Charles University

Faculty of Social Sciences
Institute of Economic Studies

MASTER'S THESIS

Exploring Bank Efficiency in Cambodia

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Study program: **Economics and Finance**

Supervisor: **Doc. PhDr. Adam Geršl, Ph.D.**

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Declaration of Authorship

The author hereby declares that she compiled this thesis independently; using only the listed resources and literature, and the thesis has not been used to obtain a different or the same degree.

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Prague, April 23, 2024 Sokheang Srin

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Abstract

This thesis intends to assess the determinants of the cost efficiency in Cambodian commercial banks from 2012 to 2022 in a quarterly basis. The study analyzes balanced panel data from thirty commercial banks. It tests three hypotheses that higher risk-taking decreases cost efficiency, greater capital levels enhance efficiency, and larger banks are more efficient. The methodology employed Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) to calculate bank efficiency scores. Additionally, this study explores the impact of risk-taking, capital position, and bank size on cost efficiency by using Fixed Effects (FE) estimator. The finding shows that for Cambodian commercial banks, higher past risk-taking adversely affects current cost efficiency, confirming that riskier operations can increase operational costs and decrease efficiency. Capital adequacy's impact on efficiency was indeterminate, with no significant correlation found, suggesting that other factors may influence the efficiency benefits of capital levels. Finally, the study revealed a complex relationship between bank size and efficiency, while DEA models associate larger size with greater efficiency, SFA models suggest the opposite, highlighting the need for further investigation into the scale of operations and their efficiency outcomes.

JEL Classification	C13, C14, C30, C61, D24, G21, G28
Keywords	Cambodian Commercial Bank, Bank Efficiency, Risk-Taking, Capital Position, Data Envelopment Analysis (DEA), Stochastic Frontier Analysis (SFA)
Title	Exploring Bank Efficiency in Cambodia

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Acronyms

ABC	Association of Banks in Cambodia
ASEAN	Association of Southeast Asian Nations
ATM	Automated Teller Machine
BICRA	Banking Industry Country Risk Assessment
BOP	Balance of Payment
CAR	Capital Adequacy Ratios
CE	Cost Efficiency
CPI	Consumer Price Index
CRS	Constant Return to Scale
DEA	Data Envelopment Analysis
DFA	Distribution-Free Approach
EMEs	Emerging Market Economies
FDI	Foreign Direct Investment
FE	Fixed Effects
FED	Federal Reserve
GDP	Gross Domestic Product
IMF	International Monetary Fund
KHR	Cambodian Riel (Khmer Riel)
LPCO	Liquidity Providing Collateralized Operation
MDI	Microfinance Deposit-Taking Institution
MFI	Microfinance Institution
MLE	Maximum Likelihood Estimator
MLF	Marginal Lending Facility
NBC	National Bank of Cambodia
NBCP	National Bank of Cambodia Platform
NCD	Negotiable Certificates of Deposit

NIM	Net Interest Margin
NIS	National Institute of Statistics
NPL	Non-Performing Loan
POLS	Pool Ordinary Least Squares
RE	Random Effects
ROA	Return on Assets
ROAA	Return on Average Assets
ROE	Return on Equities
RWA	Risk Weighted Assets
SFA	Stochastic Frontier Analysis
SOFR	Secured Overnight Financing Rate
SREP	Supervisory Review and Evaluation Process
TFA	Thick Frontier Approach
UNTAC	United Nations Transitional Authority in Cambodia
USD	U.S Dollar
VIF	Varian Inflation Factor
VRS	Variable Return to Scale
WB	World Bank
WTO	World Trade Organization

Master's Thesis Proposal

Institute of Economic Studies
Faculty of Social Sciences
Charles University

Author:	Bc. Sokheang Srin	Supervisor:	Doc. PhDr. Adam Geršl Ph.D.
Proposed Topic:	Exploring Bank Efficiency in Cambodia.		

Motivation:

Cambodia's banking sector has experienced significant growth and transformation in the last decades, driven by robust economic expansion, increasing financial inclusion, and evolving regulatory frameworks. The Banking Sector plays a vital role in the Cambodian economy. As the country strives to achieve sustainable and inclusive economic development, measuring and quantifying the bank's performance is crucial.

The liberalization of the banking sector intensifies competition among banks. This heightened competition may incentivize banks to take on excessive risks, potentially bolstering short-term profits. Regulators impose minimum capital requirements to mitigate this issue to curb such risk-taking. Berger and DeYoung (1997) suggest a relationship between bank efficiency, risk-taking behavior, and capital positions. This study will explore the relationships among these variables within our selected sample of banks. (Berger, Hancock, and Humphrey, 1993) studied the US bank by measuring bank efficiency from the profit function.

Aigner, Lovell, and Schmidt (1977) introduced the Stochastic Frontier Approach (SFA) to measure efficiency. SFA is a common stochastic frontier approach requiring a parametric functional form and relying on a large-sample assumption to estimate parameters. SFA creates the distance between the inefficiency and efficiency frontier (Iršová and Havránek, 2010). However, DEA is a nonparametric method for resolving linear programming issues by identifying a set of best-practice frontier observations. Berger and Humphrey (1997) conducted a study on financial institution efficiency across 21 countries, using five different methods to analyze the data. Their results from nonparametric methods (DEA and FDH) were comparable to those obtained from parametric frontier models (SFA, DFA, and TFA). Nguyen (2018) uses SFA to measure the bank profit and cost efficiency of six ASEAN Countries. Aiba and Hidenobu, (2021) also use SFA to measure the cost efficiency of the Cambodian Commercial Bank. However, Okuda and Aiba (2016) use DEA to test the determinants of efficiency and the total factor productivity (TFP) change of major financial institutions in Cambodia.

Hypotheses:

1. Hypothesis #1: Higher risk-taking by banks in Cambodia leads to lower cost efficiency.
2. Hypothesis #2: Higher capital level by banks in Cambodia leads to higher cost efficiency.
3. Hypothesis #3: Larger banks in Cambodia have higher cost efficiency.

Methodology:

Two main methods will be used to test bank cost efficiency in Cambodia. Firstly, the Stochastic Frontier Approach (SFA) is a proper method to measure bank efficiency. Data

Envelopment Analysis (DEA) will also be used to gain a more comprehensive view of efficiency. Furthermore, I would analyze the relationship between the efficiency and the selected bank's variables and macroeconomic variables based on appropriate panel data estimator. Bank risk will be measured by Non-Performing Loan (NPL) ratio.
I plan to incorporate a comprehensive dataset covering from 2012 to 2022 in a quarterly basis which is officially requested from the National Bank of Cambodia.

Expected Contribution:

Firstly, I would carefully go over the theoretical basis of efficiency estimates (could be both the bank factors and macro-financial-specific factors), look into the most popular techniques used in research, and then talk about how to apply these techniques to estimate the efficiency of commercial banks. After that, I would estimate the efficiency of Cambodian banks throughout the stipulated time period, evaluate the results, and begin to identify the key variables that contributed to this efficiency.

The second part of the empirical research will examine the connection and degree to which bank cost efficiency, risk-taking, and capital position have changed throughout the duration of the observation period. When assessing the performance of banks, regulators, banking experts, economists, and policymakers may find the findings of this study useful.

Outline:

- Introduction
- Literature Review
    - Theoretical Part
    - Empirical Part
- Data and Methodologies
- Discussion of the empirical result
- Conclusion

Core Bibliography:

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Author **Supervisor**

1 Introduction

In the past few decades, Cambodia's banking system has experienced significant growth, which has marked an increase in the number and diversity of financial institutions. This expansion indicates the country's development of financial inclusion and financial liberalization. Moreover, the rise in digital banking and financial technology has further revolutionized the banking system, enhancing and improving the ease of access and availability of financial services for Cambodians. This dynamic evolution of the banking industry is a main catalyst in supporting the country's economic development, promoting financial stability, and fostering inclusivity in financial participation among the stakeholders.

