Garamu (2016) evaluated the technical efficiency and productivity of Ethiopian commercial banks using Data Envelopment Analysis (DEA) from 2007 to 2011 using DEA, employing an intermediation approach. The study analysed input-output relationships focusing on fixed assets and labour as inputs, and total deposits and net loans and advances as outputs. The findings revealed that Ethiopian commercial banks were, on average, technically inefficient, with a mean technical efficiency of 0.820, pure technical efficiency of 0.925, and scale efficiency of 0.888. Scale inefficiency was identified as a major issue. Comparative studies by Lelissa (2014) and Yidersal (2018) similarly noted efficiency variations within the sector, highlighting the need for improved management and technology adoption

Bayeh, Zeleke, and Belay (2018) analysed the efficiency of Ethiopian commercial banks using Data Envelopment Analysis (DEA), focusing on inputs such as labour, capital, and operational expenses, and outputs like loan and deposit volumes. The study found significant inefficiencies in many banks, attributing these to poor management, inadequate resource allocation, and lack of technological integration. These findings align with earlier studies by Sherman and Gold (1985) and Parkan (1987), and highlight the importance of scale efficiency, as noted by Drake and Hall (2003).

Yidersal (2018) utilized DEA to evaluate the technical, cost, revenue, and profit efficiency of Ethiopian commercial banks from 2005 to 2016. The study identified four banks as the most efficient in terms of Technical Efficiency, positioned on the DEA frontier under both input and output orientations. This finding offers valuable insights into exemplary management practices and operational strategies within the Ethiopian banking sector, serving as a benchmark for other banks.

Muche (2019) analysed the efficiency level of Birhan Bank branches between 2015 and 2020 using DEA. Input variables included personnel expenses and other operating expenses, while output variables consisted of annual deposits collected. The study revealed low levels of both technical and scale efficiency among the branches, with averages of 31% and 71%, respectively. Additionally, 99% of the branches were operating at an increasing economy of scale, indicating that most branches were operating below the best practice production frontiers and had the potential to improve productivity by 29%.

Berhe (2021) conducted an empirical analysis of productivity changes in Ethiopian commercial banks using the DEA-based Malmquist Productivity Index (MPI) approach. The study aimed to measure productivity growth, decomposing it into efficiency change and technological change. Inputs included labour, capital, and operational expenses, while outputs encompassed loan volumes, deposit volumes, and financial services. The findings showed variability in productivity performance among banks, driven by differences in management practices, resource allocation, and technology adoption. This aligns with Sufian (2007) and Drake and Hall (2003), which emphasize technological progress and management efficiency.

Abebe (2022) investigated the efficiency of 277 branches within Wegagen Bank SC, employing Data Envelopment Analysis (DEA) to assess branch efficiency using both financial and non-financial data as inputs and outputs. The study's findings underscored weak management, branch size, liquidity, and operational techniques as key sources of inefficiency. Emphasizing the importance of engaging management in interpreting DEA results, the study also noted limitations such as a lack of additional data on foreign currency generation and transaction volume, as well as the exclusion of branches opened after June 2018. Overall, the research offers valuable insights into bank branch efficiency and provides recommendations for future research directions and managerial decision-making.

Bayiley (2022) conducted an evaluation of Ethiopian banks' productivity utilizing both a Malmquist productivity index approach and a one-step system GMM dynamic panel data model. The study revealed nominal efficiency changes attributed to enhanced operational and management practices, coupled with increased scales. However, there was a noted decline in efficiency resulting from technological changes, leading to a nominal regression in total factor productivity. Furthermore, the research highlighted the superior resource mobilization performance of private banks compared to state-owned banks, underscoring the significance of effective management practices in bank operations. The study recommended adopting a production approach for analysing productivity changes, emphasized the positive influence of deposit and loan growth rates on efficiency, and advocated for thorough feasibility studies to inform technology choices aimed at enhancing bank productivity.

Ali and Hailu (2022) examined the efficiency of Islamic windows within conventional banks in Ethiopia. Using Data Envelopment Analysis (DEA), the study aimed to assess the relative efficiency of these Islamic banking operations compared to their conventional counterparts. Inputs in the analysis included labour, capital, and operational expenses, while outputs were measured in terms of loan volumes, deposit volumes, and other financial services provided. The study revealed that Islamic windows in Ethiopian banks showed varied efficiency levels, with some operating efficiently and others lagging behind. The research highlighted the unique challenges and operational constraints faced by Islamic banking within a conventional banking framework. Comparative literature, such as Alexakis et al. (2019) and Sufian (2007), similarly notes the differential performance of Islamic banks under varying economic conditions and regulatory environments. Ali and Hailu's study identified gaps in the integration and management of Islamic banking practices within conventional banks, emphasizing the need for targeted strategies to enhance their efficiency.

Summary of Empirical Research

Empirical studies on bank efficiency employing Data Envelopment Analysis (DEA) and the Malmquist Productivity Index (MPI) encompass diverse methodologies, inputs, outputs, findings, and identified gaps. Numerous factors have contributed to the widespread adoption of DEA in both research and practice. Řepková (2014) underscores DEA's utility in analysing efficiency at the Decision Making Unit (DMU) level, facilitating comparisons among DMUs within a group, assessing DMU efficiency, identifying inefficiency sources, and proposing strategies for enhancing efficiency. Furthermore, DEA enables the establishment of an efficiency frontier based on empirical data rather than theoretical assumptions. Additionally, Svitálková (2014) highlights DEA's flexibility in incorporating diverse variables across different measures, thus enhancing its applicability.

A synthesis of these studies reveals nuanced differences and similarities, illustrating the evolution and application of these techniques across various contexts. Most studies utilize DEA, a non-parametric method for evaluating the efficiency of DMUs, while others employ the MPI to assess productivity changes over time. These methodologies provide a comprehensive framework for analysing efficiency by comparing multiple inputs and outputs across various branches or banks. The selection of inputs and outputs varies significantly across studies, reflecting the diversity and complexity of bank operations and research objectives.

The empirical literature review reveals several key points:

1. While DEA serves as an effective tool for measuring efficiency at the bank or branch level, its utility is maximized when complemented by managerial insights and information on branch-specific characteristics. Several studies emphasize the importance of integrating managerial insights for a more accurate interpretation of DEA results. This integration is crucial for understanding the unique characteristics of each branch or bank.
2. The selection of inputs and outputs for measuring bank or branch efficiency using the DEA model varies across banks, reflecting management's diverse objectives and resource allocations tailored to each branch's specific goals.
3. Although numerous studies focus on specific countries, comparative studies across different banking environments are less common. Research suggests the need for more cross-national studies to understand efficiency determinants in varied economic contexts.
4. Sources of inefficiency in financial institutions, such as banks or their branches, vary. Commonly identified factors include poor management practices, lack of technological advancement and integration, inefficient resource allocation, suboptimal scale of operations, regulatory and supervisory constraints, inefficiencies in operational techniques, and limited consideration of external factors.
5. Many studies are limited by the scope of their input and output measures, often restricted to a single year's data. Research indicates the need to incorporate more comprehensive and longitudinal data. Studies have also highlighted the importance of incorporating technological advancements and the impact of digital banking and fintech innovations on the analysis of bank efficiency.
6. Empirical evidence underscores the versatility and robustness of DEA and MPI in capturing the multifaceted nature of bank efficiency. These findings offer valuable guidance for policymakers and bank managers seeking to optimize performance through strategic resource allocation and technological innovation.

2.2.10 Knowledge Gap

Despite extensive research on bank efficiency, significant gaps persist, particularly at the national level, regarding the efficiency of Islamic Banking, including Interest-Free Banking (IFB) windows and Full-Fledged Branches at regional or district levels. Most existing studies focus on national-level assessments or individual bank branches, with limited regional or district-level analysis using advanced methods such as Data Envelopment Analysis (DEA) and Malmquist Productivity Index (MPI). Addressing this gap, the present study aims to comprehensively evaluate the efficiency and productivity of Dashen Bank's IFB windows

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

This chapter outlines the methodologies utilized to tackle the research problem. It provides an in-depth description of the study's research strategy and approach, the population and sample, data sources and collection methods, data analysis techniques, model variables (both input and output), and the definition of the model.

3.2 Approach and Design of Research

The research design encompasses the comprehensive strategy employed to address the topic, necessitating the integration of various study components in a cohesive and logical manner to ensure efficient problem-solving. It serves as a blueprint for the processes of data collection, measurement, analysis, interpretation, and the reporting of findings. The significance of research design lies in its ability to facilitate the smooth application of diverse research techniques, thereby producing highly professional research that maximizes informational yield while minimizing effort, time, and cost (Basias & Pollalis, 2018). According to Mohajan (2018), research design can be categorized into four distinct types based on the research's objective: exploratory research, descriptive research, explanatory research, and experimental research.

This study employed descriptive research methods, which involve characterizing a subject by collecting and tabulating data on the frequencies of study variables to create a profile of individuals, groups, or events (Babbie, 2016). Descriptive research aims to describe phenomena as they exist, with the observer recording and detailing what is discovered. It addresses questions such as what, who, where, how, and when. This method is commonly used in the social sciences, particularly in socioeconomic surveys and job and activity analyses (Creswell, 2014; Saunders, Lewis, & Thornhill, 2019).

Quantitative research is characterized by the use of measurements and numerical data, whereas qualitative research focuses on words and images. Mixed methods research integrates both quantitative and qualitative elements, combining numbers, words, and images. Basias and Pollalis (2018) explain that quantitative research elucidates events "by gathering numerical data that is examined using mathematically based approaches" (specifically statistics). This approach relies on the measurement of quantity or amount and is used to describe phenomena with numerical values. Given that this study employed numerical secondary data (financial reports), a quantitative approach was adopted.

3.3 Population and Sample

Saunders, Lewis, and Thornhill (2019) define the target population as the entire group of individuals or elements that a researcher aims to study and from which they intend to generalize their findings. This population represents the larger group about which the researcher seeks to draw conclusions. Conversely, sampling involves selecting a subset of this target population to serve as a representative group, known as the sample.

In Data Envelopment Analysis (DEA) measurement, the decision to employ a census or a sample approach is influenced by various factors and considerations. Emrouznejad and Yang (2018) underscore that the choice between a census and a sample depends on factors such as population size, resource constraints, the representativeness of the sample, statistical power, the homogeneity of Decision Making Units (DMUs), and research objectives. A census may be advantageous when the population of DMUs is small and manageable, facilitating a comprehensive analysis of efficiency across all units. However, conducting a census can be resource-intensive in terms of time, cost, and effort, particularly with a large population of DMUs. In such instances, sampling may be more practical and cost-effective (Emrouznejad & Yang, 2018).

The target population for this study includes all districts of Dashen Bank that have been operational for more than five years and exhibit similar competitive characteristics in terms of size, number of branches, and years of operation. Consequently, the study considered all of the Bank's districts as decision-making units and opted for a census rather than sampling. The selected districts for this study were twelve in number: East Addis Ababa District, West Addis Ababa District, South Addis Ababa District, North Addis Ababa District, Bahirdar District, Dessie District, Mekele District, Hawassa District, Jimma District, Adama District, Wolaita District, and Dire Dawa District.

3.4 Data Type and Source

Dashen Bank is structured into 12 Districts: four in Addis Ababa, two in the Amhara region, two in the Southern Nations, Nationalities, and Peoples' region, two in the Oromia region, one in Dire Dawa City, and one in the Tigray region. This analysis encompasses all 12 Districts over a period of sixty months, from July 2018 to June 2023. To assess productivity changes in the Districts under study, secondary data on input and output variables were gathered from the audited balance sheets and income statements of the respective Districts from Dashen Bank

3.5 Method of Data Analysis

3.5.1 Selection and Use of input-output Approach

Banking efficiency can be investigated using either a production or an intermediation method. In the 'production method,' the bank is viewed as a business that utilizes physical assets and labour inputs to provide services such as cash deposits, loan disbursements, and remittances. Here, the number of employees (labour) and capital expenditures on fixed assets typically represent the inputs, while the quantity of total bank deposits or total loans often represents the outputs (capital).

Conversely, under the 'intermediation approach,' banks act as intermediaries between lenders and depositors, receiving deposits and other forms of payment to provide financing and alternative investments. In this approach, inputs are generally indicated by operating costs, costs of providing finance to customers, and total deposits, while outputs are typically denoted by income or profit from financing and any other non-interest-bearing income.

This study focuses on the intermediation approach to explore the sensitivity of predicted efficiency scores to various techniques of assessing banking activity.

Table 3.5.1 - 1: Definition and selection of variable in intermediation Approach

S.NO.	Code	Variable name	Definition
		Input variables	
1	PE	Personnel Expenses	The total amount of employee salary and benefits
2	OE	Operating Expense	Administrative and general expenses, provision for doubtful debt, and other expenses

3	TD	Total Deposit	The sum of Deposits (Qard demand, Wadi'ah Saving, and Mudarabah fixed time deposits
		Output variables	
1	FI	Income Earned on Financing, Advance & Investment	The sum of mark-ups on Interest-Free Financings, advances, and investments
2	SC	Service Charges	Service Charges on letters of credit, letters of guarantee (Kafalah), local transfers, and other Income
3	CN	Commission	Commission and fees on International banking and local transactions

3.5.2 Malmquist Productivity Index

Sten Malmquist initially conceptualized the Malmquist index in 1953 to evaluate production. However, it was Caves et al. (1982) who formally introduced the Malmquist Index during its development. The evaluation of the Malmquist index encompasses both the catch-up effect and the frontier shift effect. The catch-up effect measures the rate of change in relative efficiency from period 1 to period 2, while the frontier shift effect, also known as the innovation effect, assesses the rate of technological advancement from period 1 to period 2, incorporating both input and output factors.

The Malmquist productivity index serves as a bidirectional indicator that compares the production technologies of two economic entities (Alexakis et al., 2019). It is grounded in the concept of the production function, which evaluates the maximum output achievable given certain input constraints. The calculation of this index involves multiple factors, including efficiency, technological change, pure efficiency change, scale of economic change, and total factor productivity (TFP) change.

This method is distinguished from others by three significant advantages associated with the Malmquist Productivity Index (MPI) (Bansal et al., 2022; Cho & Chen, 2021; Shair et al., 2021). Firstly, it does not rely on cost-cutting or benefit-amplification assumptions. Secondly, it does not require the estimation of costs for information or output. Thirdly, the method facilitates the decomposition of profitability into two groups, assuming that board information is available. The MPI is grounded in distance functions, incorporating output distance functions for output-oriented indexes and input distance functions for input-oriented indexes. The index is utilized to monitor changes in total factor productivity over time and can be divided into two components: efficiency change and technical change (Bayiley, 2022).

In this study, the Malmquist productivity index technique was employed to compare the productivity performance of Dashen Bank's Districts Interest-Free Banking Window over the periods t and t+1 relative to the technology available at period t. The research utilized the output-oriented Malmquist productivity index for Decision Making Units (DMUs) between periods t and t+1, based on the equations developed by Krishnasamy et al. (2004), Battese et al. (2004), Yang and Soltani (2021), and Huang et al. (2021), as cited by Bayiley (2022).

$$MPI_I^t = \frac{D_I^t(m^{t+1},n^{t+1}}{D_I^t(m^t,n^t)} \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where m signifies DMU input and n denotes DMU output, and $(m^t, n^t) and\ (m^{t+1}, n^{t+1})$ represent the input and output data sets for time periods t and t+1, respectively. Furthermore, $(m^t, n^t) and\ (m^{t+1}, n^{t+1})$ denote the production point at time t and t+1, respectively. The input orientation of the MPI model is indicated by the subscript 'I.'

Using the technology at t + 1 as the reference, the period (t + 1)-based MPI is defined as:

$$MPI_I^t = \frac{D_I^{t+1}(m^{t+1},n^{t+1}}{D_I^t(m^t,n^t)} \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Equation (3) represents the measure of the Malmquist total productivity change index, calculated as the geometric mean of the two Malmquist productivity indexes (MPIs) from equations (1) and (2) (Bjurek, 1996; Grifell-Tatjé & Lovell, 1999; Pastor & Lovell, 2005; Huang et al., 2014, as cited in Bayiley, 2022).

$$MPI_I^G = (MPI_I^t * MPI_I^{t+1})^{1/2} = \left(\left(\frac{D_I^t(m^{t+1},n^{t+1}}{D_I^t(m^t,n^t)}\right) * \left(\frac{D_I^{t+1}(m^{t+1},n^{t+1}}{D_I^t(m^t,n^t)}\right)\right)^{1/2} \ldots\ldots\ldots (3)$$

As illustrated in the works of Bayiley (2022), the MPI in equation (3) measures the productivity of the most recent production point $(m^{t+1}, n^{t+1}))$ relative to the earlier production point m^t, n^t. This indicates that the efficiency change is calculated by dividing the efficiency in (t+1) period by the efficiency in t period. The index employs the technology of both perio period t and period t+1 technology. A geometric mean of two MPIs is used to determine productivity growth. When the MPI_I^G value is greater than one, it signifies an increase in overall productivity from period t to period t+1. A value less than one implies a decrease in total production, while MPI_I^G =1 indicates stagnation in productivity between period t and t +1.

Using the concepts of output-oriented efficiency change (EFFCH) and output -oriented technology change (TECHCH), the output -oriented geometric mean of MPI (i.e. Malmquist total productivity change index) may be deconstructed as shown in equation 4.

$$MPI_I^G = (EFFCH_I) * (TECHCH_I) = \left(\frac{D_I^t(m^{t+1},n^{t+1})}{D_I^t(m^t,n^t)}\right) * \left[\left(\frac{D_I^t(m^1,n^1)}{D_I^{t+1}(m^t,n^t)}\right)\left(\left(\frac{D_I^{t+1}(m^{t+1},n^{t+1})}{D_I^{t+1}(m^{t+1},n^t+1)}\right)\right)\right]^{\frac{1}{2}} \text{......} (4)$$

The first and second terms represent the efficiency change and the technology change, respectively. The MPI, as given by Equations (3) and (4), can be defined using a DEA-like distance function. Specifically, the components of MPI can be derived from the estimation of distance functions defined on a frontier technology (Bayiley, 2022). According to Bayiley (2022), the formal derivation of MPI was presented by Färe et al. (1997), Oh and Lee (2009), and Casu et al. (2016), and it is the most common approach among the various methods created to estimate a production technology (Howcroft & Ataullah, 2006; Dorri & Rostamy-Malkhalifeh, 2017). By utilizing both CRS and VRS DEA frontiers to estimate the distance functions in Equation (4), the efficiency change (EFFCH) can be decomposed into scale efficiency change (SECH) and pure efficiency change (PECH) components. The scale efficiency change (SECH) is provided in Equation (5).

$$SECH = \left[\left[\left(\frac{D_{VRS}^{t+1}(m^{t+1},n^{t+1})/D_{CRS}^{t+1}(m^{t+1},n^{t+1})}{D_{VRS}^{t+1}(m^t,n^t)/D_{CRS}^{t+1}(m^t,n^t)}\right) * \frac{D_{VRS}^t(m^{t+1},n^{t+1})/D_{CRS}^t(m^{t+1},n^{t+1})}{D_{VRS}^t(m^t,n^t)/D_{CRS}^t(m^t,n^t)}\right]\right]^{1/2} \text{................} (5)$$

In addition, the pure efficiency change (PECH) is given in Equation (6)

$$PECH = \left(\frac{D_{VRS}^{t+1}(m^{t+1},n^{t+1})}{D_{CRS}^t(m^t,n^t)}\right) \text{..} (6)$$

CHAPTER FOUR: RESULT AND DISCUSSION

4.1 Introduction

This chapter presents the empirical findings and interpretations of the study. The initial section addresses descriptive statistics for the selected financial metrics, both as inputs and outputs. Subsequently, the primary objective of the study—evaluating the efficiency of 12 selected Districts—is examined using the Data Envelopment Analysis (DEA) approach detailed in Chapter Three. This method quantifies the efficiency, productivity, and inefficiency of the twelve Districts. The final section performs a correlation analysis of the input-output variables.

The Data Envelopment Analysis software, DEAP-xp (version 2.1), is utilized to measure the Districts' efficiency change (EFFCH), technological change (TECHCH), pure efficiency change (PECH), scale of economic change (SECH), and total factor productivity change (TFPCH) within the Bank’s IFB window. Additionally, STATA (version 13) software is employed to assess the correlation between variables.

4.2 Descriptive Statistics of Input and Output Variables

The statistical results presented in Table 4.2-1 show descriptive data of Dashen Bank’s twelve Districts’ Interest-Free banking window across selected financial metrics as inputs and outputs variables from July 2018 to June 2023. The key findings and insights are discussed in the following sections.

Output Variables

Income Earned on Financings, Advances and Investments

During the study period, the average income earned from financing, advances, and investments was 6,081,035.13 ETB. The maximum income recorded was 137,346,432.93 ETB, observed in the South Addis Ababa District in June 2023. Conversely, the minimum income was 0 ETB in various districts across different months, attributable to the absence of financing, advances, or investments in the initial stages of the business.

The standard deviation for income earned on financing, advance, and Investment is 13,716,368.74 ETB. The substantial standard deviations indicate that Districts experience considerable variability in income earned in financing income, highlighting differences in financing activities and financing uptake. South AA leads in variability, suggesting an inconsistent financing portfolio with significant changes in disbursement and repayment patterns.

Service Charge

As can be seen from Table 4.2-1 below, service charge represents the smallest in magnitude compared to other metrics used. The average service charge collected from each district was 57,893.93 ETB. The maximum service charge collected was 503.792.43 ETB at East Addis Ababa District in June 2023. On the contrary, the minimum service charge was 0 ETB, recorded in multiple Districts, indicating months with no service charges at an early stage of the commencement of the business.

The standard deviation for service charge is 79,339.39 ETB. The high variability in service charges collected across Districts shows significant month-to-month fluctuations. South Addis Ababa District shows the highest variability among Districts. This could be due to varying customer activity levels.

Commissions

The average commission collected from Districts was 199,219.80 ETB. North Addis Ababa District recorded the maximum income collected from the commission in June 2023 which reached 4,982,961.75 ETB. On the other hand, Adama District recorded the minimum commission, i.e., -31,348.20 ETB in June 2023 which may suggest a possible reversal or adjustment in commission income at the District. However, many Districts had 0 ETB commission in their record at the start of the Interest-Free banking business.

The standard deviation for commission income is 499,728.83 ETB. It is the highest variability among the metrics used. It shows a significant fluctuation in commission-based banking services across the Districts. North Addis Ababa District leads Districts in showing high fluctuation in commission income reflecting volatile commission-based activities

Input Variables

Personnel Expense

Personnel expenses represent the majority portion of District expenses. The average personnel expense during the study period was 3,278,028.42 ETB. The maximum personal expense incurred was 33,727,717.96 ETB which was at West Addis Ababa District in June 2023. The minimum personnel expense incurred was 0 ETB in multiple Districts indicating months when no personnel expenses were incurred at the early stage of the business.

The standard deviation for personnel expense is 4,629,251.80 ETB reflecting significant variability in monthly personnel expenses among Districts. West Addis Ababa and Dire Dawa Districts show high variability in personnel expenses, suggesting inconsistent costs associated with staffing.

Operating Expense

The average operating expense of Districts was 1,266,384.96 ETB. The maximum operating expense, 18,751,844.20 ETB, was incurred at West Addis Ababa District in June 2023. East Addis Ababa, on the contrary, recorded the minimum operating expense, i.e., -627,549.59.00 ETB. This negative value suggests a possible accounting adjustment or reversal of expense in that period. However, few Districts had recorded 0 ETB operating expenses in their books of account at an early stage of providing Interest-Free banking services.

The standard deviation for operating expenses is 2,325,731.41 ETB. The highest standard deviation shows substantial month-to-month variability, suggesting fluctuating operating needs or costs. Dessie District has the highest standard deviation in operating expenses, pointing to inconsistent operational costs. This might be due to fluctuating overheads, variable utility costs, or irregular expenses.

Total Deposits

The average total deposits mobilized by Districts during the study period was 290,643,113.32 ETB. The maximum deposit mobilized was at West Addis Ababa District which is 1,693,706,307.43 in February 2023. Adama District recorded the lowest deposit in July 2018, i.e., 2,575,734.14 ETB.

The standard deviation for the total deposit is 271,552,300.42. This is the lowest standard deviation among the metrics used. However, it shows a moderate level of variability reflecting fluctuations in deposit mobilization activity or existence of irregular or one-time large deposits. The finding may also point to economic dynamics that can impact the stability and predictability of deposit inflows at the respective Districts. South Addis Ababa and North Addis Ababa Districts show significant variability in total deposits.

Table 4.2 - 1: Descriptive Statistics of the Study variables

	Output Variable			***Input Variable***		
	Income Earned on Financing, Advance & Investment [FI]	Service Charge [SC]	Commission [CN]	Personnel Expenses [PE}	Operating Expense [OE]	Total Deposit [TD]
Count	720	720	720	720	720	720
Mean	6,081,035.13	57,839.93	199,219.80	3,278,028.42	1,266,384.96	290,643,113.32
St.dev	13,716,368.74	79,339.39	499,728.83	4,629,251.80	2,325,731.41	271,552,300.42
Min	-	-	(31,348.20)	-	(627,549.59)	2,575,734.14
Max	137,346,432.93	503,792.43	4,982,961.75	33,727,717.96	18,751,844.20	1,693,706,307.43

4.3 Malmquist Productivity Change

The Malmquist Productivity Index (MPI) provides a comprehensive measure of productivity change over time by decomposing these changes into efficiency and technological components. It further decomposes the efficiency change into pure efficiency change and scale efficiency change. It also gives the total factor productive change over the study period.

This analysis examines the productivity of various Districts using the MPI, highlighting the dynamics of efficiency and technological changes across different regions. The following sections discuss how Malmquist's total factor productivity is interpreted over the study periods and among Districts.

4.3.1 Interpretation of Malmquist Productivity Index of Periodic Changes

Efficiency Change (EFFCH)

Efficiency Changes (EFFCH) measures the change in efficiency over time. The analysis of the Malmquist Index highlights notable fluctuations in efficiency change (EFFCH) over the study period from July 2018 to June 2023. Specifically, the data shown in Table 4.3.1-1 below, reveals that the highest efficiency change occurred in July 2021/22 (M1), with an EFFCH value of 1.428, indicating a significant 42.8%improvement in efficiency during that month. Conversely, lower efficiency changes were observed in months such as June 2020/21 (M12), with a value of 0.691, reflecting a decline in efficiency by 30.9%.

Overall, the mean EFFCH value across all periods is approximately 1.002, suggesting a marginal 0.2 % overall improvement in efficiency over the entire period. This means that, on average, the Bank has become slightly more efficient in converting inputs into outputs over the study period in its IFB business.

Technology Change (TECHCH)

Technology change (TECHCH) measures the shift in technology over time. Technology change (TECHCH) exhibits substantial variability, reflecting the dynamic nature of technological advancements within the evaluated timeframe. Noteworthy peaks in Table 4.3.1-1 with regards to TECHCH are observed in May 2021/22 (M11) and December 2021/22 (M6), with values of 13.927 (1,292.7% improvement) and 9.170 (817% improvement), respectively. These significant increases indicate periods of substantial technological progress, likely driven by innovations or investments in new technologies. Conversely, months such as August 2020/21 (M2) and April 2021/22 (M10) show minimal TECHCH values of 0.042 (95.8% decline) and 0.044 (95.6% decline), respectively, suggesting periods of technological regress or limited technological development.

The mean TECHCH value is 1.025, indicating an overall positive trend in technological change across the study period. This highlights a significant 2.5% improvement in technology change, suggesting technological advancements have played a major role in enhancing productivity and operational efficiency. These advancements could include the adoption of new technologies, improvements in existing processes, or innovations that lead to better output with the same or fewer inputs.

Pure Efficiency Change (PECH)

The pure efficiency change (PECH) metric which excludes scale effects measures changes in efficiency purely from a managerial perspective. It remained relatively stable across the study periods. The highest PECH value of 1.328 (32.8% improvement) is observed in July 2020/21 (M1), denoting significant improvements in pure efficiency. In contrast, the lowest PECH value of 0.828 (17.2% decline) is recorded in June 2019/20 (M12), reflecting a decline in pure efficiency.

The overall mean PECH value is approximately 1.001, suggesting minor 0.1% improvements in pure efficiency over the entire period. It suggests a very slight improvement in pure efficiency. This means that the Bank's internal processes and management practices have become just a bit more effective in using inputs to produce outputs.

Scale Efficiency Change (SECH)

Scale efficiency change (SECH) metrics indicate changes attributable to the scale of operations. The SECH values are predominantly close to 1, signifying minor fluctuations in scale efficiency over the periods. The highest SECH value of 1.208 (20.8% increase) is observed in July 2021/22 (M1), suggesting optimal scaling operations during that month. Conversely, the lowest SECH value of 0.800 (20% decline) is recorded in June 2020/21 (M12), indicating suboptimal scale efficiency.

The mean SECH value is approximately 1.001, indicating overall stability in scale efficiency with a 0.1% change over the five years. Similarly, an SECH value of 1.001 indicates a very slight improvement in scale efficiency, implying the Bank is operating at a slightly more optimal scale, by increasing its footprint in the IFB business to achieve better efficiency.

Total Factor Productivity Change (TFPCH)

Total factor productivity change (TFPCH), which combines both efficiency and technology changes, measures the overall productivity change. It exhibited significant variability, reflecting the combined impact of the aforementioned metrics. The highest TFPCH value of 12.229 (1,122.9% improvement) is recorded in May 2021/22 (M11), driven by substantial technological advancements during that month. Other notable peaks include December 2021/22 (M6) with a TFPCH value of 9.101 (810% improvement). In contrast, lower TFPCH values, such as 0.017 (98.3% regress) in September 2022/23 (M3) and 0.039 (96.1% regress) in August 2020/21 (M2), reflect periods of highest productivity losses.

The mean TFPCH value is 1.026, indicating the Bank's overall IFB business total factor productivity showed a positive trend of 2.6% annually over the study period. The TFPCH value of 1.026 indicates an overall improvement in productivity, taking into account both efficiency and technological changes. This shows that the combined effect of slight improvements in efficiency and substantial technological advancements has resulted in a meaningful increase in total factor productivity.