Although an increase in the number of banking institutions may indicate that the market is expanding, it can also cause an imbalance in the sector, weakening financial systems by increasing competitiveness and encouraging excessive risk-taking. Financial stability risks in Cambodia may escalate because of some factors such as (1) extensive use of foreign currency, which restricts the central bank's capacity to act as a lender of last resort; (2) the non-existence of an interbank market, which limits the sharing of risks and hampers effective liquidity management; (3) inadequate government fiscal reserves and foreign currency holdings that could bolster the banking sector during periods of economic slowdown; (4) constraints on regulatory and supervisory frameworks due to an excess number of banks; and (5) a still-recovering trust in the banking system as a result of Cambodia's past episodes of internal conflict (Unteroberdoerster, 2014).

Recognizing the importance of a comprehensive empirical understanding of bank behavior in addressing these challenges, this thesis aims to fill a notable gap in existing research. Previous studies, such as those by Okuda and Aiba (2016); Nguyen, (2018); Aiba and Hidenobu (2021), have begun to explore operational cost savings and profitability enhancements through efficiency improvements. However, a detailed investigation into the interconnected dynamics of bank efficiency, risk-taking behavior, and capital position within the Cambodian context remains unexplored.

The interconnection of bank efficiency, risk-taking behavior, and capital position has been steadily getting more attention, not only in developed countries where the challenges are distinct but also extends to developing countries where it often acts as a critical measure of the banking sector's growth and development. Various studies have been proposed in the academic field to explain the nature of the relation between these variables. For example, it is argued that banks lacking in efficiency might come from underqualified management teams who fail to effectively oversee their lending activities, thereby increasing the credit risk in the bank. Additionally, the competitive environment may encourage banks to invest in short-term gains with the cost of higher risk levels. Regulatory authorities often enforce minimum capital requirements to mitigate such risks, aiming to reduce the likelihood of bank failure and enhance financial stability. Based on the previous empirical research, our study seeks to explore these dynamics in Cambodia.

This research employs Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) to assess the cost efficiency of Cambodian Commercial banks on a quarterly basis from 2012 to 2022. Further, it also examines the impact of risk-taking, capital position, and bank size on cost efficiency by using fixed effects estimator. These analytical efforts contribute significantly to the discussion on the strategic complexity and operational challenges that define the banking environment in Cambodia.

This thesis is structured as follow: In the following chapter, we do a literature review on the macroeconomic condition and the evolution of the banking sector in Cambodia. Chapter 3 describes the literature review based on historical studies on bank efficiency, risk-taking, capital position, and their relationship. Chapter 4 displays the cost efficiency measurement. Firstly, we begin with the microeconomic theory that forms the basis of cost efficiency concepts and go over the two main measurement methods, DEA and SFA. Additionally, we outline the determination of the cost function's structure and the selection of the bank's inputs and outputs. Chapter 5 presents the empirical analysis, which is separated into two sections. In the first section, we estimate the cost efficiency scores of Cambodian Commercial Banks. In the second section, we run the regression in order to examine the relationship between the bank's risk-taking, capital position, bank size, and cost efficiency. Chapter 6 is the last chapter that presents the conclusion.

2 Macroeconomic Conditions in Cambodia

2.1 Country Profile

As located in the lower part of the Indochina Peninsula, Cambodia occupies a position in the southeastern region of Asia. It borders Thailand to the northwest, Laos to the northeast, Vietnam to the east, and Thailand's Gulf to the southwest. Cambodia's capital city, Phnom Penh, is the political, economic, and cultural center. The country spans 181,035 square kilometers and has a diverse topography, including a central plain, the Tonle Sap Lake and river system, coastal plains, and mountainous regions. Cambodia has over 16 million people, Khmer is recognized as the official language, while Buddhism is the predominant religion. Agriculture continues to be a cornerstone of the economy, with key products including cassava, rice, and rubber. The industrial sector is diverse, from tourism and garment production to more traditional activities like rice milling and fishing. Cambodia’s export and import partners reflect a diverse trade network, with major exports of clothing, footwear, and agricultural commodities (The World Factbook, 2024).

In the late 20th century, Cambodia emerged from a period marked by extensive internal strife and political isolation, initiating a transformative reconciliation process. The landmark Paris Peace Accord of 1991 played a main role in this transition, setting the stage for United Nations facilitated elections in 1993. The establishment of the United Nations Transitional Authority in Cambodia (UNTAC) was instrumental in guiding the country towards stability. Post-conflict efforts in Cambodia concentrated on rebuilding and modernizing its socioeconomic framework. Central to these efforts was the development of a robust private sector, anticipated to be the cornerstone of economic recovery. This economic strategy was complemented by substantial investment in physical infrastructure and judicial reforms, both of which received support from various international organizations. These comprehensive reforms aimed to bolster social justice and cultivate an environment conducive to business and investment. On the international stage, Cambodia’s integration into the Association of Southeast Asian Nations (ASEAN) in 1999 marked a significant shift in its foreign relations, symbolizing its commitment to regional collaboration. Furthermore, Cambodia’s accession to the World Trade Organization (WTO) in 2004 as its 148th member underscored its readiness to engage in global economic systems. These milestones were accompanied by a series of bilateral and multilateral treaties underscoring Cambodia’s proactive stance in fostering diplomatic, social, and economic ties (Hem Socheth, 2013).

2.2 Macroeconomic Overview

2.2.1 Gross Domestic Product (GDP)'s Growth

Cambodia is a small and open dollarized economy. This economy mainly relies on manufacturing, tourism, agriculture, construction, and real estate. Cambodia's economy has experienced remarkable economic growth over the last two decades, positioning itself as one of the world's fastest-growing economies, with an average 7.7% yearly growth rate from 1998 to 2019. This growth was primarily fueled by the garment exports and tourism sectors, leading the country to achieve lower middle-income status in 2015 and set targets to become upper-middle-income by 2030 (World Bank, 2023).

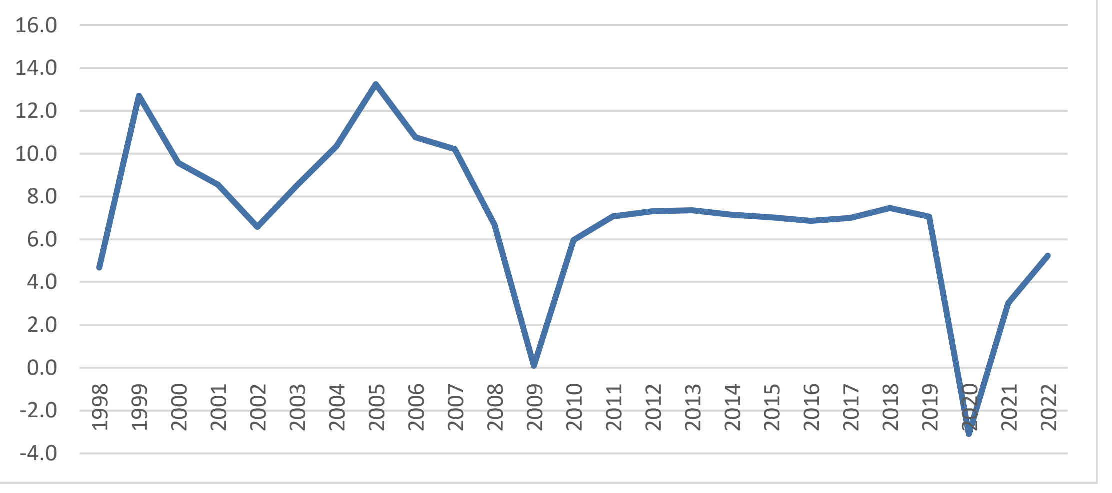
In the wake of the 2008 global financial crisis, Cambodia's economy exhibited a significant slowdown, with GDP growth decelerating to 0.1 percent in 2009, reflecting the country's exposure to worldwide economic disturbances. In 2020, the Cambodian economy again faced a substantial setback, contracting by 3.1 percent due to the widespread socioeconomic upheavals caused by the COVID-19 pandemic. Despite the COVID-19 pandemic's impact on the world economy, Cambodia's economy has shown resilience and continued recovery, particularly in 2022. The economy, which expanded by 5.2 percent in 2022, is on a positive trajectory, with projections placing growth at 5.5 percent for 2023.