Table 4.3.1 - 1: Malmquist Index Summary of Monthly Mean Using Intermediation approach

Year*	Efficiency change (EFFCH)	Technology change (TECHCH)	Pure Efficiency change (PECH)	Scale Efficiency change (SECH)	Total Factor Productivity change (TFPCH)
2018/19 M2	1.118	0.795	1.045	1.070	0.889
2018/19 M3	0.987	0.317	0.987	1.000	0.313
2018/19 M4	0.973	0.654	0.990	0.983	0.636
2018/19 M5	0.950	1.894	0.948	1.002	1.799
2018/19 M6	0.979	1.172	0.979	1.000	1.147
2018/19 M7	1.056	1.677	1.058	0.998	1.771
2018/19 M8	1.039	1.682	1.026	1.013	1.747
2018/19 M9	1.000	0.206	1.006	0.995	0.206
2018/19 M10	0.947	5.678	0.984	0.962	5.376
2018/19 M11	0.915	0.776	0.883	1.036	0.709
2018/19 M12	0.971	0.939	1.117	0.870	0.912
2019/20 M1	1.205	1.812	1.033	1.167	2.184
2019/20 M2	1.005	0.303	1.009	0.996	0.305
2019/20 M3	0.960	1.114	0.996	0.963	1.069
2019/20 M4	1.038	1.202	1.004	1.034	1.247
2019/20 M5	0.962	0.983	0.976	0.986	0.946
2019/20 M6	1.049	1.075	1.024	1.025	1.128
2019/20 M7	1.001	2.402	1.000	1.001	2.403
2019/20 M8	0.902	0.385	0.960	0.940	0.347
2019/20 M9	0.878	0.858	0.997	0.881	0.753
2019/20 M10	1.036	5.322	0.961	1.079	5.516
2019/20 M11	1.021	1.093	0.974	1.048	1.116
2019/20 M12	0.854	3.402	0.828	1.031	2.906
2020/21 M1	1.297	2.075	1.328	0.976	2.691
2020/21 M2	0.947	0.042	0.943	1.004	0.039
2020/21 M3	1.059	1.742	1.067	0.993	1.845
2020/21 M4	1.018	2.103	1.008	1.010	2.142
2020/21 M5	1.032	0.711	0.988	1.045	0.734
2020/21 M6	1.007	0.535	1.013	0.995	0.539
2020/21 M7	0.814	0.608	0.843	0.965	0.495
2020/21 M8	1.181	1.429	1.186	0.996	1.688
2020/21 M9	1.009	8.658	0.965	1.046	8.739
2020/21 M10	1.025	0.238	1.021	1.004	0.243
2020/21 M11	0.963	0.862	0.970	0.992	0.830
2020/21 M12	0.691	0.588	0.864	0.800	0.406

2021/22 M1	1.428	2.658	1.182	1.208	3.795
2021/22 M2	1.029	1.043	1.023	1.006	1.074
2021/22 M3	1.040	2.777	1.000	1.040	2.888
2021/22 M4	0.797	1.762	0.883	0.902	1.403
2021/22 M5	1.202	0.773	1.114	1.079	0.929
2021/22 M 6	0.993	9.170	0.972	1.021	9.101
2021/22 M7	1.002	0.490	1.023	0.979	0.491
2021/22 M8	1.006	1.020	0.995	1.010	1.026
2021/22 M9	1.026	3.744	1.014	1.012	3.843
2021/22 M10	0.909	0.044	0.957	0.950	0.040
2021/22 M11	0.878	13.927	0.899	0.977	12.229
2021/22 M12	1.266	0.339	1.174	1.079	0.429
2022/23 M1	0.980	1.821	1.001	0.979	1.785
2022/23 M 2	1.020	4.164	1.001	1.019	4.249
2022/23 M3	0.867	0.019	0.871	0.995	0.017
2022/23 M4	1.143	4.331	1.128	1.013	4.950
2022/23 M5	1.014	1.180	1.014	1.000	1.197
2022/23 M6	0.950	0.670	0.984	0.966	0.636
2022/23 M7	1.020	1.100	1.017	1.004	1.122
2022/23 M8	0.968	1.102	0.958	1.011	1.067
2022/23 M9	1.035	1.458	1.019	1.016	1.509
2022/23 M10	1.017	1.315	1.014	1.004	1.338
2022/23 M11	0.994	0.248	0.997	0.997	0.247
2022/23 M12	1.000	0.340	1.006	0.994	0.340
Mean	**1.002**	**1.025**	**1.001**	**1.001**	**1.026**

The Bank's fiscal year starts in July [M1] and ends in June [M12]

Period-Specific Analysis

1. **2018/19 Period**:

   This period is characterized by significant fluctuations in technology change (TECHCH), with a notable high in April 2018/19 (M10) at 5.678 and a low in September 2018/19 (M3) at 0.317. Correspondingly, as can be noted from Table 4.3.1-1 above, total factor productivity change (TFPCH) also varies widely, correlating with the TECHCH variations. The TFPCH in April 2018/19 (M10) was 5.376 while and it was 0.313 in September 2018/19 (M3).

2. **2019/20 Period**:

   During this period, high TECHCH values are observed in January 2019/20 (M7) at 2.402 and April 2019/20 (M10) at 5.322, with corresponding high TFPCH values (2.403 and

5.516, respectively). Efficiency change (EFFCH) showed improvement in early July 2019/20 (M1) with 1.205 but regressed in subsequent months.

3. **2020/21 Period**:

   This period exhibits significant TECHCH increases in March 2020/21 (M9) at 8.658 and October 2020/21 (M4) at 2.103, leading to high TFPCH values (8.739 and 2.142, respectively) EFFCH is highest in July 2020/21 (M1) at 1.297, indicating strong efficiency growth early in the period but showed regress in subsequent month.

4. **2021/22 Period**:

   Marked by high TECHCH values, particularly in May 2021/22 (M11) at 13.927 and December 2021/22 (M6) at 9.170, resulting in substantial TFPCH improvements (12.229 and 9.101, respectively). As can be seen from Figure 4.3.1-1 below, EFFCH peaks in July 2021/22 (M1) at 1.428, indicating a strong start to the period but a declining trend like the previous four periods.

5. **2022/23 Period**:

   Noticeable TECHCH values are recorded in October 2022/23 (M4) at 4.331 and August 2022/23 (M2) at 4.164, contributing to increased TFPCH (4.950 and 4.249, respectively). Unlike the preceding periods EFFCH remained relatively stable with slight variations around 1.

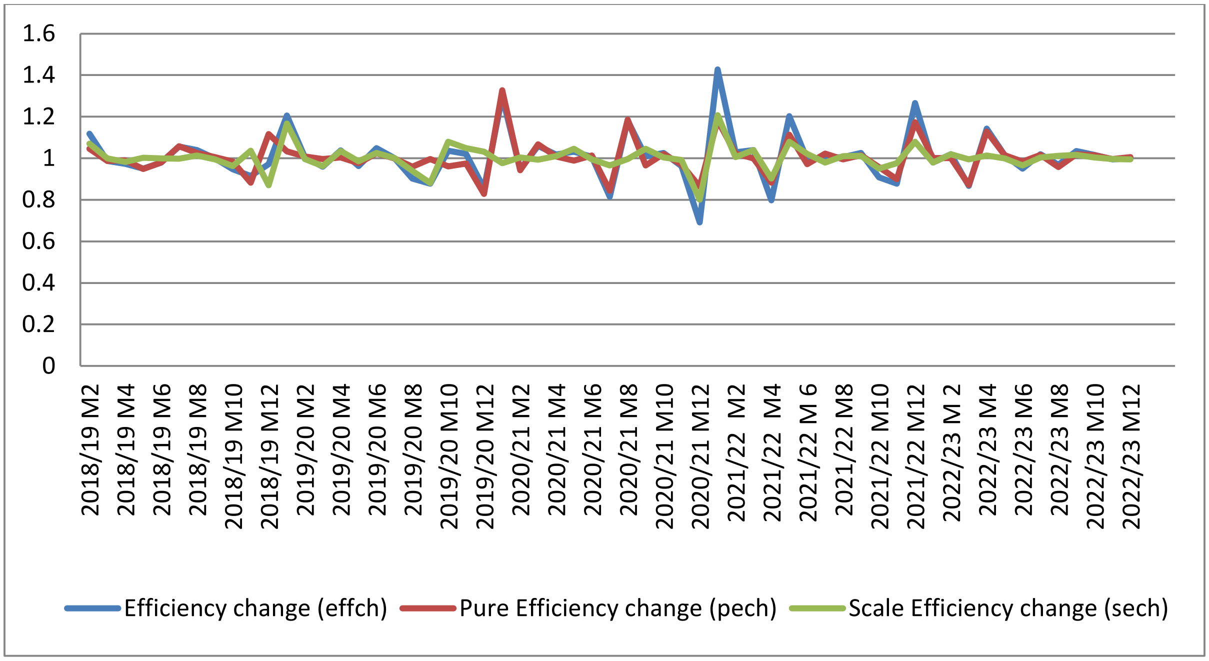

Figure 4.3.1-1: A Malmquist Index Summary of monthly Mean

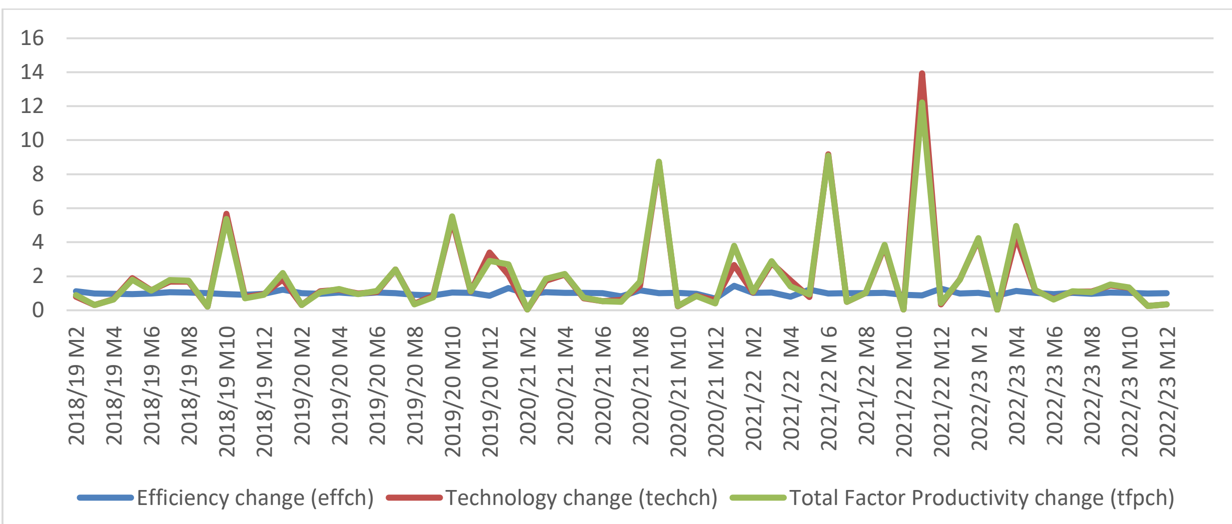

Figure 4.3.1-2: A Malmquist Index Summary of monthly Mean (EFFCH, TECHCH and TFPCH)

In summary, the TFPCH value of 1.026 (a 2.6% average annual growth) reflects the cumulative effect of efficiency and technological changes, resulting in a substantial overall productivity increase. This suggests that the combined impact of slight efficiency gains and notable technological advancements has led to a significant improvement in total factor productivity. The analysis, thus, indicates that while the Bank has experienced slight improvements in internal operational efficiency and scale, the primary driver of productivity growth has been technological advancements. The marginal improvements in efficiency metrics (EFFCH (1.002), PECH (1.001), and SECH (1.001)) indicate a stable operational environment with incremental gains. These improvements are marginal but positive, indicating that the Bank is moving in the right direction in terms of operational effectiveness and scale optimization. In contrast, the significant improvement in technology change (TECHCH) highlights the critical role of innovation and technological adoption in driving overall productivity. The TECHCH value of 1.025 underscores that technology has been a significant driver of productivity gains. Technological improvements have made a notable impact, enhancing the Bank's ability to produce more output with the same or fewer inputs. This aligns with the findings of Xie et al. (2021), Berger et al. (1992) and Worthington (1999) who showed that productivity improvements were primarily driven by technological advancements.

To sustain and enhance productivity growth, the Bank should continue to invest in and leverage new technologies while also exploring further opportunities for improving internal efficiencies and optimizing operational scale. This balanced approach will ensure that technological advancements are fully complemented by efficient internal processes and optimal scaling, leading to sustained and robust productivity growth.

This comprehensive understanding provides valuable insights for strategic decision-making and policy formulation, guiding the Bank towards continued improvement and competitiveness in the market.

4.3.2 Interpretation of Malmquist Productivity Index of Districts

Efficiency Change (EFFCH)

Efficiency change (EFFCH) captures shifts in efficiency over the study period. An EFFCH value greater than 1 indicates improvements, whereas less than 1 value indicates regress. A value equal to 1 indicates minimal or no change in efficiency. The summary of the Malmquist Productivity Index of Dashen Bank's District Means in Table 4.3.2-1 reveals that all Districts have EFFCH values very close to 1, with the average mean efficiency change being 1.002. This suggests that efficiency has remained relatively stable across the Districts with a marginal 0.2% improvement over the years of the study period.

Dire Dawa District exhibited the highest efficiency change at 1.006, indicating a slight 0.6% improvement while Dessie and East Addis Ababa Districts showed a marginal efficiency increase with an EFFCH of 1.004 (0.4% improvement). On the contrary Adama District showed a minor decrease with an EFFCH of 0.998. This indicates that the District's efficiency regressed by 0.2% over the period of the study.

Four Districts namely Bahirdar District, South Addis Ababa, West Addis Ababa, and Wolaita District showed neither improvements nor regress (with a 1.00 level of efficiency). The remaining four Districts namely Hawassa (0.3 %), Jimma (0.2 %), Mekele (0.2 %), and North Addis Ababa (0.1 %) were efficient Districts with marginal progressive efficiency.

The overall marginal efficiency of Districts, as indicated by the efficiency change (EFFCH) values in Table 4.3.2-1 below, is a reflection of how well each District has managed to maintain or improve its efficiency over the study period. Districts that have well-established and consistent operational processes and management practices are more likely to maintain stable efficiency levels. The close-to-one efficiency change values suggest that these Districts have not experienced significant disruptions in their operations. Regular optimization of operational processes can also lead to slight improvements in efficiency. Districts with EFFCH values slightly above 1 may have engaged in incremental improvements in their workflows and resource utilization. Adama District's slight decrease in efficiency, indicating marginal inefficiencies of 0.2% over the years, is possibly due to minor operational challenges or resource allocation issues.

Technology Change (TECHCH)

Technology change (TECHCH) measures shifts in the technological frontier. It represents the innovation in banking systems that has been adopted by Districts. Values greater than 1 indicate technological progress, while values below 1 denote technological regression. The mean technology change is 1.025, suggesting overall technological progress of 2.5% annually.

Eight Districts, West Addis Ababa, Wolaita, South Addis Ababa, North Addis Ababa, Jimma, Mekele, Hawasa, and East Addis Ababa (66.7% of Districts) have shown improvements in technology changes. Adama, Bahir Dar, Dessie, and Diredawa (33.3% of the Districts) have exhibited regress in technology change. West Addis Ababa District exhibited the highest technological progress with a TECHCH of 1.172 (17.2% progress) followed by Wolaita and South Addis Ababa Districts which have shown significant technological advancement with a TECHCH of 1.156 (15.6% progress) and 1.150 (15% progress), respectively. Besides, North Addis Ababa (TECHCH of 1.137), Jimma **(**TECHCH of 1.126), Mekelle **(**TECHCH of 1.116) and Hawassa (TECHCH of 1.073), Districts have also demonstrated substantial progress of 13.7%, 12.6%, 11.6% and 7.3%.

On the contrary, Adama showed the most significant technological regression with a TECHCH of 0.793 (20.7% regress). Bahirdar District, Dessie, and Dire Dawa have also indicated technological regression of 20.3%, 9.5% and 3% with a TECHCH of 0.797, 0.905, and 0.970, respectively.

The variability of technology changes among Districts deploying the same technology is influenced by a combination of internal and external factors. The extent to which technology is implemented and utilized effectively can vary. Some Districts may fully leverage the technology's capabilities, while others may use it sub-optimally due to a lack of training or resources. The skill levels of staff and the quality of training received can greatly influence the effectiveness of technology deployment.

The availability of technical support and maintenance services can also affect the performance of technology. Districts with better access to support services can ensure smoother operation and quicker resolution of issues. Local market conditions, including competition and customer demand, can drive the need for more effective use of technology, leading to variability in outcomes. External factors like telecom infrastructure, availability and consistency of telecom services have also the potential to impact the utilization of adapted technologies leading to progress or regress in technology change. Understanding and addressing these factors can help Districts maximize the benefits of technology and achieve more consistent improvements in productivity and performance.

Pure Efficiency Change (PECH)

Pure efficiency change (PECH) measures changes in efficiency solely due to managerial effectiveness, independent of scale and technological factors. It reflects how well the management practices contribute to improving or maintaining efficiency. The pure efficiency change values across most Districts are remarkably stable. As can be noted from Table 4.3.2-1 below, six Districts (50%) have PECH values exactly equal to 1, four Districts (33.3%) have marginal PECH values greater than 1 and the rest two Districts (16.7%) have PECH values less than one but having minimal impact. This clearly indicates no significant change is observed in managerial efficiency during the study period. This uniformity suggests that managerial practices have remained consistent across the Districts during the observed period.

Most Districts have maintained consistent managerial practices, which have neither significantly improved nor deteriorated efficiency. This consistency is a positive indicator of steady management. The minor 0.1% regress observed in some Districts (e.g., Dessie and Dire Dawa Districts (each with PECH value of 0.999) are negligible, indicating that any changes in managerial practices have had a minimal impact on overall efficiency. Districts like East Addis Ababa (PECH value of 1.003), Hawassa (PECH value of 1.003), Jimma (PECH value of 1.002), and North Addis Ababa (PECH value of 1.001) show slight improvements of 0.3%, 0.3%, 0.2% and 0.1 %, respectively in pure efficiency. These reflects successful managerial initiatives that might have marginally enhanced efficiency. The overall stable pure efficiency changes highlight the importance of maintaining effective management practices to ensure steady operational performance. It also suggests that any significant improvements in productivity in these Districts are likely due to factors other than management practices, such as technological advancements.

Scale Efficiency Change (SECH)

Scale efficiency change (SECH) assesses shifts in efficiency related to the scale of operations. Similar to pure efficiency change, SECH values are close to 1 across all Districts, with a mean of 1.001. This indicates minimal changes in scale efficiency, suggesting that the Districts are operating at or near their optimal scale. It also implies that the scale of operations has not significantly impacted overall efficiency.

Table 4.3.2-1 below shows Bahir Dar, Hawassa, Jimma, North Addis Ababa, South Addis Ababa, West Addis Ababa, and Wolaita Districts have SECH values equal to 1, indicating neither improvement nor regress in scale efficiency change and are continuing to operate at their optimal scale. These Districts constitute 58.3% of the Bank's Districts. Dire Dawa (SECH value of 1.007), Dessie (SECH value of 1.005), Mekele (SECH value of 1.002), and East Addis Ababa (SECH value of 1.001) Districts had slight improvements of 0.7%, 0.5%, 0.2%, and 0.1%, respectively in scale efficiency, suggesting minor optimization in how it uses its scale of operations. Adama District showed a slight decrease in scale efficiency (SECH value of 0.998 or regress of 0.2%), suggesting that there might be minor inefficiencies in how the District is utilizing its scale of operations.

The stability in scale efficiency across most Districts suggests effective management of operational scale, contributing to overall efficiency and productivity. Districts with slight declines or improvements should investigate further to identify areas for potential optimization and sustained efficiency.

Total Factor Productivity Change (TFPCH)

Total factor productivity change (TFPCH) combines both efficiency and technology changes to provide a holistic view of productivity evolution. A TFPCH value greater than 1 indicates an improvement in productivity, while a value less than 1 indicates a decline. The mean TFPCH is 1.026, indicating an overall 2.6% yearly average improvement in productivity across the Districts.

As can be noted from Table 4.3.2-1 below, eight Districts representing 66.7% of the total Districts have a higher mean positive change in total factor productivity implying that these Districts have managed to generate more revenue (output variables were Income Earned from Financing, Service Charge and Commission) by incurring the given expenses (inputs were Personnel & Operating Expenses) and utilizing the available resource (Total Deposit), or conversely, that it requires fewer inputs to generate a given level of revenue. This increase in productivity is generally attributed to improvements in efficiency and technological advancements.

On the contrary four Districts (33.3 %) had TFPCH less than 1 indicating a decline in TFP throughout the study period (July 2018 to June 2023). This shows that the Districts were inefficient in generating the expected revenue from the given inputs. The Districts could have reduced the inputs to record the same revenue they earned over the period.

As shown in Figure 4.3.2-1, West Addis Ababa leads Districts by showing the most significant improvement with a TFPCH of 1.172 (17.2% annual average growth) during the study period. The District benefited from significant technological progress (TECHCH value of 1.172), resulting in a major productivity gain with stable efficiency metrics. Wolaita and South Addis Ababa follow closely with a TFPCH of 1.156 and 1.150, respectively. North Addis Ababa (TFPCH value of 1.138) Jimma (TFPCH value of 1.128), Mekele (TFPCH value of 1.118), Hawassa (TFPCH value of 1.077) and East Addis Ababa (TFPCH value of 1.016) have also exhibited notable productivity gains during the periods. Conversely, Adama and Bahirdar Districts have exhibited a significant decline in productivity with TFPCH values of 0.791 and 0.797, respectively. Dessie (TFPCH value of 0.908) and Dire Dawa (TFPCH value of 0.976) Districts have also shown a marginal decline in productivity over the study periods.

The primary driver of TFPCH changes across Districts is technological progress. Districts with significant technological advancements, such as West Addis Ababa, Wolaita, South Addis Ababa, North Addis Ababa, and Jimma, exhibited the highest total factor productivity gains. Most Districts maintain stable pure and scale efficiency, indicating that TFPCH is largely influenced by technological factors rather than managerial or operational efficiency.

Districts like Adama and Bahirdar, which showed technological regression, experienced significant declines in TFPCH. This highlights the critical role of technology in driving productivity improvements. Districts with slight declines in TFPCH, such as Dessie and Dire Dawa, reflect minor changes in both efficiency and technological factors, leading to modest overall productivity changes.

Table 4.3.2 - 1: Summary of Malmquist Productivity Index of Bank District Means

District	Efficiency change (EFFCH)	Technology change (TECHCH)	Pure Efficiency change (PECH)	Scale Efficiency change (SECH)	Total Factor Productivity change (TFPCH)
Adama	0.998	0.793	1.000	0.998	0.791
Bahirdar	1.000	0.797	1.000	1.000	0.797
Dessie	1.004	0.905	0.999	1.005	0.908
Dire Dawa	1.006	0.970	0.999	1.007	0.976
East Addis Ababa	1.004	1.013	1.003	1.001	1.016
Hawassa	1.003	1.073	1.003	1.000	1.077
Jimma	1.002	1.126	1.002	1.000	1.128
Mekele	1.002	1.116	1.000	1.002	1.118
North Addis Ababa	1.001	1.137	1.001	1.000	1.138
South Addis Ababa	1.000	1.150	1.000	1.000	1.150
West Addis Ababa	1.000	1.172	1.000	1.000	1.172
Wolaita	1.000	1.156	1.000	1.000	1.156
Mean	**1.002**	**1.025**	**1.001**	**1.001**	**1.026**

The Total Factor Productivity (TFP) change results underscore the importance of technological innovation and adoption in enhancing productivity within the banking sector. As shown in Figure 4.3.1-2 Districts that have embraced technological advancements demonstrate significant productivity improvements, while those experiencing technological regression show notable declines. Maintaining stable efficiency levels while fostering technological progress is crucial for sustained productivity growth. Policymakers and bank management should focus on encouraging technological adoption and innovation to drive further productivity enhancements across all Districts.

The above findings align with the findings of Xie et al. (2021), Berger et al. (1992) and Worthington (1999) who showed that productivity improvements were primarily driven by technological advancements. Besides, the observed decline in District's TFP due to technological regress is also observed in studies like Ascarya and Yumanita (2008), Agrawal (2021), Berhe (2021) and Bayiley (2022) who have shown variability in DMUs efficiency driven by differences in technological changes, adoption or integration.

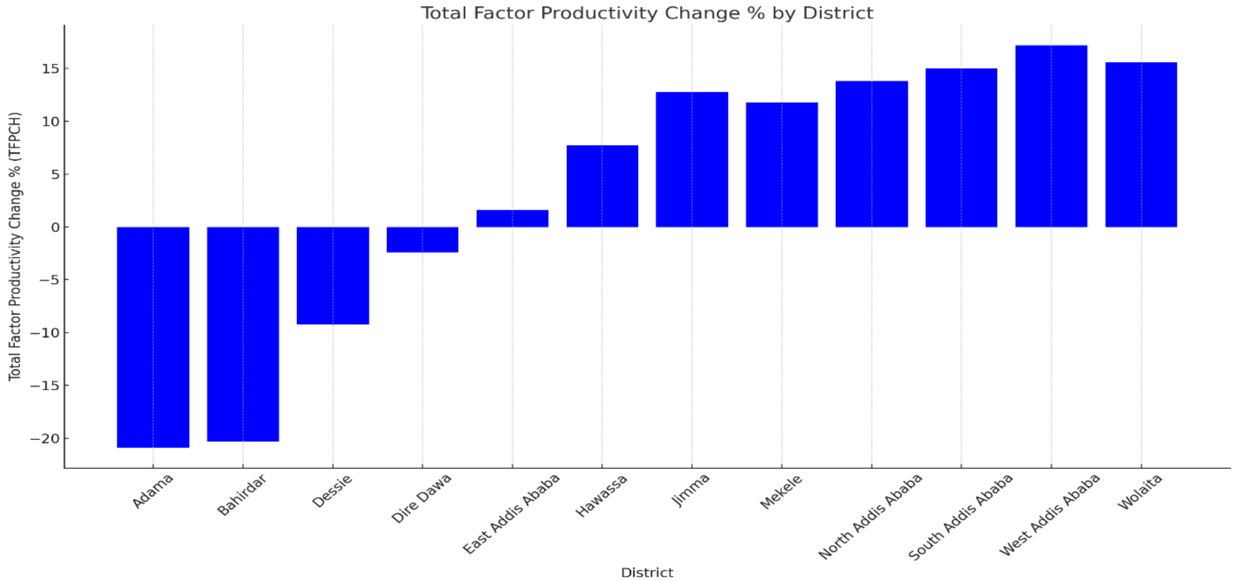

Figure 4.3.2-1: Malmquist Index Summary of Annual Mean of Total Factor Productivity Change

4.4 Determinants of Districts Efficiency

Upon examining efficiency as a critical determinant of performance, we have transitioned our quantitative analysis to investigate which input and output variables serve as determinant factors of efficiency. The District efficiency score is regressed using a one-step system GMM, with efficiency as the dependent variable. The independent variables include the previous year's District efficiency, total deposit growth, total income growth, and expense growth.

The results indicate that the deposit growth rate and income growth have a significant and positive impact on the efficiency of the Bank’s Districts. Conversely, expense growth has a negative and insignificant impact on the Districts’ efficiency.

Other things remain constant; a 1% increase in the deposit growth rate per District results in a 0.076% increase in District efficiency. This outcome is attributable to the fact that higher deposit growth translates to more funds available for financing and investment, allowing banks to generate more revenue from interest-free banking activities such as financing, trade, and investment. Additionally, a steady and positive deposit growth rate contributes to the stability and liquidity of a bank's operations, enhancing overall efficiency by mitigating the risk of liquidity shortages or dependency on costly short-term borrowing during periods of need. This finding aligns with the results of Bayiley (2022) in Ethiopia, Abdullah, Parvez, and Ayreen (2014) in Bangladesh, and Yuan et al. (2022) in Southeast Asian countries.

Total income growth also exhibits a positive and significant effect on the efficiency of Interest-Free banking in each District. Other things remain constant; a 1% increase in the income growth rate per District results in a 0.256% increase in District efficiency. Higher-income streams from various sources such as financing, investments, and fees contribute to the overall revenue of interest-free banking institutions. Efficient management of these income sources can enhance the bank's overall profitability and efficiency. A stable and growing income often reflects customer trust in the institution's services and products, fostering customer retention and attracting new clients, thereby positively influencing efficiency through increased business opportunities. This finding is consistent with the studies of Li et al. (2021), Dao (2020) and Zhou (2021), which also found that income positively and significantly affects the efficiency of banks.

In contrast, the growth rate of expenses per District has a negative and insignificant effect on efficiency. Expenses can have a complex relationship with the efficiency of interest-free banking. While expenses are necessary for the operation and growth of any banking institution, inefficient or unmanaged expenses can indeed negatively impact efficiency. Uncontrolled or unnecessary expenses may indicate operational inefficiencies within the bank, such as excessive administrative costs, redundant processes, or inefficient resource allocation, all of which can hinder overall efficiency (Shair et al., 2021; Syafrizal et al., 2023).

In summary, the analysis underscores the critical role of deposit and income growth in driving District efficiency. These results offer valuable insights for policymakers and District managers aiming to enhance efficiency by focusing on strategies that promote deposit mobilization and income growth.

Table 4.4 - 1: Regression Results on Efficiency Determinants

Empirical Results on Efficiency Determinants		
Regressors	One-step system GMM result	
	Coefficients	P- value
l.Eff	0.010	0.729
ln(TD)	0.076	0.000***
ln(TI)	0.256	0.000***
ln(TE)	-0.070	0.265
Cons_	14.51	0.000***
Hansen Test of Overid. Restrictions	chi2(64) =433.92	Pr > chi2 = 0.559
Arellano-Bond Test Autocorrelation	AR (1): z = -4.47 AR(2): z = 1.06	Pr > z = 0.000 Pr > z = 0.288
No of observation	12 IFB Districts* 60 Months =720 Observations	

CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary of Findings

The objective of this study is to analyse the efficiency of Dashen Bank's Interest-Free banking window service in all Districts. The study included all 12 Districts spread across the country.

The study used the DEA-based Malmquist productivity index technique to measure the changes in total factor productivity and efficiency performance of Dashen Bank's Districts with respect to their interest-free banking during the period July 2018 to June 30, 2023.