While the economic recovery is progressing, Cambodia faces several potential setbacks. Short-term growth could be hindered by reduced demand from key trading partners in advanced economies, a slowdown in China's recovery, substantial levels of private debt, and a tightening of the global financial environment. In the medium term, the economy could confront significant obstacles from geopolitical strife, potential trade disruptions, a structural slowdown in China's economic growth, and the pervasive threats posed by climate change (IMF, 2023).

Figure 2.1 indicates the path of Cambodia's GDP growth rate from 1998 to 2022. The graph portrays a volatile yet predominantly upward trend in economic expansion. The initial years showcase an impressive surge in growth rate, peaking at just over 10 percent in the early 2000s, followed by a period of fluctuation that dips dramatically around 2009, which can be attributed to the global financial crisis's repercussions.

Post-crisis, the graph reflects a resilient recovery, with growth rates rebounding and maintaining a higher level until a sharp decline is observed around 2020, likely a consequence of the global economic impact of the COVID-19 pandemic. The subsequent years indicate a commendable recovery effort, with the growth rate climbing sharply once again in 2021.

Figure 2.1: GDP Growth Rate from 1998-2022 (In percentage)

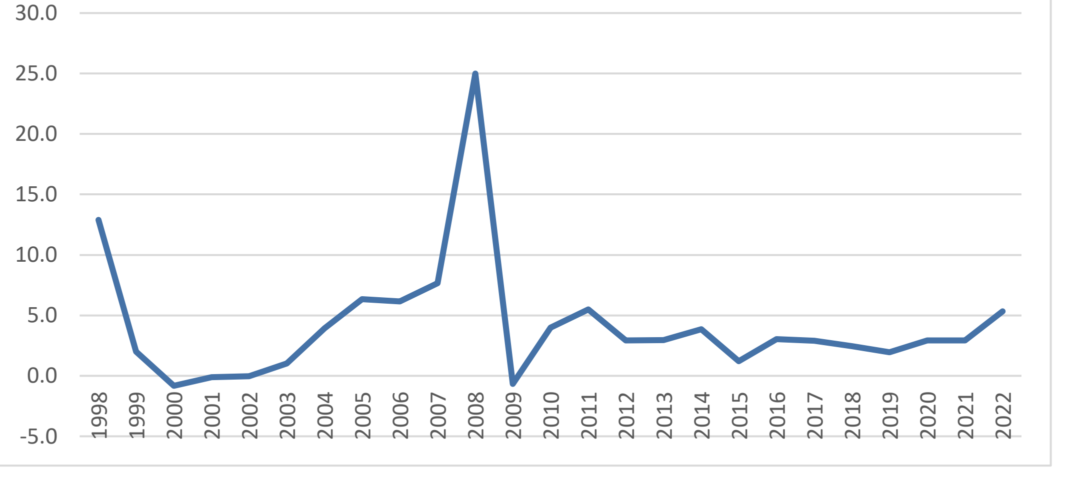


Sources: IMF, World Economic Outlook Database (2023)

2.2.2 Inflation

Based on Figure 2.2, the graph shows that 2008, there was a notable spike when the inflation rate rose to 25 percent. This could be reflective of a global economic trend, as 2008 was the year of the global financial crisis. Following the spike in 2008, the graph shows a general trend of decline and relative stability in the inflation rate. The subsequent years saw the rate decrease and then level off to under 10 percent with minor ups and downs. In 2022, the inflation rate is 5.3 percent, higher than in 2021 (2.9 percent) due to increased food and fuel prices (IMF, 2023).

Figure 2.2: Inflation rate from 1998-2022 (In percentage)

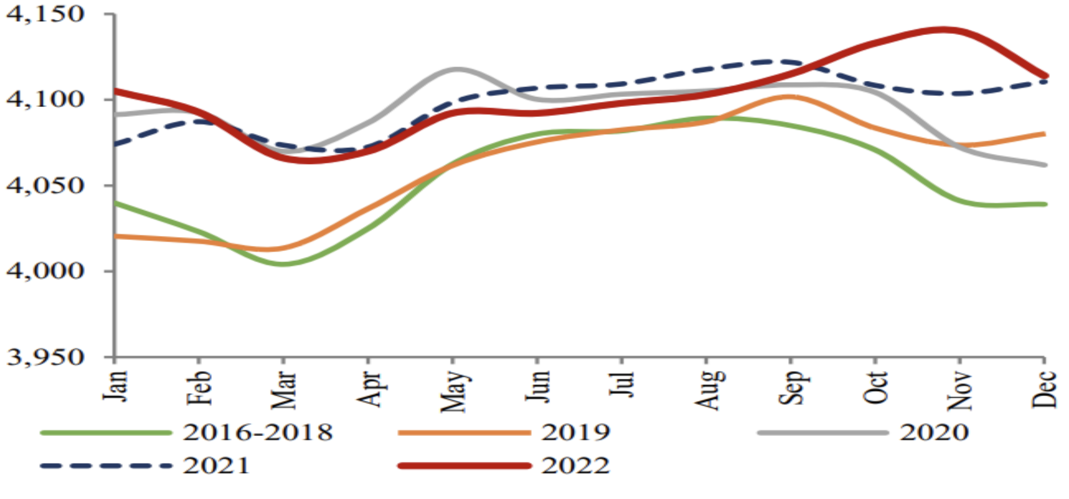


Sources: IMF, World Economic Outlook Database (2023)

2.2.3 Exchange Rate

Cambodia uses a managed floating regime for its exchange rate. National Bank of Cambodia (NBC) employs foreign exchange market intervention as a converting tool for monetary policy in the context of a dollarized economy. In 2022, the KHR displayed remarkable stability in its exchange rate against the USD, a commendable position given the global economic disturbances. Despite a slight depreciation, the resilience of the KHR stands in contrast to the volatile nature of currency exchanges often witnessed in emerging economies. This steadiness can be partially attributed to Cambodia's monetary policies and adaptive economic strategies post-crisis. The average exchange rate of the KHR against the USD has depreciated by 1.2 percent from the pre-crisis levels (2016-2018) and by a marginal 0.1 percent from the preceding year (2021). This indicates a controlled devaluation, implying a proactive approach by NBC to align with the market's natural corrective mechanisms. The minimal depreciation signals a cautious yet optimistic economic outlook, emphasizing the recovery phase of the Cambodian economy (NBC, 2022a).