- The analysis of the Malmquist Productivity Index over the study period reveals distinct patterns in efficiency and productivity changes. The Malmquist Index for total factor productivity change was 1.026, indicating that the Bank's IFB overall productivity improved by 2.6% annually. This was the result of the combined impact of slight efficiency gains and notable technological advancements across Districts during the study period.
- The mean value of technological change was 1.025, showing a 2.5% annual improvement in technological change.
- The efficiency change has a mean value of 1.002, indicating that growth is increasing by 0.2%. The decomposition of the efficiency change index into its mutually exhaustive pure technical and scale efficiency components reveals that a marginal annual improvement of 0.1% was shown in both pure and scale efficiency change.
- A 0.1% improvement in scale efficiency implies that the Bank's Districts have slightly enhanced their ability to achieve an optimal scale of operation, potentially leading to better utilization of resources and improved productivity.
- The pure efficiency change of 1.001 implies a minimal improvement in the efficiency of the management, operations, and processes being deployed. This improvement could signify better resource utilization and operational enhancements within the Bank's Districts.

Finally, the District efficiency score is regressed using a one-step system GMM using efficiency as the dependent variable with the previous year's District efficiency, total deposit growth, total income growth, and expense growth (determining variable). The study revealed that deposit and income growth positively influence district efficiency, while expense growth has a negative but insignificant impact

5.2. Conclusions

Based on the analysis conducted in this study, the following conclusions have been drawn:

- The primary inputs utilized in measuring the efficiency of IFB (Interest-Free Banking) include personnel expenses, operating expenses, and total deposits, while the main outputs consist of income earned from financing, advances and investments, service charges, and commissions.

- The findings indicate that both deposit growth rate and income growth have a significant and positive impact on the efficiency of the Districts. Conversely, expense growth has a negative and insignificant impact on the efficiency of the Districts' IFB operations.

- The District-wise analysis of the Malmquist Productivity Index reveals that, although efficiency has remained relatively stable across most Districts, technological advancements have significantly driven overall productivity. Specifically, the West Addis Ababa, Wolaita, and South Addis Ababa Districts demonstrated the highest annual productivity improvements, with increases of 17.2%, 15.6%, and 15%, respectively, during the study period. These Districts have benefited substantially from technological advancements, leading to significant productivity gains. In contrast, the Adama and Bahirdar Districts experienced technological regressions, resulting in decreased productivity by 20.9% and 20.7%, respectively, over the study period. These results underscore the critical role of technological innovation in enhancing productivity within the banking sector.

- The study identifies technological deficiency as the most significant source of inefficiency within the Bank's Interest-Free Banking division, as observed across various Districts.

- Overall, the study concludes that there exists a stable operational environment, and the Bank is progressing in the right direction concerning operational effectiveness and scale optimization.

5.3. Recommendations

The results of this study provide policymakers and management with critical insights into the relative efficiency and productivity of Dashen Bank Districts, enabling them to implement remedial actions to enhance the efficiency of the District's IFB windows where necessary. Additionally, these insights will assist management and policymakers in making informed strategic decisions concerning the bank's IFB business and District operations.

Through a comprehensive analysis of financial data, statistical findings, and the DEA Malmquist Index results, several key insights into the Bank's District efficiency and productivity trends have been identified. The findings underscore areas of strength, notably in technological advancements, as well as opportunities for further improvement in operational efficiency and scale optimization. In this section, we present targeted recommendations designed to leverage these insights, aiming to enhance the Bank's overall performance and competitive position. By implementing these strategic recommendations, the Bank can build on its current successes, address identified inefficiencies, and drive sustained growth and productivity improvements.

1. Continue Investing in Technology

    - Prioritize investments in new technologies and innovations to enhance operational efficiency and output.
    - Adopt advanced data analytics, automation, and digital transformation strategies to streamline processes and reduce operational costs.

2. Enhance Internal Operational Efficiency

    - Optimize internal processes to maximize efficiency gains.
    - Implement continuous improvement methodologies to identify and eliminate inefficiencies within the Bank's operations.
    - Utilize resource optimization strategies to ensure effective use of human capital, financial assets, and technological tools. Regularly assess resource allocation to identify and eliminate inefficiencies.

3. Optimize Scale of Operations
    - Evaluate the Bank’s operational scale to ensure it is appropriately sized for maximum efficiency.
    - Conduct a thorough analysis of production capacity and market demand to determine the most efficient scale of operation.
4. Monitor and Evaluate Performance Regularly
    - Enhance the regular monitoring and evaluation of efficiency and productivity metrics across Districts for continuous improvement.
    - Utilize performance management tools and dashboards to provide real-time insights into operational performance and make data-driven decisions to address inefficiencies promptly.
5. Employee Training and Development
    - Invest in employee training and development programs to support the integration of new technologies and process improvements.
    - Ensure employees are well-versed in the latest technologies and best practices to enhance their contribution to the Bank’s efficiency and productivity.
    - Implement regular training sessions, workshops, and certification programs to keep employees updated on industry trends and technological advancements.
6. Strategic Partnerships and Collaborations
    - Form strategic partnerships and collaborations with technology providers, research institutions, and industry experts to stay at the forefront of technological innovations and best practices.
    - Engage in industry forums and networks to share knowledge and gain insights into emerging trends that can improve the Bank’s operations.
7. Enhance Deposit Mobilization Strategies
    - Prioritize strategies that enhance deposit mobilization.
    - Develop innovative and Shari’ah-compliant deposit products.

- Improve customer service and leverage technology to reach a broader customer base.

8. Focus on Revenue Generation Activities

- Concentrate on activities that boost income generation.
- Develop innovative and Shari'ah-compliant financing and investment products.
- Diversify revenue sources by expanding into new financial products and services that generate more service charges and commissions.

9. Optimize Expense Management

- Focus on optimizing expense management to ensure that any increase in expenses does not adversely impact efficiency.
- Implement cost control measures to enhance operational efficiency.

10. Maintain a Baseline Level of Efficiency

- Establish a baseline level of efficiency and continuously monitor performance metrics, benchmarking against industry standards, and adopting best practices in operational management.

11. Continuous Improvement Program

- Foster a culture of continuous improvement across all Districts. Regularly review processes, identify areas for improvement, and implement best practices to enhance efficiency and effectiveness.
- Create a platform for experience sharing among Districts, benchmarking high-performing Districts for performance improvements.

12. District Re-Organization

- Consider reorganizing Districts across the country to achieve balanced and manageable decision-making units across various geographic, demographic, and administrative regions.
- Ensure consistent credit management across the Districts in line with the economic activity of each region.

- Implement strategic interventions to support underperforming Districts to ensure balanced regional development.

5.3 Suggestions for Further Research

The findings of this study have shed light on the efficiency analysis of the IFB windows at Dashen Bank's Districts. The developed framework could be adapted by other researchers. However, there are limitations as discussed in section 1.6 of this study. Addressing these gaps could enable future research to provide a more comprehensive understanding of bank efficiency and productivity, leading to better strategic decision-making and policy formulation in the financial sector. Future research could explore the following aspects:

1. Extending the analysis to the efficiency of the Bank's IFB window services at the Branch level as more relevant data become available.
2. Combining the intermediation approach used in this study with the production approach or model to offer a more comprehensive interpretation of the efficiency of the IFB windows at either the District or Branch level.
3. Repeating the study with the inclusion of additional variables not considered in this research.
4. Conducting a comparative analysis of IFB window services by incorporating IFB windows from other banks.
5. Comparing the efficiency of IFB windows of conventional banks and Full-Fledged IFB banks.
6. Including factors unique to the IFB business to provide a holistic assessment of the efficiency of the IFB windows.
7. Investigating the impact of digital banking, fintech innovations, and technological advancements on bank efficiency, given that technological change was found to be the primary driver of bank efficiency.

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APPENDICES

Appendix A : Results from DEAP

```
Results from DEAP Version 2.1

Instruction file = eg4-ins.txt
Data file         = EG4-dta.txt

Output orientated Malmquist DEA

MALMQUIST INDEX SUMMARY

 year =     2

   firm   effch  techch    pech    sech   tfpch

     1    1.000   0.140   1.000   1.000   0.140
     2    1.000   0.273   1.000   1.000   0.273
     3    1.331   0.468   1.000   1.331   0.622
     4    1.500   0.729   1.000   1.500   1.092
     5    1.242   1.314   1.178   1.054   1.632
     6    1.250   1.236   1.221   1.024   1.545
     7    1.101   1.216   1.112   0.990   1.338
     8    1.049   1.052   0.996   1.053   1.103
     9    1.071   1.221   1.066   1.005   1.308
    10    1.000   1.219   1.000   1.000   1.219
    11    0.998   1.243   1.000   0.998   1.241
    12    1.000   1.273   1.000   1.000   1.273

 mean     1.118   0.795   1.045   1.070   0.889

 year =     3

   firm   effch  techch    pech    sech   tfpch

     1    1.000   0.214   1.000   1.000   0.214
     2    1.000   1.538   1.000   1.000   1.538
     3    1.000   0.749   1.000   1.000   0.749
     4    0.944   0.581   0.970   0.973   0.548
     5    1.000   0.154   1.000   1.000   0.154
     6    1.000   0.241   1.000   1.000   0.241
     7    1.012   0.230   1.000   1.012   0.233
     8    0.994   0.225   0.975   1.019   0.224
     9    0.900   0.228   0.900   1.000   0.205
    10    1.000   0.232   1.000   1.000   0.232
    11    1.002   0.256   1.000   1.002   0.256
    12    1.000   0.273   1.000   1.000   0.273

 mean     0.987   0.317   0.987   1.000   0.313

 year =     4
```

firm	effch	techch	pech	sech	tfpch
1	1.000	0.628	1.000	1.000	0.628
2	0.829	0.447	1.000	0.829	0.371
3	0.943	0.406	1.000	0.943	0.383
4	1.059	0.698	1.031	1.028	0.740
5	0.792	0.639	0.794	0.998	0.506
6	0.999	0.670	1.000	0.999	0.669
7	1.001	0.651	1.000	1.001	0.652
8	0.994	0.664	0.972	1.022	0.660
9	1.111	0.659	1.111	1.000	0.733
10	0.997	0.753	1.000	0.997	0.751
11	1.000	0.888	1.000	1.000	0.888
12	1.000	0.937	1.000	1.000	0.937
mean	0.973	0.654	0.990	0.983	0.636

year = 5

firm	effch	techch	pech	sech	tfpch
1	1.000	2.209	1.000	1.000	2.209
2	0.653	1.178	0.633	1.032	0.769
3	0.762	1.536	0.764	0.997	1.170
4	1.000	1.777	1.000	1.000	1.777
5	1.224	2.085	1.229	0.996	2.551
6	1.001	2.377	1.000	1.001	2.379
7	1.000	2.397	1.000	1.000	2.397
8	0.883	2.230	0.890	0.991	1.969
9	1.000	1.860	1.000	1.000	1.860
10	1.003	1.976	1.000	1.003	1.982
11	1.000	1.649	1.000	1.000	1.649
12	1.000	1.867	1.000	1.000	1.867
mean	0.950	1.894	0.948	1.002	1.799

year = 6

firm	effch	techch	pech	sech	tfpch
1	1.000	10.448	1.000	1.000	10.448
2	1.846	1.158	1.579	1.169	2.138
3	1.217	1.398	1.309	0.929	1.700
4	1.000	1.411	1.000	1.000	1.411
5	1.031	1.492	1.025	1.006	1.538
6	0.507	0.794	0.508	0.997	0.402
7	0.630	0.663	0.631	0.998	0.418
8	1.156	0.474	1.184	0.977	0.547
9	0.943	0.633	1.000	0.943	0.597
10	0.958	1.111	0.961	0.996	1.064
11	1.000	1.110	1.000	1.000	1.110
12	1.000	0.970	1.000	1.000	0.970
mean	0.979	1.172	0.979	1.000	1.147

year = 7

firm	effch	techch	pech	sech	tfpch
1	1.000	0.315	1.000	1.000	0.315
2	0.807	0.955	0.833	0.969	0.771
3	1.048	1.126	0.918	1.142	1.180
4	0.769	1.617	0.881	0.873	1.244
5	0.889	1.900	0.901	0.987	1.689
6	1.974	3.270	1.968	1.003	6.455
7	1.586	2.928	1.584	1.002	4.644
8	1.039	2.296	1.005	1.033	2.385
9	1.061	2.290	1.000	1.061	2.428
10	1.006	2.160	1.040	0.967	2.172
11	1.000	2.120	1.000	1.000	2.120
12	0.959	2.064	1.000	0.959	1.979
mean	1.056	1.677	1.058	0.998	1.771

year = 8

firm	effch	techch	pech	sech	tfpch
1	0.938	0.976	1.000	0.938	0.916
2	1.239	1.361	1.201	1.032	1.686
3	1.092	1.087	1.090	1.002	1.187
4	1.133	1.016	0.994	1.140	1.150
5	1.043	1.717	1.041	1.002	1.791
6	0.989	2.449	1.000	0.989	2.421
7	0.984	2.309	1.000	0.984	2.272
8	1.000	1.816	1.000	1.000	1.816
9	1.000	1.816	1.000	1.000	1.816
10	1.038	2.006	1.000	1.038	2.084
11	1.000	2.237	1.000	1.000	2.237
12	1.043	2.423	1.000	1.043	2.527
mean	1.039	1.682	1.026	1.013	1.747

year = 9

firm	effch	techch	pech	sech	tfpch
1	1.067	0.669	1.000	1.067	0.714
2	1.000	0.173	1.000	1.000	0.173
3	1.000	0.163	1.000	1.000	0.163
4	1.054	0.149	1.053	1.001	0.157
5	1.078	0.160	1.066	1.012	0.173
6	1.011	0.181	1.000	1.011	0.183
7	0.961	0.190	1.000	0.961	0.183
8	0.950	0.200	0.969	0.981	0.190
9	0.967	0.219	0.985	0.982	0.212
10	0.926	0.217	1.000	0.926	0.201
11	1.000	0.201	1.000	1.000	0.201

12	1.000	0.197	1.000	1.000	0.197
mean	1.000	0.206	1.006	0.995	0.206

year = 10

firm	effch	techch	pech	sech	tfpch
1	1.000	2.586	1.000	1.000	2.586
2	0.856	2.632	1.000	0.856	2.252
3	0.714	5.727	0.727	0.982	4.088
4	0.732	6.479	1.085	0.674	4.740
5	0.989	5.503	1.000	0.989	5.442
6	1.000	6.431	1.000	1.000	6.431
7	1.058	6.359	1.000	1.058	6.725
8	1.052	6.267	1.032	1.020	6.594
9	1.008	6.199	1.015	0.993	6.248
10	1.080	6.350	1.000	1.080	6.860
11	1.000	9.257	1.000	1.000	9.257
12	0.968	8.659	1.000	0.968	8.384
mean	0.947	5.678	0.984	0.962	5.376

year = 11

firm	effch	techch	pech	sech	tfpch
1	1.000	2.592	1.000	1.000	2.592
2	0.975	0.701	0.941	1.036	0.683
3	0.313	0.940	0.325	0.961	0.294
4	1.188	0.929	0.815	1.457	1.104
5	0.901	0.741	0.898	1.003	0.667
6	1.000	0.642	1.000	1.000	0.642
7	1.000	0.621	1.000	1.000	0.621
8	0.990	0.642	1.000	0.990	0.635
9	1.026	0.643	1.000	1.026	0.659
10	1.000	0.665	1.000	1.000	0.665
11	1.000	0.622	1.000	1.000	0.622
12	1.033	0.594	1.000	1.033	0.614
mean	0.915	0.776	0.883	1.036	0.709

year = 12

firm	effch	techch	pech	sech	tfpch
1	0.338	0.515	1.000	0.338	0.174
2	0.717	0.731	0.956	0.750	0.524
3	2.698	0.895	3.153	0.856	2.415
4	1.080	0.797	1.177	0.918	0.861
5	1.010	0.942	1.060	0.953	0.951
6	0.979	1.132	1.000	0.979	1.108
7	1.000	1.237	1.000	1.000	1.237
8	1.010	1.177	1.000	1.010	1.189

9	1.000	1.069	1.000	1.000	1.069
10	1.000	1.033	1.000	1.000	1.033
11	1.000	1.052	1.000	1.000	1.052
12	1.000	0.967	1.000	1.000	0.967
mean	0.971	0.939	1.117	0.870	0.912

year = 13

firm	effch	techch	pech	sech	tfpch
1	2.958	4.275	1.000	2.958	12.647
2	1.672	2.816	1.112	1.504	4.708
3	1.646	2.215	1.342	1.227	3.646
4	1.055	2.212	0.960	1.099	2.333
5	1.075	1.895	1.026	1.047	2.037
6	1.022	1.857	1.000	1.022	1.897
7	1.000	1.555	1.000	1.000	1.555
8	1.000	1.378	1.000	1.000	1.378
9	0.995	1.286	1.000	0.995	1.279
10	1.000	1.221	1.000	1.000	1.221
11	1.000	1.202	1.000	1.000	1.202
12	1.000	1.497	1.000	1.000	1.497
mean	1.205	1.812	1.033	1.167	2.184

year = 14

firm	effch	techch	pech	sech	tfpch
1	1.000	0.174	1.000	1.000	0.174
2	1.000	0.226	1.000	1.000	0.226
3	1.003	0.274	1.000	1.003	0.275
4	1.099	0.302	1.085	1.013	0.332
5	1.026	0.295	1.024	1.002	0.302
6	0.937	0.262	0.999	0.937	0.245
7	0.993	0.274	1.000	0.993	0.272
8	1.000	0.286	1.000	1.000	0.286
9	1.005	0.296	1.000	1.005	0.297
10	1.000	0.458	1.000	1.000	0.458
11	1.000	0.468	1.000	1.000	0.468
12	1.000	0.489	1.000	1.000	0.489
mean	1.005	0.303	1.009	0.996	0.305

year = 15

firm	effch	techch	pech	sech	tfpch
1	0.770	0.438	1.000	0.770	0.337
2	0.879	0.737	1.000	0.879	0.648
3	0.911	0.884	0.986	0.925	0.806
4	0.964	0.902	1.000	0.964	0.869
5	0.973	1.108	0.978	0.995	1.078

6	1.068	1.173	1.001	1.067	1.253
7	1.007	1.283	1.000	1.007	1.293
8	1.000	1.668	1.000	1.000	1.668
9	0.985	1.788	0.993	0.991	1.761
10	1.000	1.465	1.000	1.000	1.465
11	1.000	1.516	1.000	1.000	1.516
12	1.000	1.286	1.000	1.000	1.286
mean	0.960	1.114	0.996	0.963	1.069

year = 16

firm	effch	techch	pech	sech	tfpch
1	1.298	20.932	1.000	1.298	27.179
2	1.138	14.634	1.000	1.138	16.653
3	0.999	0.954	1.015	0.985	0.954
4	1.008	0.870	1.000	1.008	0.877
5	1.031	0.902	1.023	1.008	0.930
6	1.000	0.856	1.000	1.000	0.856
7	1.000	0.862	1.000	1.000	0.862
8	1.000	0.562	1.000	1.000	0.562
9	1.015	0.564	1.007	1.009	0.573
10	1.000	0.592	1.000	1.000	0.592
11	1.000	0.591	1.000	1.000	0.591
12	1.000	0.485	1.000	1.000	0.485
mean	1.038	1.202	1.004	1.034	1.247

year = 17

firm	effch	techch	pech	sech	tfpch
1	0.773	0.070	1.000	0.773	0.054
2	1.000	0.143	1.000	1.000	0.143
3	1.104	1.100	1.000	1.104	1.215
4	0.999	1.357	0.975	1.025	1.357
5	0.912	1.253	0.907	1.005	1.143
6	0.834	1.323	0.847	0.985	1.103
7	1.000	1.408	1.000	1.000	1.408
8	0.971	1.346	1.000	0.971	1.307
9	1.000	1.416	1.000	1.000	1.416
10	1.000	3.046	1.000	1.000	3.046
11	1.000	3.158	1.000	1.000	3.158
12	1.000	1.272	1.000	1.000	1.272
mean	0.962	0.983	0.976	0.986	0.946

year = 18

firm	effch	techch	pech	sech	tfpch
1	1.294	0.421	1.000	1.294	0.544
2	1.000	0.330	1.000	1.000	0.330

3	1.000	1.939	1.000	1.000	1.939
4	1.031	2.124	1.026	1.005	2.189
5	1.081	1.627	1.096	0.986	1.758
6	1.200	1.501	1.181	1.016	1.801
7	1.000	1.393	1.000	1.000	1.393
8	1.030	1.238	1.000	1.030	1.275
9	1.000	1.132	1.000	1.000	1.132
10	1.000	1.016	1.000	1.000	1.016
11	1.000	0.936	1.000	1.000	0.936
12	1.000	0.914	1.000	1.000	0.914
mean	1.049	1.075	1.024	1.025	1.128

year = 19

firm	effch	techch	pech	sech	tfpch
1	1.000	1.082	1.000	1.000	1.082
2	1.000	3.575	1.000	1.000	3.575
3	1.000	3.641	1.000	1.000	3.641
4	1.000	3.278	1.000	1.000	3.278
5	1.008	2.862	0.997	1.012	2.886
6	1.000	2.353	1.000	1.000	2.353
7	1.000	2.213	1.000	1.000	2.213
8	1.000	2.289	1.000	1.000	2.289
9	0.998	2.290	1.000	0.998	2.285
10	1.000	2.169	1.000	1.000	2.169
11	1.000	2.284	1.000	1.000	2.284
12	1.000	2.060	1.000	1.000	2.060
mean	1.001	2.402	1.000	1.001	2.403

year = 20

firm	effch	techch	pech	sech	tfpch
1	0.558	0.414	1.000	0.558	0.231
2	0.559	0.121	0.662	0.845	0.068
3	1.000	0.286	1.000	1.000	0.286
4	1.000	0.290	1.000	1.000	0.290
5	0.933	0.339	0.931	1.003	0.316
6	1.000	0.412	1.000	1.000	0.412
7	1.000	0.439	1.000	1.000	0.439
8	1.000	0.445	1.000	1.000	0.445
9	1.002	0.493	1.000	1.002	0.494
10	1.000	0.531	1.000	1.000	0.531
11	1.000	0.558	1.000	1.000	0.558
12	1.000	0.638	1.000	1.000	0.638
mean	0.902	0.385	0.960	0.940	0.347

year = 21

firm effch techch pech sech tfpch

1	1.791	20.076	1.000	1.791	35.965
2	1.788	1.709	1.511	1.184	3.057
3	0.720	0.774	1.000	0.720	0.557
4	0.654	0.734	1.000	0.654	0.480
5	0.775	0.693	1.084	0.715	0.538
6	0.527	0.731	1.000	0.527	0.385
7	0.570	0.610	0.784	0.727	0.348
8	0.804	0.495	0.821	0.979	0.398
9	0.811	0.509	0.932	0.870	0.413
10	0.919	0.497	0.977	0.941	0.457
11	1.000	0.414	1.000	1.000	0.414
12	1.000	0.506	1.000	1.000	0.506
mean	0.878	0.858	0.997	0.881	0.753

year = 22

firm	effch	techch	pech	sech	tfpch
1	0.365	0.108	1.000	0.365	0.039
2	0.417	1.108	0.538	0.775	0.462
3	0.853	1.485	0.676	1.262	1.267
4	1.528	2.878	1.000	1.528	4.398
5	1.398	8.684	1.000	1.398	12.141
6	1.896	7.191	1.000	1.896	13.636
7	1.756	11.062	1.276	1.376	19.421
8	1.245	14.179	1.218	1.022	17.647
9	1.234	12.400	1.073	1.150	15.295
10	1.088	12.907	1.024	1.063	14.047
11	0.996	21.868	0.999	0.998	21.787
12	1.000	29.537	1.000	1.000	29.537
mean	1.036	5.322	0.961	1.079	5.516

year = 23

firm	effch	techch	pech	sech	tfpch
1	2.137	1.113	1.000	2.137	2.378
2	2.400	1.388	1.860	1.290	3.332
3	1.401	1.069	1.274	1.100	1.497
4	0.628	1.187	0.648	0.969	0.746
5	0.620	0.941	1.000	0.620	0.583
6	0.790	0.995	0.794	0.995	0.786
7	0.714	1.089	0.727	0.983	0.778
8	0.819	1.078	0.826	0.992	0.883
9	1.000	1.374	1.000	1.000	1.374
10	1.000	1.319	1.000	1.000	1.319
11	0.990	1.047	1.001	0.989	1.037
12	1.000	0.714	1.000	1.000	0.714
mean	1.021	1.093	0.974	1.048	1.116

year = 24

firm	effch	techch	pech	sech	tfpch
1	1.055	4.147	1.000	1.055	4.377
2	0.578	3.690	0.643	0.899	2.134
3	0.551	4.002	0.576	0.958	2.206
4	0.995	3.601	0.993	1.002	3.584
5	0.981	3.673	0.619	1.586	3.605
6	0.851	3.276	0.858	0.992	2.788
7	0.970	3.337	0.963	1.008	3.239
8	0.941	2.946	0.941	1.000	2.774
9	0.828	2.979	0.832	0.995	2.465
10	0.816	2.640	0.819	0.997	2.155
11	0.875	2.909	0.865	1.012	2.545
12	1.000	4.028	1.000	1.000	4.028
mean	0.854	3.402	0.828	1.031	2.906

year = 25

firm	effch	techch	pech	sech	tfpch
1	0.761	2.518	1.000	0.761	1.917
2	1.402	2.192	1.555	0.902	3.074
3	2.108	1.927	2.017	1.045	4.062
4	1.600	1.983	1.553	1.030	3.173
5	1.645	2.091	1.616	1.018	3.439
6	1.487	2.318	1.469	1.013	3.448
7	1.442	2.073	1.429	1.010	2.989
8	1.273	2.088	1.287	0.989	2.658
9	1.075	2.134	1.088	0.988	2.294
10	1.127	2.045	1.128	0.999	2.304
11	1.158	2.042	1.157	1.002	2.366
12	1.000	1.615	1.000	1.000	1.615
mean	1.297	2.075	1.328	0.976	2.691

year = 26

firm	effch	techch	pech	sech	tfpch
1	1.595	0.062	1.000	1.595	0.098
2	0.969	0.027	0.932	1.039	0.027
3	0.640	0.037	0.734	0.871	0.024
4	0.673	0.048	0.675	0.997	0.032
5	0.983	0.034	1.000	0.983	0.034
6	0.920	0.032	0.989	0.930	0.029
7	0.726	0.028	0.941	0.771	0.021
8	1.019	0.051	1.000	1.019	0.052
9	1.124	0.049	1.105	1.017	0.056
10	1.036	0.049	1.040	0.996	0.051
11	1.000	0.049	1.000	1.000	0.049
12	1.000	0.047	1.000	1.000	0.047

mean	0.947	0.042	0.943	1.004	0.039

year = 27

firm	effch	techch	pech	sech	tfpch
1	0.910	0.123	1.000	0.910	0.112
2	0.959	0.779	1.072	0.894	0.747
3	1.400	1.574	1.362	1.028	2.203
4	1.253	2.471	1.410	0.889	3.096
5	0.914	2.478	0.954	0.959	2.265
6	1.084	2.575	1.011	1.072	2.791
7	1.378	2.685	1.062	1.297	3.698
8	1.000	2.621	1.000	1.000	2.621
9	0.975	2.581	0.991	0.983	2.516
10	1.046	2.607	1.040	1.006	2.727
11	0.936	2.663	1.000	0.936	2.493
12	1.000	2.597	1.000	1.000	2.597
mean	1.059	1.742	1.067	0.993	1.845

year = 28

firm	effch	techch	pech	sech	tfpch
1	0.629	2.008	1.000	0.629	1.263
2	1.327	1.251	1.000	1.327	1.660
3	1.117	1.712	1.000	1.117	1.912
4	1.186	1.362	1.051	1.128	1.615
5	1.038	1.646	1.049	0.990	1.709
6	1.004	1.568	1.000	1.004	1.573
7	1.000	1.889	1.000	1.000	1.889
8	0.998	2.304	1.000	0.998	2.299
9	1.026	3.611	1.009	1.017	3.704
10	0.985	3.362	0.991	0.994	3.312
11	1.068	3.120	1.000	1.068	3.332
12	1.000	3.011	1.000	1.000	3.011
mean	1.018	2.103	1.008	1.010	2.142

year = 29

firm	effch	techch	pech	sech	tfpch
1	1.748	0.851	1.000	1.748	1.488
2	0.989	0.460	1.000	0.989	0.455
3	1.000	0.370	1.000	1.000	0.370
4	0.948	0.513	0.980	0.968	0.487
5	1.072	0.634	1.000	1.072	0.680
6	1.000	0.616	1.000	1.000	0.616
7	0.937	0.683	0.964	0.972	0.640
8	0.889	0.727	0.913	0.973	0.646
9	0.992	0.771	0.993	0.999	0.764

10	1.018	0.883	1.009	1.010	0.900
11	0.992	1.277	1.000	0.992	1.268
12	1.000	1.326	1.000	1.000	1.326
mean	1.032	0.711	0.988	1.045	0.734

year = 30

firm	effch	techch	pech	sech	tfpch
1	0.970	0.258	1.000	0.970	0.251
2	1.011	0.451	1.000	1.011	0.457
3	1.000	0.482	1.000	1.000	0.482
4	1.055	0.517	1.021	1.034	0.545
5	0.987	0.575	0.998	0.990	0.567
6	1.000	0.627	1.000	1.000	0.627
7	1.067	0.651	1.037	1.029	0.695
8	1.128	0.650	1.095	1.030	0.733
9	0.980	0.618	1.007	0.974	0.606
10	1.000	0.630	1.000	1.000	0.630
11	0.996	0.577	1.000	0.996	0.575
12	0.909	0.555	1.000	0.909	0.505
mean	1.007	0.535	1.013	0.995	0.539

year = 31

firm	effch	techch	pech	sech	tfpch
1	1.030	12.442	1.000	1.030	12.820
2	1.000	0.477	1.000	1.000	0.477
3	0.757	0.336	0.916	0.826	0.255
4	0.674	0.281	0.868	0.777	0.189
5	0.692	0.478	0.751	0.922	0.331
6	0.555	0.635	0.569	0.974	0.352
7	0.526	0.533	0.536	0.982	0.280
8	0.760	0.509	0.764	0.995	0.387
9	0.969	0.496	0.950	1.019	0.480
10	0.974	0.475	0.979	0.995	0.463
11	1.012	0.472	1.000	1.012	0.478
12	1.100	0.501	1.000	1.100	0.552
mean	0.814	0.608	0.843	0.965	0.495

year = 32

firm	effch	techch	pech	sech	tfpch
1	1.000	0.119	1.000	1.000	0.119
2	0.706	0.979	1.000	0.706	0.692
3	1.143	1.253	1.091	1.047	1.431
4	1.368	1.483	1.152	1.187	2.029
5	1.421	1.918	1.335	1.064	2.724
6	1.803	2.697	1.757	1.026	4.862