Figure 2.3: Exchange Rate of KHR against US (KHR per USD, 2016-2022)

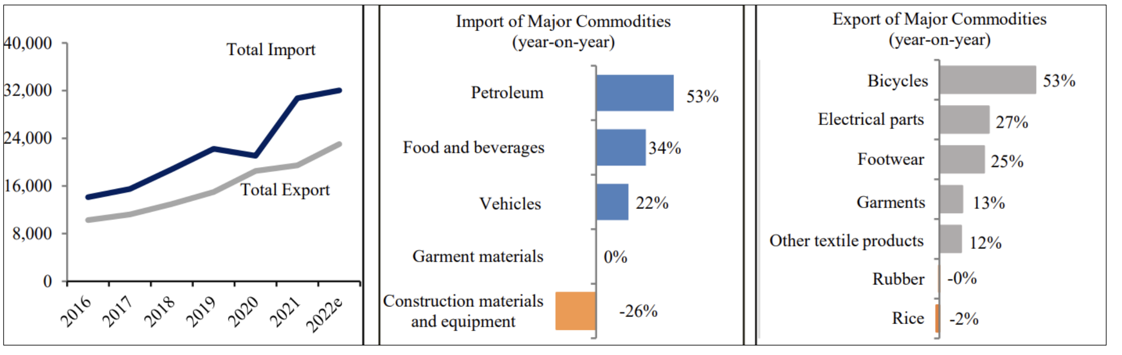


Sources: NBC, Annual Report (2022)

2.2.4 Balance of Payment

The Balance of Payments (BOP) in Cambodia is recorded as a surplus of USD 298.8 million in 2022, a significant rise from the USD 82.7 million surplus in 2021. This increase signifies a recovering economy, supported by a boost in financial account heightened investor confidence and efficient economic management. In 2022, Cambodia's current and capital accounts rebounded from 2021's deficit, aided by increased imports of essential items and a decline in tourism due to the COVID-19 pandemic. The capital account deficit narrowed to 30.6 percent of GDP, excluding gold imports, which represented 23.2 percent. Export growth of 18.3 percent, especially to the US and EU, coupled with a modest 4.3 percent rise in imports, contributed to a roughly 20 percent reduction in the trade deficit. Key imports like petroleum and vehicles surged, while construction material imports fell. Diversified exports, including bicycles and electrical parts, reflected strong export sector growth. Service account deficits shrank significantly with a boost from tourism, offsetting the primary income account deficit worsened by increased foreign payments. Remittances showed slight growth (NBC, 2022a).

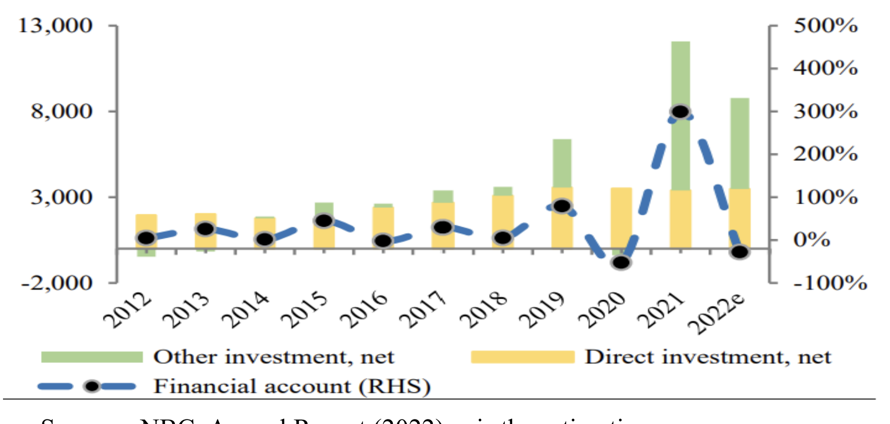
Figure 2.4: Import and Export of Goods in 2022 (In Million USD)



Sources: The General Department of Customs and Excise and NBC's Calculations

Cambodia's financial account in 2022 saw a positive net inflow of USD 9.4 billion, signifying robust Foreign Direct Investment (FDI), particularly in the non-banking sector, which alone surged by 9.3 percent. This sector contributed significantly to the total net FDI inflow of USD 3.5 billion, marking a 2.6 percent increase from the previous period. Conversely, the banking sector experienced a 7.7 percent decline in FDI. The broader category of other investments also reported a substantial net inflow of USD 6 billion, although a considerable reduction in other private investments partially offset this. The net foreign assets of the banking sector grew by 6.5 percent, while the government's net borrowing increased by 14.4 percent, underscoring a nuanced landscape of financial activity in Cambodia (NBC, 2022a).

Figure 2.5: Financial Account (2012-2022e)



Sources: NBC, Annual Report (2022), e is the estimation

2.3 Monetary Policy Implementation

In 2022, NBC encountered a challenging economic landscape in implementing its monetary policy, primarily influenced by external factors such as global increases in food and oil prices and the exchange rate depreciation against a strengthening US dollar following the US Federal Reserve's interest rate hikes. This period also demanded support for Cambodia's economic resurgence following the COVID-19 pandemic, necessitating a balanced approach to stabilize the exchange rate, control inflation, and foster economic growth.

NBC's strategic employment of monetary instruments was aimed at counteracting inflationary pressures while preserving the Khmer Riel (KHR) stability and ensuring sufficient liquidity within the banking system. By reducing the interest rates for the riel, NBC intended to stimulate economic activities without intensifying existing economic pressures. NBC uses several monetary instruments, such as:

- *Foreign Exchange Intervention*: NBC uses this tool to influence the exchange rate and stabilize the domestic currency. In 2022, NBC only sold USD 9 million to banks and financial institutions. This transaction is in contrast to the previous year when NBC sold of USD 291.2 million while purchasing USD 37 million. In collaboration with relevant government entities, NBC's transactions also were a shift; it sold USD 54 million and bought USD 23.1 million, a notable change from the 2021 transaction of USD 7.1 million sold and USD 55.3 million purchased (NBC, 2022a).

- *Reserve Requirement Rate*: refers to the proportion of depositor's balances that banks must retain and not lend out. The reserve requirement rate is 7 percent for KHR and USD in 2022. Compared to the pre-crisis (COVID-19 Pandemic) rates (12.5 percent for USD and 8 percent for KHR), the banking system achieved additional liquidity of KHR 10.9 trillion (USD 2.6 billion) at such a low cost (NBC, 2022b). By adjusting the reserve requirement rates, the NBC can directly influence the liquidity available in the banking system, thereby controlling the money supply and influencing interest rates.

- *Negotiable Certificates of Deposit (NCDs)*: is the short-term securities issued by the NBC. It serves to manage liquidity in the financial system. By absorbing excess liquidity, NCDs help regulate money market rates and support the financial sector's stability. Changes in NCD issuance and interest rates indicate shifting strategies in liquidity management and interest rate policy. In 2022, NBC issued NCDs increased to USD 37.5 billion, marking a 3.7 percent rise. KHR-denominated NCDs issuance decreased by 4.4 percent, with a notable shift from shorter to longer tenors.

Conversely, USD-denominated NCDs issuance rose by 4.9 percent, with gains in both shorter and longer tenors but declines in mid-range ones. Interest rates for NCDs in both currencies increased due to higher Secured Overnight Financing Rate (SOFR) after the Federal Reserve's rate increases, particularly impacting USD NCDs with the rate adjustments varying across different tenors (NBC, 2022a).

- *Issuing Government Securities:* is the process by which the NBC, sells securities such as bonds to investors to raise funds. These funds are typically used for government spending and investment projects. Government securities are considered a low-risk investment option as they are backed by the government's credit. In 2022, the NBC resumed issuing government securities to develop Cambodia's financial market and raise local currency resources for financing medium and long-term investments. The issuance amounted to KHR 72.1 billion, which was below the planned KHR 1.2 trillion due to delays and some unsuccessful bids. These securities were offered with a one-year maturity at a 2.2 percent annual interest rate (NBC, 2022a).

- *Liquidity Providing Collateralized Operation (LPCO):* involves providing of liquidity to financial institutions against collateral. LPCOs are critical for ensuring that banks have adequate short-term liquidity, thus stabilizing the money market and supporting the overall liquidity of the banking sector. The LPCO outstanding decreased by 53.7 percent to KHR 947 billion in 2022 (NBC, 2022a). This decrease underscores a broader strategy to tighten liquidity conditions, potentially to respond to inflationary pressures or to support the KHR.