7	1.902	2.556	1.867	1.019	4.862
8	1.315	2.291	1.309	1.005	3.013
9	1.014	1.941	1.052	0.964	1.968
10	1.027	1.919	1.021	1.005	1.970
11	1.000	1.782	1.000	1.000	1.782
12	1.000	1.667	1.000	1.000	1.667
mean	1.181	1.429	1.186	0.996	1.688

year = 33

firm	effch	techch	pech	sech	tfpch
1	1.000	5.837	1.000	1.000	5.837
2	1.416	3.613	1.000	1.416	5.115
3	1.156	6.087	1.000	1.156	7.039
4	0.863	7.949	0.801	1.078	6.858
5	0.894	9.349	0.881	1.014	8.355
6	1.000	9.716	1.000	1.000	9.716
7	0.911	10.104	0.928	0.982	9.208
8	0.986	10.721	1.000	0.986	10.573
9	1.047	12.701	1.000	1.047	13.294
10	1.000	11.856	1.000	1.000	11.856
11	0.971	10.745	1.000	0.971	10.436
12	0.969	10.926	1.000	0.969	10.588
mean	1.009	8.658	0.965	1.046	8.739

year = 34

firm	effch	techch	pech	sech	tfpch
1	1.000	0.183	1.000	1.000	0.183
2	1.000	0.141	1.000	1.000	0.141
3	0.921	0.149	0.923	0.998	0.137
4	1.141	0.175	1.139	1.002	0.200
5	1.153	0.177	1.135	1.016	0.204
6	1.000	0.212	1.000	1.000	0.212
7	1.097	0.337	1.077	1.019	0.370
8	1.014	0.337	1.000	1.014	0.341
9	0.936	0.277	0.999	0.937	0.259
10	1.000	0.311	1.000	1.000	0.311
11	1.030	0.336	1.000	1.030	0.346
12	1.032	0.392	1.000	1.032	0.404
mean	1.025	0.238	1.021	1.004	0.243

year = 35

firm	effch	techch	pech	sech	tfpch
1	1.000	0.664	1.000	1.000	0.664
2	0.971	0.768	1.000	0.971	0.746
3	0.922	0.826	0.933	0.988	0.762

4	0.745	0.912	0.746	0.998	0.679
5	1.000	0.793	1.000	1.000	0.793
6	1.000	0.843	1.000	1.000	0.843
7	1.000	0.776	1.000	1.000	0.776
8	1.000	0.865	1.000	1.000	0.865
9	1.012	0.846	1.001	1.010	0.856
10	0.940	0.813	1.000	0.940	0.764
11	1.000	1.171	1.000	1.000	1.171
12	1.000	1.215	1.000	1.000	1.215
mean	0.963	0.862	0.970	0.992	0.830

year = 36

firm	effch	techch	pech	sech	tfpch
1	1.000	6.911	1.000	1.000	6.911
2	0.930	0.855	1.000	0.930	0.796
3	0.492	0.606	0.869	0.565	0.298
4	0.687	0.420	1.242	0.553	0.288
5	0.376	0.421	0.612	0.615	0.158
6	0.459	0.405	0.592	0.775	0.186
7	0.667	0.393	0.880	0.758	0.262
8	0.677	0.428	0.849	0.798	0.290
9	0.743	0.459	0.834	0.890	0.341
10	0.747	0.446	0.807	0.927	0.333
11	0.878	0.480	0.885	0.992	0.422
12	1.000	0.400	1.000	1.000	0.400
mean	0.691	0.588	0.864	0.800	0.406

year = 37

firm	effch	techch	pech	sech	tfpch
1	0.718	0.212	1.000	0.718	0.152
2	1.017	1.000	1.000	1.017	1.017
3	2.246	1.992	1.317	1.705	4.474
4	1.849	2.783	1.069	1.730	5.146
5	2.439	3.311	1.525	1.599	8.075
6	2.179	4.228	1.689	1.291	9.216
7	1.461	4.612	1.137	1.285	6.736
8	1.476	4.572	1.178	1.254	6.751
9	1.414	4.371	1.198	1.180	6.179
10	1.283	4.373	1.131	1.134	5.609
11	1.138	4.370	1.130	1.008	4.975
12	1.000	4.303	1.000	1.000	4.303
mean	1.428	2.658	1.182	1.208	3.795

year = 38

firm	effch	techch	pech	sech	tfpch

1	0.843	1.762	1.000	0.843	1.486
2	1.089	2.710	1.000	1.089	2.950
3	1.066	1.543	1.014	1.052	1.645
4	1.156	1.258	1.108	1.044	1.454
5	1.090	1.226	1.071	1.018	1.337
6	1.000	1.026	1.000	1.000	1.026
7	1.026	0.902	1.000	1.026	0.925
8	0.998	0.744	1.000	0.998	0.743
9	1.006	0.713	1.000	1.006	0.718
10	1.109	0.690	1.096	1.012	0.766
11	1.000	0.660	1.000	1.000	0.660
12	1.000	0.655	1.000	1.000	0.655
mean	1.029	1.043	1.023	1.006	1.074

year = 39

firm	effch	techch	pech	sech	tfpch
1	1.651	12.812	1.000	1.651	21.153
2	0.994	3.236	1.000	0.994	3.216
3	1.000	4.024	1.000	1.000	4.024
4	0.997	2.597	1.000	0.997	2.589
5	1.000	2.311	1.000	1.000	2.311
6	0.987	1.351	1.000	0.987	1.334
7	1.000	3.000	1.000	1.000	3.000
8	0.991	2.313	1.000	0.991	2.292
9	1.000	3.388	1.000	1.000	3.388
10	0.998	1.384	1.000	0.998	1.381
11	1.000	2.430	1.000	1.000	2.430
12	1.000	1.969	1.000	1.000	1.969
mean	1.040	2.777	1.000	1.040	2.888

year = 40

firm	effch	techch	pech	sech	tfpch
1	0.846	0.178	1.000	0.846	0.151
2	1.006	1.584	1.000	1.006	1.594
3	0.750	1.395	1.000	0.750	1.047
4	1.010	1.804	1.000	1.010	1.822
5	1.000	1.586	1.000	1.000	1.586
6	1.013	2.119	1.000	1.013	2.147
7	0.224	2.136	0.226	0.992	0.478
8	1.011	1.649	1.000	1.011	1.667
9	0.590	2.352	1.000	0.590	1.389
10	0.816	3.881	1.000	0.816	3.168
11	0.916	3.502	1.000	0.916	3.209
12	1.000	3.330	1.000	1.000	3.330
mean	0.797	1.762	0.883	0.902	1.403

year = 41

firm	effch	techch	pech	sech	tfpch
1	1.182	0.690	1.000	1.182	0.815
2	0.887	0.300	1.000	0.887	0.266
3	1.333	0.448	1.000	1.333	0.597
4	1.000	0.564	1.000	1.000	0.564
5	1.000	0.400	1.000	1.000	0.400
6	0.814	1.011	0.823	0.989	0.823
7	4.468	2.362	4.432	1.008	10.556
8	1.000	1.236	1.000	1.000	1.236
9	1.694	1.071	1.000	1.694	1.815
10	0.966	0.940	1.000	0.966	0.907
11	1.092	0.917	1.000	1.092	1.001
12	1.000	0.804	1.000	1.000	0.804
mean	1.202	0.773	1.114	1.079	0.929

year = 42

firm	effch	techch	pech	sech	tfpch
1	1.000	0.122	1.000	1.000	0.122
2	0.720	1.025	0.656	1.097	0.738
3	1.000	9.323	1.000	1.000	9.323
4	0.843	10.300	0.895	0.942	8.686
5	1.000	13.728	1.000	1.000	13.728
6	1.229	26.370	1.215	1.011	32.396
7	1.000	20.911	1.000	1.000	20.911
8	1.000	20.858	1.000	1.000	20.858
9	1.000	20.794	1.000	1.000	20.794
10	1.250	19.397	1.000	1.250	24.243
11	0.980	21.547	1.000	0.980	21.118
12	1.000	21.511	1.000	1.000	21.511
mean	0.993	9.170	0.972	1.021	9.101

year = 43

firm	effch	techch	pech	sech	tfpch
1	0.903	0.219	1.000	0.903	0.198
2	1.342	0.892	1.524	0.880	1.197
3	1.000	0.357	1.000	1.000	0.357
4	1.186	0.397	1.117	1.062	0.471
5	0.876	0.430	0.892	0.982	0.377
6	0.856	0.417	0.867	0.987	0.357
7	0.925	0.458	1.000	0.925	0.423
8	0.988	0.454	1.000	0.988	0.448
9	1.000	0.500	1.000	1.000	0.500
10	1.017	0.678	1.000	1.017	0.689
11	1.020	0.708	1.000	1.020	0.722
12	1.000	0.766	1.000	1.000	0.766

mean	1.002	0.490	1.023	0.979	0.491

year = 44

firm	effch	techch	pech	sech	tfpch
1	1.107	2.118	1.000	1.107	2.345
2	1.167	1.032	1.000	1.167	1.204
3	0.803	1.011	0.878	0.914	0.812
4	0.870	1.197	0.960	0.906	1.041
5	1.141	1.098	1.121	1.018	1.253
6	1.168	1.078	1.153	1.013	1.259
7	1.041	1.035	0.970	1.074	1.078
8	0.940	1.040	0.956	0.984	0.978
9	0.910	0.997	0.937	0.971	0.907
10	1.000	0.711	1.000	1.000	0.711
11	1.000	0.739	1.000	1.000	0.739
12	1.000	0.721	1.000	1.000	0.721
mean	1.006	1.020	0.995	1.010	1.026

year = 45

firm	effch	techch	pech	sech	tfpch
1	1.000	2.093	1.000	1.000	2.093
2	1.000	2.372	1.000	1.000	2.372
3	1.233	1.851	1.134	1.088	2.282
4	1.150	3.407	1.042	1.104	3.918
5	0.957	3.366	0.963	0.993	3.221
6	0.885	3.910	0.904	0.979	3.461
7	0.966	4.554	1.031	0.937	4.401
8	1.077	6.250	1.046	1.029	6.729
9	1.095	5.551	1.067	1.026	6.077
10	1.000	5.088	1.000	1.000	5.088
11	0.999	4.873	0.999	1.000	4.868
12	1.000	4.705	1.000	1.000	4.705
mean	1.026	3.744	1.014	1.012	3.843

year = 46

firm	effch	techch	pech	sech	tfpch
1	1.000	0.267	1.000	1.000	0.267
2	1.000	0.052	1.000	1.000	0.052
3	0.754	0.046	0.972	0.776	0.035
4	0.819	0.028	0.991	0.826	0.023
5	0.670	0.029	0.808	0.829	0.020
6	0.880	0.035	0.907	0.969	0.031
7	0.939	0.036	0.894	1.050	0.034
8	0.933	0.040	0.937	0.995	0.037
9	1.004	0.039	1.000	1.004	0.039
10	0.999	0.038	1.000	0.999	0.038

11	1.001	0.039	1.001	1.000	0.039
12	1.000	0.033	1.000	1.000	0.033
mean	0.909	0.044	0.957	0.950	0.040

year = 47

firm	effch	techch	pech	sech	tfpch
1	0.692	0.357	1.000	0.692	0.247
2	0.158	1.614	0.166	0.950	0.255
3	1.340	6.210	1.035	1.295	8.321
4	1.082	13.213	0.924	1.171	14.294
5	1.320	26.608	1.200	1.100	35.109
6	1.284	33.943	1.219	1.053	43.594
7	1.144	46.883	1.119	1.022	53.638
8	1.072	51.550	1.067	1.005	55.248
9	0.984	38.109	1.000	0.984	37.489
10	0.898	33.484	1.000	0.899	30.084
11	0.882	22.620	1.000	0.882	19.958
12	0.817	17.869	1.000	0.817	14.603
mean	0.878	13.927	0.899	0.977	12.229

year = 48

firm	effch	techch	pech	sech	tfpch
1	1.444	0.326	1.000	1.444	0.471
2	5.801	0.268	6.011	0.965	1.557
3	1.000	0.298	1.000	1.000	0.298
4	1.122	0.395	1.089	1.030	0.443
5	1.153	0.463	1.050	1.098	0.534
6	1.000	0.379	1.000	1.000	0.379
7	1.000	0.335	1.000	1.000	0.335
8	1.000	0.340	1.000	1.000	0.340
9	1.017	0.339	1.000	1.017	0.345
10	1.115	0.329	1.000	1.114	0.367
11	1.133	0.316	1.000	1.133	0.358
12	1.224	0.316	1.000	1.224	0.387
mean	1.266	0.339	1.174	1.079	0.429

year = 49

firm	effch	techch	pech	sech	tfpch
1	1.000	3.555	1.000	1.000	3.555
2	1.091	2.245	1.000	1.091	2.448
3	0.714	2.091	1.000	0.714	1.493
4	1.007	1.684	1.003	1.003	1.695
5	1.016	1.815	1.020	0.997	1.844
6	1.000	1.516	1.000	1.000	1.516
7	0.999	1.550	1.000	0.999	1.548

8	1.000	1.451	1.000	1.000	1.451
9	1.000	1.471	1.000	1.000	1.471
10	0.984	1.524	0.984	0.999	1.499
11	1.000	1.597	1.000	1.000	1.597
12	1.000	2.142	1.000	1.000	2.142
mean	0.980	1.821	1.001	0.979	1.785

year = 50

firm	effch	techch	pech	sech	tfpch
1	1.000	4.853	1.000	1.000	4.853
2	1.000	3.944	1.000	1.000	3.944
3	1.401	3.424	1.000	1.401	4.796
4	1.000	4.175	1.000	1.000	4.175
5	1.009	5.018	1.000	1.009	5.061
6	1.000	5.060	1.000	1.000	5.060
7	0.999	4.523	1.000	0.999	4.519
8	1.000	4.462	1.000	1.000	4.462
9	0.932	4.145	1.000	0.932	3.864
10	1.017	3.915	1.016	1.001	3.980
11	1.000	3.630	1.000	1.000	3.630
12	0.952	3.289	1.000	0.952	3.132
mean	1.020	4.164	1.001	1.019	4.249

year = 51

firm	effch	techch	pech	sech	tfpch
1	1.000	0.057	1.000	1.000	0.057
2	1.000	0.023	1.000	1.000	0.023
3	0.493	0.015	0.534	0.924	0.007
4	0.543	0.017	0.585	0.928	0.009
5	0.688	0.014	0.692	0.995	0.009
6	1.000	0.015	1.000	1.000	0.015
7	0.980	0.017	0.982	0.998	0.016
8	1.000	0.017	1.000	1.000	0.017
9	1.008	0.019	0.942	1.070	0.019
10	0.947	0.018	0.959	0.987	0.017
11	1.000	0.019	1.000	1.000	0.019
12	1.050	0.021	1.000	1.050	0.022
mean	0.867	0.019	0.871	0.995	0.017

year = 52

firm	effch	techch	pech	sech	tfpch
1	1.000	0.775	1.000	1.000	0.775
2	0.928	1.750	0.932	0.996	1.623
3	1.746	2.267	1.638	1.066	3.960
4	1.843	2.825	1.710	1.078	5.206