- *Marginal Lending Facility (MLF):* served as a short-term liquidity provision facility. MLF allows banks to borrow overnight up to five days at a 4 percent annual rate against collateral like NCDs and government securities, with three banks participating with a total borrowing of KHR 32.8 billion. This facility underscores NBC's commitment to providing liquidity support to the banking sector.

- *Net Liquidity Injection in KHR:* is a process by which the NBC injects the local currency (KHR) into the financial system to manage liquidity levels. This is achieved through various operations, including open market operations, lending facilities, and changes in reserve requirements. In 2022, there was a strategic reduction from KHR 585.1 billion in January to KHR 288.8 billion in October 2022, with a notable decrease aimed at easing depreciation pressure on the KHR (NBC, 2022a).

2.4 Banking Sector Developments in Cambodia

2.4.1 Brief History

The Cambodian banking system has experienced significant transformations over the past few decades. In 1954, after Cambodia got independent from France, this country set up its own central bank called the National Bank of Cambodia (NBC). The NBC obtained autonomy to oversee the banking sector in Cambodia and print the national currency know as Khmer Riel (KHR). But then, between 1975 and 1979, when the Khmer Rouge was in power, they destroyed the entire banking system and got rid of the KHR. After the Khmer Rouge era ended in 1979, Cambodia started putting things back together. In 1980, they brought back the NBC and reintroduced the KHR. It was a big deal because Cambodia was working hard to fix its economy and regain public confidence in KHR.

The early 1990s marked the beginning of Cambodia's integration into the global banking system, with the entry of foreign banks and the licensing of commercial banks by 1998. This period was characterized by a regulatory framework that initially required foreign subsidiaries to maintain a minimum capital of USD 5 million, with a 15 percent ownership stake by NBC. However, the banking sector underwent significant reforms under the new governorship of H.E Chea Chanto in the late 1990s, which included abolishing NBC's mandatory ownership in private and foreign banks and introducing the classification system for financial institutions.

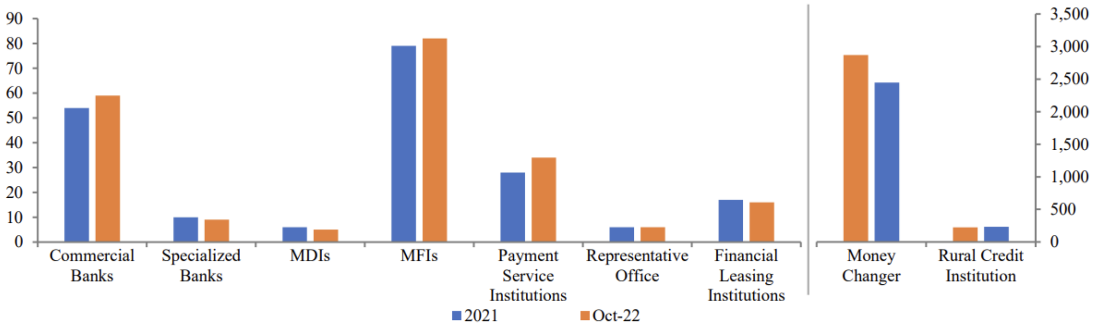
The early 2000s witnessed further expansion and modernization of the Cambodian banking sector. Key developments included privatizing the Foreign Trade Bank, entering new foreign banks from Australia, Korea, and Japan, and implementing measures to counter over-liquidity and inflation pressures. NBC's membership in the Asia Pacific Group on Anti-Money Laundering and its efforts to combat the financing of terrorism highlighted Cambodia's commitment to adhering to international financial standards.

A pivotal shift towards digitalization commenced in 2009, spearheaded by the launch of mobile banking and the introduction of an accommodative monetary policy. The establishment of the Cambodia Financial Intelligence Unit and the launch of the National Payment System in 2012 further demonstrated Cambodia's dedication to enhancing its financial infrastructure. The development of the "Shared Switch" system was a notable advancement, facilitating the integration of bank Automatic Teller Machines (ATMs) and enabling payment via mobile phones and the internet.

The period from 2016 to the present has been characterized by continued innovation and improvement in the banking sector's efficiency and accessibility. The World Bank's recognition of Cambodia as the 7th of 190 countries for "ease access to loan" in 2016 underscored the significant progress made in this area. The launch of the "FAST Payment" system and the introduction of online banking systems further underscored the sector's modernization. Moreover, NBC's exploration of blockchain technology for cross-payment and regional transactions indicates a forward-looking approach to banking and finance (ABC, no date). Project Bakong, initiated by NBC in 2017 and launched in 2020, marks a major advancement in digital payments, leveraging blockchain dual-currency accounts (KHR and USD) to foster the use of local currency and accommodate Cambodia's dollarized economy. By enabling real-time transactions across various financial institutions without a centralized clearinghouse, Bakong significantly cuts transaction times and costs, enhancing financial inclusion and transforming Cambodia's payment landscape (The Asian Banker, 2020).

The banking landscape in Cambodia is characterized by a dual-tier framework, with the NBC anchoring the public sector and a diverse private sector (NBC, 2015). By 2022, the banking system boasted 59 commercial banks, 9 specialized banks, 5 deposit-taking microfinance institutions, 82 non-deposit microfinance institutions, 16 financial leasing institutions, 223 rural credit institutions, 5 third-party processors, 34 payment services providers, 1 credit bureau, 6 representative offices, and 2,869 money changers. Commercial banks are categorized into three groups such as foreign branch banks, locally incorporated banks, and subsidiary banks (NBC, 2022a).

Figure 2.6: Cambodian Banking System (2021-2022)

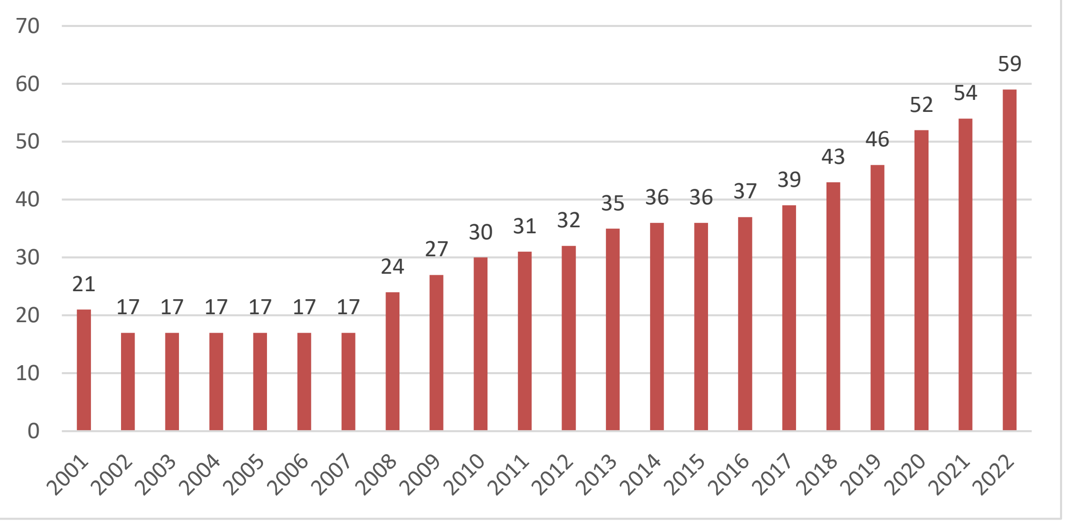


Sources: NBC, Annual Report (2022)

2.4.2 Banking Sector Performances and Trends

Over the past two decades, there has been a rapidly expanding number of commercial banks in Cambodia. In 2001, there were 21 commercial banks, and this number remained fairly steady for the next several years. Starting in 2008, there is a noticeable upward trend, with the number gradually increasing from 24 to 59 commercial banks by 2022. The most significant growth appears to have occurred in the later years, with the count of commercial banks rising sharply from 46 in 2019 to 59 in 2022.

Figure 2.7: Number of Commercial Banks in Cambodia (2001-2022)



Source: NBC

In Table 2.1 presents a comprehensive overview of the Cambodian banking sector's development between 2018 and 2022 through a series of growth indicators. The table shows that asset growth experienced a consistent expansion, peaking in 2018 and 2019 at 21.4 percent and 21.5 percent, respectively before declining to 10.4 percent by 2022. Customer credit growth also displayed robust figures, starting at 24.3 percent in 2018, and after a slight dip in subsequent years, it rose again in 2021 to 22.0 percent before a modest decrease to 19.5 percent in 2022.

Similarly, customer deposit growth rates fluctuated, with an initial high of 27.9 percent in 2018, which substantially reduced to 7.3 percent by 2022, indicating a trend of decelerating deposit accumulation over the period. The ratios of banking assets and customer credit to GDP demonstrated a remarkable upward, with assets to GDP increasing from 143.6 percent in 2018 to 256.1 percent in 2022, and customer credit to GDP escalating from 83.5 percent to 174.6 percent across the same timeframe.

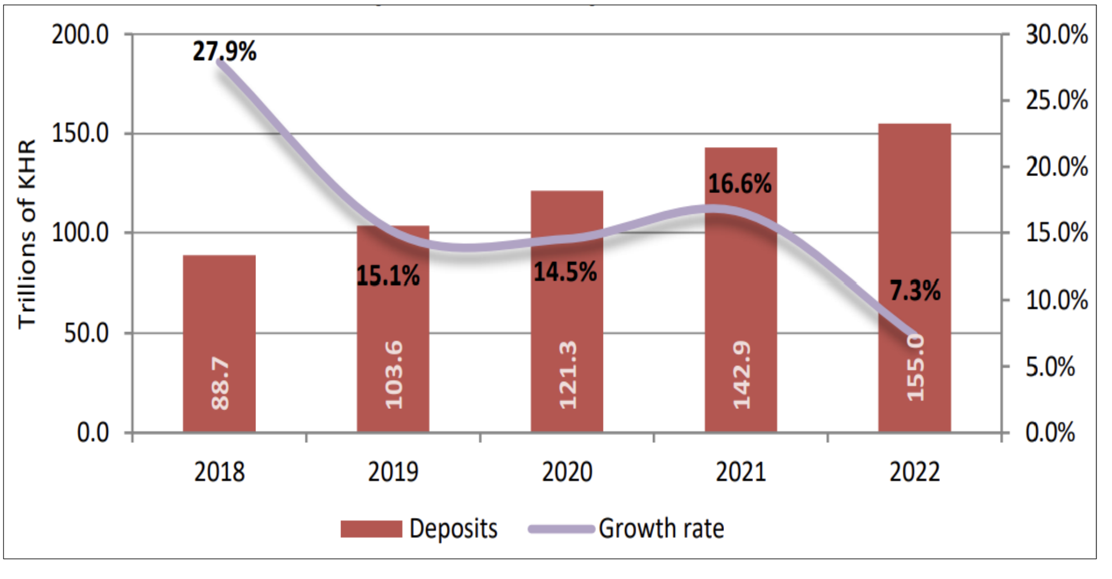
Furthermore, the customer's deposit to GDP ratio exhibited growth, escalating from 91.1 percent in 2018 to 145.6 percent by 2022, suggesting an overall strengthening of the banking sector's role in the Cambodian economy.

Table 2.1: Banking Sector Development in Cambodia (2018-2022)

Indicators	2018	2019	2020	2021	2022
Asset Growth	21.4%	21.5%	14.7%	17.5%	10.4%
Customer's Credit Growth	24.3%	23.9%	16.1%	22.0%	19.5%
Customer's Deposit Growth	27.9%	15.1%	14.5%	16.6%	7.3%
Asset to GDP	143.6%	155.1%	186.1%	232%	256.1%
Customer's Credit to GDP	83.5%	92.0%	114.8%	149.3%	174.6%
Customer's Deposit to GDP	91.1%	93.3%	110.9%	135.6%	145.6%

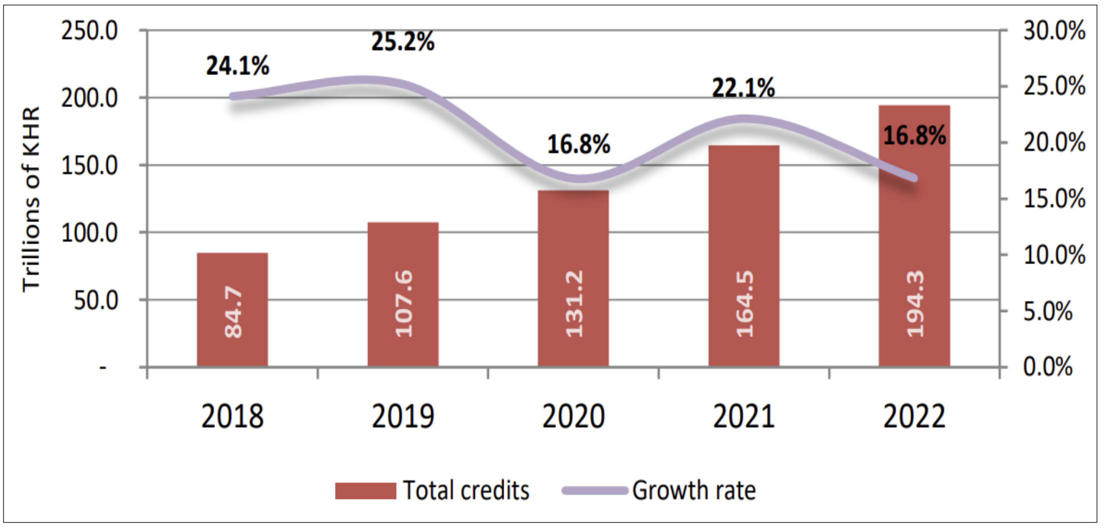
Source: NBC, Annual Supervision Report (2022)

Figure 2.8: Banks-Total Deposits and Deposits Growth (2018-2021)



Source: NBC, Annual Supervision Report (2022)

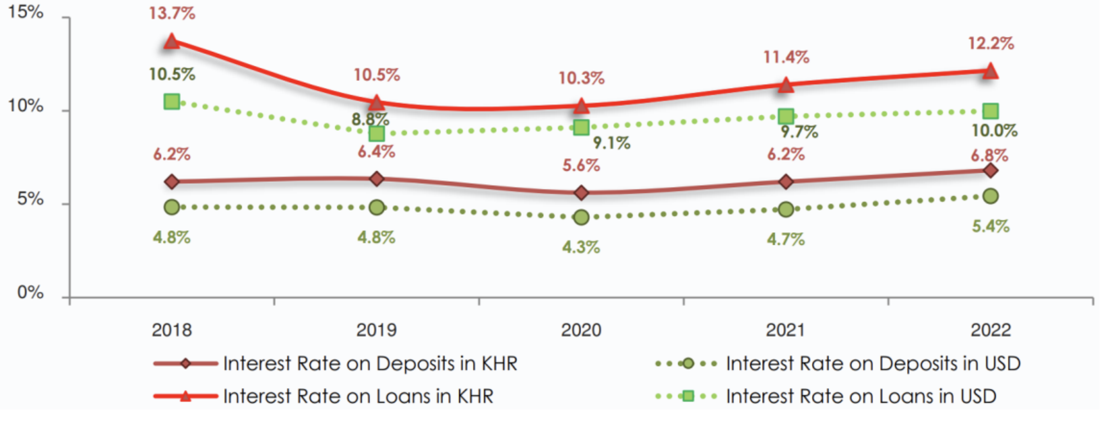
Figure 2.9: Banks-Total Credits and Credit Growth (2018-2021)



Source: NBC, Annual Supervision Report (2022)

In 2022, the average deposit rates for KHR and USD demonstrated a marginal elevation from the previous year, recording 6.8 percent for KHR and 5.4 percent for USD. Correspondingly, the average interest rate for KHR-denominated loans saw an uptick from 11.4 percent to 12.2 percent, while USD loans experienced an increase of 10 percent from the previous year's rate of 9.7 percent.