5	1.453	3.067	1.446	1.005	4.457
6	0.995	3.097	1.000	0.995	3.083
7	1.022	6.769	1.018	1.004	6.918
8	1.000	9.561	1.000	1.000	9.561
9	1.064	10.550	1.061	1.002	11.222
10	1.056	10.294	1.042	1.013	10.868
11	1.000	8.674	1.000	1.000	8.674
12	1.000	8.669	1.000	1.000	8.669
mean	1.143	4.331	1.128	1.013	4.950

year = 53

firm	effch	techch	pech	sech	tfpch
1	1.000	1.525	1.000	1.000	1.525
2	1.078	1.353	1.073	1.005	1.458
3	1.161	1.548	1.144	1.015	1.797
4	0.943	1.149	0.967	0.976	1.084
5	1.000	1.149	1.000	1.000	1.149
6	1.005	1.081	1.000	1.005	1.086
7	0.999	1.019	1.000	0.999	1.018
8	1.000	1.086	1.000	1.000	1.086
9	1.000	1.140	1.000	1.000	1.140
10	1.000	1.123	1.000	1.000	1.123
11	1.000	1.064	1.000	1.000	1.064
12	1.000	1.062	1.000	1.000	1.062
mean	1.014	1.180	1.014	1.000	1.197

year = 54

firm	effch	techch	pech	sech	tfpch
1	0.725	0.373	1.000	0.725	0.271
2	1.000	0.410	1.000	1.000	0.410
3	0.875	0.303	0.924	0.948	0.265
4	0.983	0.580	0.982	1.001	0.570
5	1.000	0.637	1.000	1.000	0.637
6	0.942	0.783	0.942	1.000	0.738
7	1.001	0.749	1.000	1.001	0.749
8	0.920	0.860	0.958	0.960	0.792
9	1.000	0.943	1.000	1.000	0.943
10	1.000	0.956	1.000	1.000	0.956
11	1.000	0.986	1.000	1.000	0.986
12	1.000	1.058	1.000	1.000	1.058
mean	0.950	0.670	0.984	0.966	0.636

year = 55

firm	effch	techch	pech	sech	tfpch
1	1.026	1.213	1.000	1.026	1.244

2	0.907	1.014	0.965	0.940	0.920
3	1.142	1.131	1.082	1.055	1.292
4	1.078	1.050	1.053	1.024	1.132
5	1.000	0.975	1.000	1.000	0.975
6	1.036	1.020	1.061	0.977	1.057
7	1.000	1.130	1.000	1.000	1.130
8	1.087	1.135	1.044	1.041	1.234
9	1.000	1.183	1.000	1.000	1.183
10	0.987	1.189	1.000	0.987	1.173
11	1.000	1.092	1.000	1.000	1.092
12	1.000	1.098	1.000	1.000	1.098
mean	1.020	1.100	1.017	1.004	1.122

year = 56

firm	effch	techch	pech	sech	tfpch
1	1.346	5.091	1.000	1.346	6.851
2	1.102	5.091	1.036	1.064	5.613
3	0.840	1.118	0.954	0.881	0.940
4	0.911	1.335	1.000	0.911	1.217
5	0.735	0.942	0.741	0.991	0.692
6	0.879	0.946	0.883	0.996	0.832
7	0.950	0.804	0.950	1.000	0.763
8	0.960	0.828	0.974	0.986	0.795
9	1.000	0.731	1.000	1.000	0.731
10	1.013	0.680	1.000	1.013	0.689
11	1.000	0.547	1.000	1.000	0.547
12	1.000	0.513	1.000	1.000	0.513
mean	0.968	1.102	0.958	1.011	1.067

year = 57

firm	effch	techch	pech	sech	tfpch
1	1.000	1.301	1.000	1.000	1.301
2	1.000	0.852	1.000	1.000	0.852
3	1.190	1.500	1.049	1.135	1.785
4	0.909	1.160	0.856	1.062	1.055
5	1.157	1.482	1.185	0.977	1.715
6	1.096	1.549	1.086	1.010	1.698
7	1.053	1.628	1.053	1.000	1.715
8	1.041	1.569	1.027	1.014	1.634
9	1.000	1.663	1.000	1.000	1.663
10	1.000	1.671	1.000	1.000	1.671
11	1.000	1.737	1.000	1.000	1.737
12	1.000	1.688	1.000	1.000	1.688
mean	1.035	1.458	1.019	1.016	1.509

year = 58

firm	effch	techch	pech	sech	tfpch
1	1.000	0.542	1.000	1.000	0.542
2	1.000	1.981	1.000	1.000	1.981
3	1.000	1.386	1.000	1.000	1.386
4	1.137	1.241	1.112	1.022	1.412
5	1.175	1.385	1.138	1.033	1.629
6	1.018	1.350	1.000	1.018	1.374
7	0.991	1.308	0.992	0.999	1.296
8	1.000	1.493	1.000	1.000	1.493
9	1.000	1.451	1.000	1.000	1.451
10	0.938	1.377	0.939	0.998	1.291
11	1.000	1.349	1.000	1.000	1.349
12	0.973	1.470	1.000	0.973	1.430
mean	1.017	1.315	1.014	1.004	1.338

year = 59

firm	effch	techch	pech	sech	tfpch
1	1.000	0.133	1.000	1.000	0.133
2	1.000	0.044	1.000	1.000	0.044
3	0.813	0.535	0.845	0.962	0.435
4	1.009	0.224	1.016	0.993	0.226
5	1.000	0.263	1.000	1.000	0.263
6	1.024	0.280	1.043	0.981	0.287
7	1.009	0.296	1.008	1.001	0.299
8	1.000	0.335	1.000	1.000	0.335
9	1.000	0.287	1.000	1.000	0.287
10	1.067	0.319	1.065	1.002	0.340
11	1.000	0.332	1.000	1.000	0.332
12	1.028	0.350	1.000	1.028	0.360
mean	0.994	0.248	0.997	0.997	0.247

year = 60

firm	effch	techch	pech	sech	tfpch
1	0.869	0.126	1.000	0.869	0.110
2	1.000	0.473	1.000	1.000	0.473
3	1.164	0.383	1.121	1.038	0.446
4	1.005	0.339	0.989	1.016	0.340
5	1.000	0.327	1.000	1.000	0.327
6	1.000	0.249	0.986	1.014	0.249
7	1.000	0.272	1.000	1.000	0.272
8	1.000	0.291	1.000	1.000	0.291
9	0.987	0.362	0.988	0.999	0.357
10	1.000	0.410	1.000	1.000	0.410
11	1.000	0.445	1.000	1.000	0.445
12	1.000	0.721	1.000	1.000	0.721
mean	1.000	0.340	1.006	0.994	0.340

MALMQUIST INDEX SUMMARY OF ANNUAL MEANS

year	effch	techch	pech	sech	tfpch
2	1.118	0.795	1.045	1.070	0.889
3	0.987	0.317	0.987	1.000	0.313
4	0.973	0.654	0.990	0.983	0.636
5	0.950	1.894	0.948	1.002	1.799
6	0.979	1.172	0.979	1.000	1.147
7	1.056	1.677	1.058	0.998	1.771
8	1.039	1.682	1.026	1.013	1.747
9	1.000	0.206	1.006	0.995	0.206
10	0.947	5.678	0.984	0.962	5.376
11	0.915	0.776	0.883	1.036	0.709
12	0.971	0.939	1.117	0.870	0.912
13	1.205	1.812	1.033	1.167	2.184
14	1.005	0.303	1.009	0.996	0.305
15	0.960	1.114	0.996	0.963	1.069
16	1.038	1.202	1.004	1.034	1.247
17	0.962	0.983	0.976	0.986	0.946
18	1.049	1.075	1.024	1.025	1.128
19	1.001	2.402	1.000	1.001	2.403
20	0.902	0.385	0.960	0.940	0.347
21	0.878	0.858	0.997	0.881	0.753
22	1.036	5.322	0.961	1.079	5.516
23	1.021	1.093	0.974	1.048	1.116
24	0.854	3.402	0.828	1.031	2.906
25	1.297	2.075	1.328	0.976	2.691
26	0.947	0.042	0.943	1.004	0.039
27	1.059	1.742	1.067	0.993	1.845
28	1.018	2.103	1.008	1.010	2.142
29	1.032	0.711	0.988	1.045	0.734
30	1.007	0.535	1.013	0.995	0.539
31	0.814	0.608	0.843	0.965	0.495
32	1.181	1.429	1.186	0.996	1.688
33	1.009	8.658	0.965	1.046	8.739
34	1.025	0.238	1.021	1.004	0.243
35	0.963	0.862	0.970	0.992	0.830
36	0.691	0.588	0.864	0.800	0.406
37	1.428	2.658	1.182	1.208	3.795
38	1.029	1.043	1.023	1.006	1.074
39	1.040	2.777	1.000	1.040	2.888
40	0.797	1.762	0.883	0.902	1.403
41	1.202	0.773	1.114	1.079	0.929
42	0.993	9.170	0.972	1.021	9.101
43	1.002	0.490	1.023	0.979	0.491
44	1.006	1.020	0.995	1.010	1.026
45	1.026	3.744	1.014	1.012	3.843
46	0.909	0.044	0.957	0.950	0.040
47	0.878	13.927	0.899	0.977	12.229
48	1.266	0.339	1.174	1.079	0.429
49	0.980	1.821	1.001	0.979	1.785

50	1.020	4.164	1.001	1.019	4.249
51	0.867	0.019	0.871	0.995	0.017
52	1.143	4.331	1.128	1.013	4.950
53	1.014	1.180	1.014	1.000	1.197
54	0.950	0.670	0.984	0.966	0.636
55	1.020	1.100	1.017	1.004	1.122
56	0.968	1.102	0.958	1.011	1.067
57	1.035	1.458	1.019	1.016	1.509
58	1.017	1.315	1.014	1.004	1.338
59	0.994	0.248	0.997	0.997	0.247
60	1.000	0.340	1.006	0.994	0.340
mean	1.002	1.025	1.001	1.001	1.026

MALMQUIST INDEX SUMMARY OF FIRM MEANS

firm	effch	techch	pech	sech	tfpch
1	0.998	0.793	1.000	0.998	0.791
2	1.000	0.797	1.000	1.000	0.797
3	1.004	0.905	0.999	1.005	0.908
4	1.006	0.970	0.999	1.007	0.976
5	1.004	1.013	1.003	1.001	1.016
6	1.003	1.073	1.003	1.000	1.077
7	1.002	1.126	1.002	1.000	1.128
8	1.002	1.116	1.000	1.002	1.118
9	1.001	1.137	1.001	1.000	1.138
10	1.000	1.150	1.000	1.000	1.150
11	1.000	1.172	1.000	1.000	1.172
12	1.000	1.156	1.000	1.000	1.156
mean	1.002	1.025	1.001	1.001	1.026

[Note that all Malmquist index averages are geometric means]

Appendix B: Regression Results from One-Step System GMM using STATA

```
. xtunitroot llc lntotal_expense

Levin-Lin-Chu unit-root test for lntotal_expense
------------------------------------------------
H0: Panels contain unit roots               Number of panels  =     59
Ha: Panels are stationary                   Number of periods =     12

AR parameter: Common                        Asymptotics: N/T -> 0
Panel means:  Included
Time trend:   Not included

ADF regressions: 1 lag
LR variance:     Bartlett kernel, 7.00 lags average (chosen by LLC)
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 Unadjusted t       -51.7739
 Adjusted t*        -44.3388        0.0000
------------------------------------------------------------------------------

.
```

```
Levin-Lin-Chu unit-root test for efficiency
-------------------------------------------
H0: Panels contain unit roots               Number of panels  =     59
Ha: Panels are stationary                   Number of periods =     12

AR parameter: Common                        Asymptotics: N/T -> 0
Panel means:  Included
Time trend:   Not included

ADF regressions: 1 lag
LR variance:     Bartlett kernel, 7.00 lags average (chosen by LLC)
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 Unadjusted t       -16.7184
 Adjusted t*         -8.5658        0.0000
------------------------------------------------------------------------------

.
```

```
Levin-Lin-Chu unit-root test for TOTAL_DEPOSIT
----------------------------------------------
H0: Panels contain unit roots               Number of panels  =     59
Ha: Panels are stationary                   Number of periods =     12

AR parameter: Common                        Asymptotics: N/T -> 0
Panel means:  Included
Time trend:   Not included

ADF regressions: 1 lag
LR variance:     Bartlett kernel, 7.00 lags average (chosen by LLC)
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 Unadjusted t       -12.6034
 Adjusted t*         -3.8617        0.0001
------------------------------------------------------------------------------
```

.

```
Levin-Lin-Chu unit-root test for TotalIncome
--------------------------------------------
H0: Panels contain unit roots               Number of panels  =     59
Ha: Panels are stationary                   Number of periods =     12

AR parameter: Common                        Asymptotics: N/T -> 0
Panel means:  Included
Time trend:   Not included

ADF regressions: 1 lag
LR variance:     Bartlett kernel, 7.00 lags average (chosen by LLC)
------------------------------------------------------------------------------
                    Statistic      p-value
------------------------------------------------------------------------------
 Unadjusted t       -18.7348
 Adjusted t*         -4.9105        0.0000
------------------------------------------------------------------------------
```

```
Dynamic panel-data estimation, one-step system GMM
------------------------------------------------------------------------------
Group variable: Month                           Number of obs      =       634
Time variable : districtid                      Number of groups   =        59
Number of instruments = 69                      Obs per group: min =         9
Wald chi2(4)  = 857475.06                                      avg =     10.75
Prob > chi2   =     0.000                                      max =        11
---------------------------------------------------------------------------------
     efficiency | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
----------------+----------------------------------------------------------------
     efficiency |
            L1. |   .0101402    .029233     0.35   0.729    -.0471555    .0674359
                |
           lnTI |   .2561335   .0104766    24.45   0.000     .2355998    .2766671
           lnTD |   .0762015   .0184661     4.13   0.000     .0400087    .1123944
lntotal_expense |  -.0707446   .0634896    -1.11   0.265    -.1951819    .0536927
          _cons |   14.51903   .5479751    26.50   0.000     13.44502    15.59304
---------------------------------------------------------------------------------
Instruments for orthogonal deviations equation
  Standard
    FOD.(lnTI lnTD lntotal_expense)
  GMM-type (missing=0, separate instruments for each period unless collapsed)
    L(1/11).L.efficiency
Instruments for levels equation
  Standard
    lnTI lnTD lntotal_expense
    _cons
  GMM-type (missing=0, separate instruments for each period unless collapsed)
    D.L.efficiency
------------------------------------------------------------------------------
Arellano-Bond test for AR(1) in first differences: z =  -4.47  Pr > z =  0.000
Arellano-Bond test for AR(2) in first differences: z =   1.06  Pr > z =  0.288
------------------------------------------------------------------------------
Sargan test of overid. restrictions: chi2(64)   = 433.92  Prob > chi2 =  0.000
  (Not robust, but not weakened by many instruments.)
```