Figure 2.10: Bank's Interest Rate on Deposits and Loans (KHR and USD)



Source: NBC, Annual Supervision Report (2022)

2.4.3 Banking Sector's Prudential Ratio

The Capital Adequacy Ratio (CAR) of Cambodia's bank remained significantly above the Basel III mandate throughout the period, with a high of 24.24 percent in 2012 and never dropping below 20.31 percent even in years of economic stress. In 2022, the CAR of Cambodian banks is 21.66 percent, which is well above the international standard of 10.5 percent (including the capital conservation buffer).

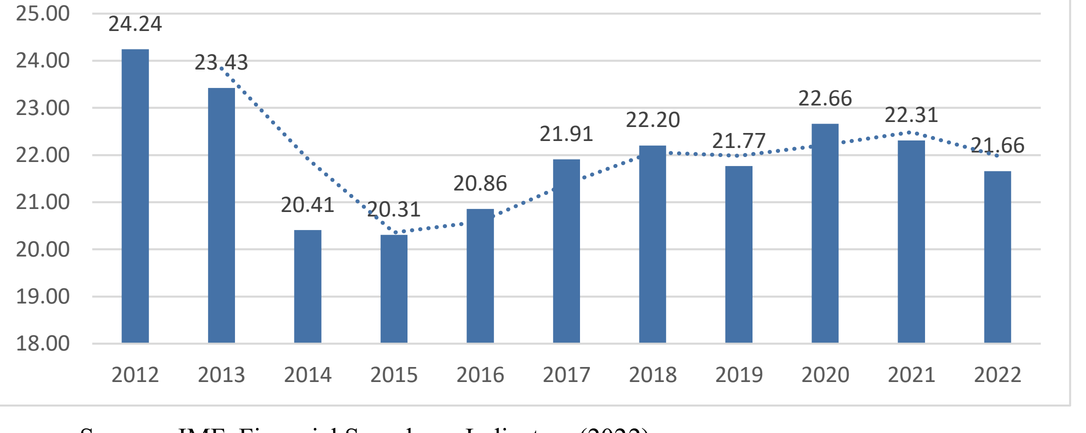
In terms of profitability, the Return on Assets (ROA) reached its peak at 2.91 percent in 2013, which illustrates a period of heightened efficiency in asset utilization to generate earnings. Despite a downturn to 1.50 percent in 2017, a subsequent rise to 2.45 percent by 2022 indicates an adaptive recovery, likely reflective of strategic management adaptations and an improving macroeconomic context. Similarly, the Return on Equity (ROE) trend presents an illustration of recovery, climbing from a low of 6.11 percent in 2018 to a substantial 9.93 percent in 2022.

However, the increase in the Non-Performing Loans (NPLs) to 2.71 percent in 2022 from a low of 1.55 percent in 2019 raises some flags about credit risk management. This recent increase signifies potential vulnerabilities in loan portfolios, necessitating diligent oversight to mitigate escalating credit risk.

The liquid assets over total assets ratio, starting at 15.29 percent in 2012, the ratio peaked at 17.93 percent in 2013, indicating a strong liquidity position. Following this peak, the ratio mostly fluctuated within a narrow band, suggesting consistent liquidity management. In the last year, 2022 there is a noticeable dip to 11.75 percent, which could reflect changes in asset composition or potentially tighter liquidity (IMF, 2024).

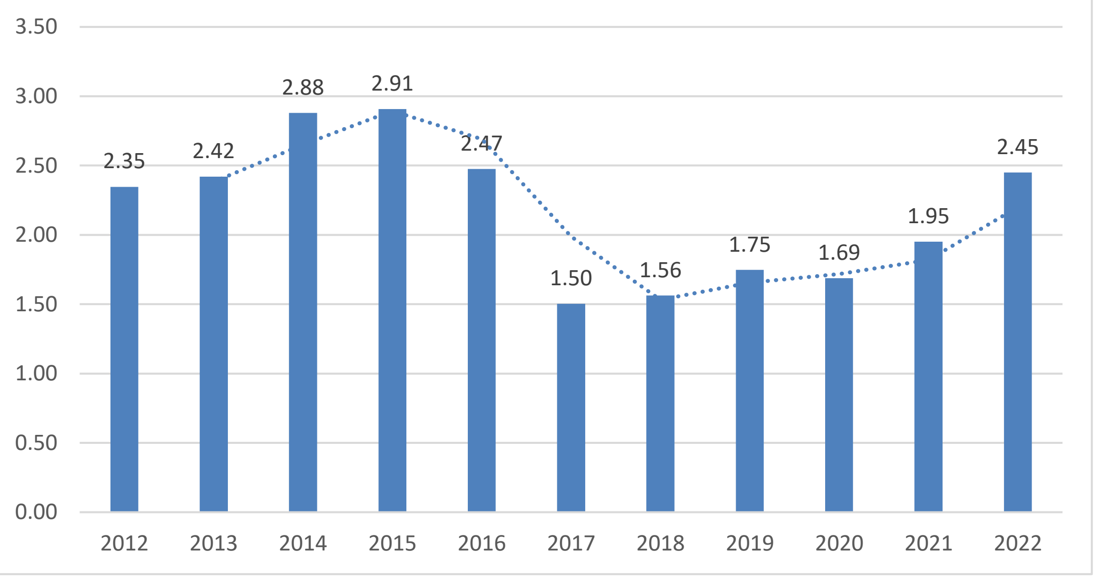
The resilience of the banking sector is evident from adherence to prudential regulations, robust corporate governance, and effective internal controls. With a solvency ratio standing strong at 22.3 percent (remained compliant with the regulatory ratio of 15 percent) and a liquidity coverage ratio at 143.8 percent (remained compliant with the regulatory ratio of 100 percent), banks have displayed commendable financial stability. Profitability metrics are equally promising, with ROA of 1.4 percent and ROE of 7 percent, indicating healthy earnings performance. Moreover, the management of credit risk is within a controlled threshold, as highlighted by the NPL ratio of 3.1 percent (NBC, 2022b).

Figure 2.11: Capital Adequacy Ratio (2012-2022, In percentage)



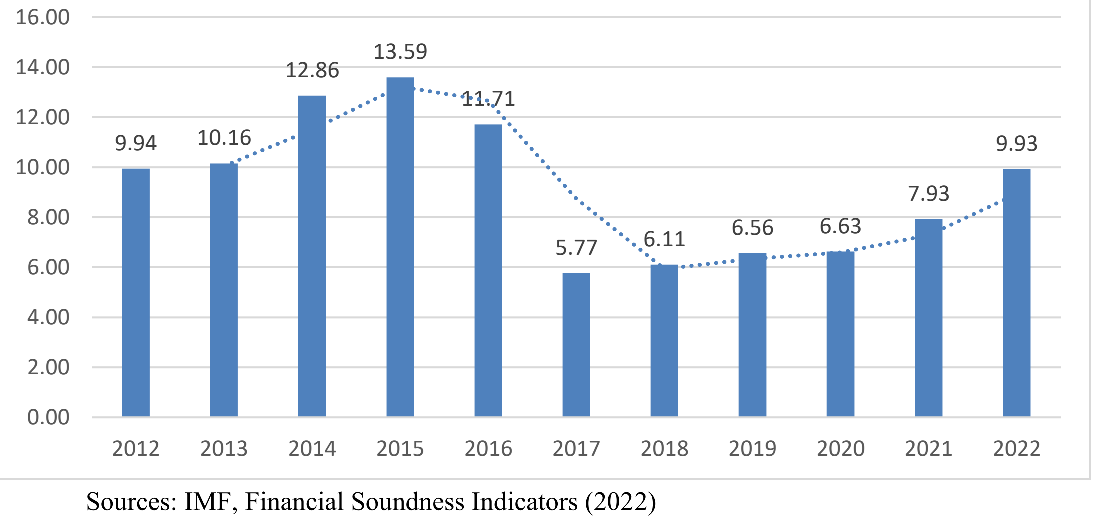
Sources: IMF, Financial Soundness Indicators (2022)

Figure 2.12: Return on Assets (2012-2022, In percentage)



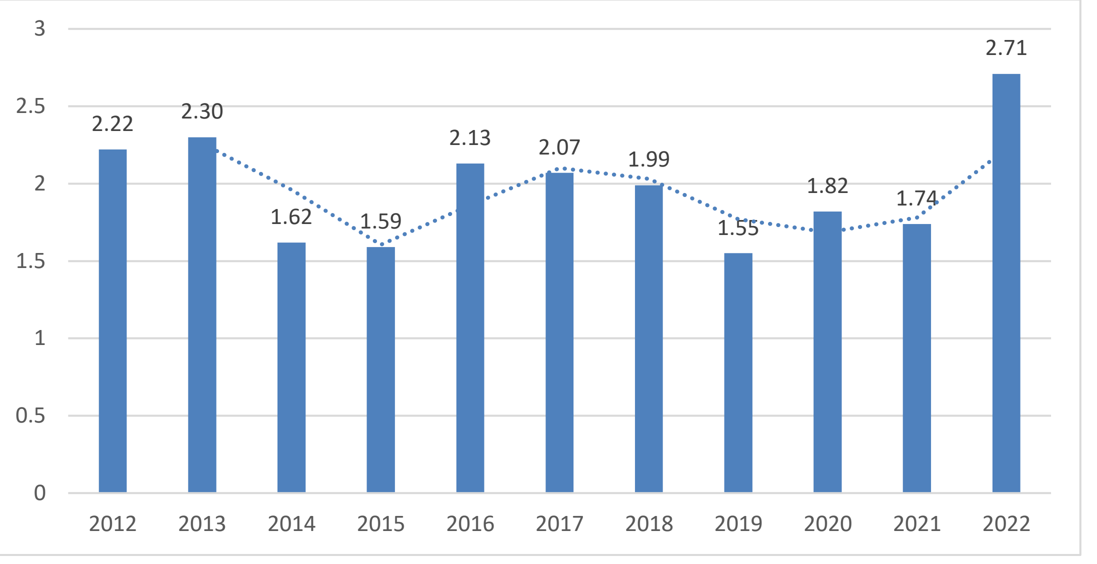
Sources: IMF, Financial Soundness Indicators (2022)

Figure 2.13: Return on Equities (2012-2022, In percentage)



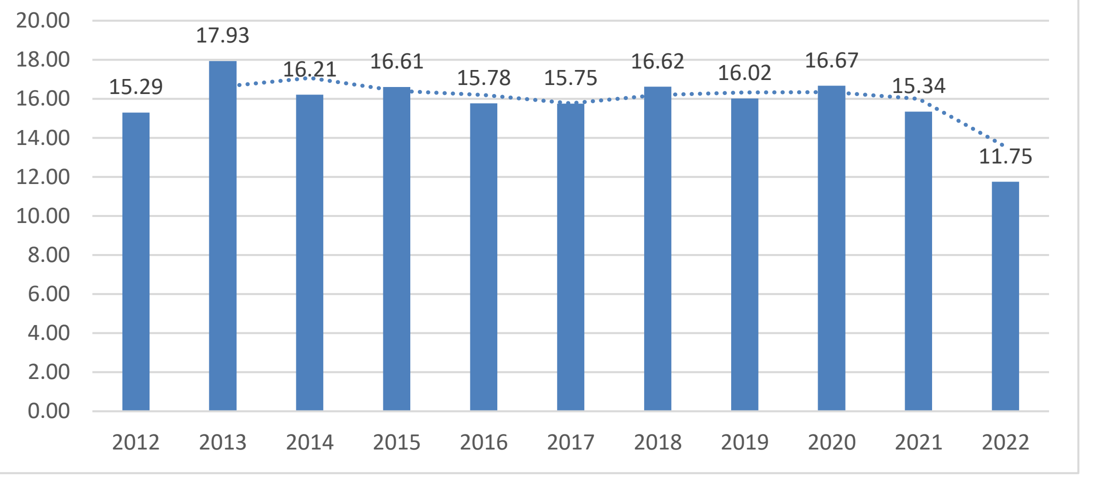
Sources: IMF, Financial Soundness Indicators (2022)

Figure 2.14: Non-Performing Loans (2012-2022, In percentage)



Sources: IMF, Financial Soundness Indicators (2022)

Figure 2.15: Liquid Assets over Total Assets (2012-2022, In percentage)



Sources: IMF, Financial Soundness Indicators (2022)

2.4.4 Supervisory and Regulatory Framework Development

NBC has been revising and enhancing its supervisory architecture to boost the effectiveness of the banking sector. To strengthen the supervisory functions, the NBC has promulgated two critical guidelines for supervisory authorities. The first one is a guideline for the enactment of the official proclamation on Credit Risk Grading and Impairment Provisioning, which mandates precise provisions for credit risk measurement in alignment with prevailing accounting standards. The second guideline details the application of the Supervisory Review and Evaluation Process (SREP) methodology, which is integral for implementing incisive risk-based supervision of banks and financial institutions.

Simultaneously, NBC has reassessed the regulatory forbearance measures instigated during the COVID-19 pandemic. This includes adjustments such as the reduction of reserve requirements and capital conservation buffers, underpinning discussion with key stakeholders on the strategic withdrawal of such measures to guarantee the sector's continued resilience and stability.

In addition, the NBC is diligently developing updated regulations for Capital Adequacy aligned with Basel III norms. This initiative is a crucial component of the broader Risk-Based Supervision strategy, ensuring that the Cambodian Banking System remains robust and well-equipped to manage potential financial challenges (NBC, 2022b).

3 Bank Efficiency, Risk-Taking, and Capital Position

3.1 Bank Efficiency

In 1957, Farrell pioneered the formal study of efficiency within firms by extending the foundational theories introduced by Debreu (1951) and Koopmans (1951). He proposed a method to evaluate a firm's performance that encapsulates two distinct dimensions of efficiency: technical and allocative. Technical efficiency reflects a firm's capability to maximize output from given inputs, while allocative efficiency assesses how effectively a firm allocates these inputs, considering their costs, to achieve optimal output. These concepts collectively contribute to the firm's overall economic efficiency. Using a simple model, Farrell illustrated these ideas by analyzing firms utilizing double inputs to produce one output, under the assumption of constant returns to scale (Farrell, 1957).

Maudos *et al.* (2002) explores cost and profit efficiency European banks across ten countries from 1993 to 1996. The study shows that there is a significant difference in both cost and profit efficiency across the banks in the sample, with profit efficiency being notably lower than cost efficiency. They found that medium-sized banks exhibit highest levels of cost and profit efficiency, indicating bank size plays a crucial role in banking efficiency, but in a non-linear manner. Banking specialization does not significantly impact efficiency, indicating that a bank's target area does not inherently affect its performance. Banks that exhibit a higher degree of risk-taking, as evidenced by the variability in their returns, demonstrate an enhanced propensity towards profit efficiency but do not necessarily exhibit cost efficiency. In markets with fewer competitors, bank enjoy higher profit efficiency due to increased market power, but this advantage does not translate into better cost efficiency, possibly because lesser competition reduces the incentive to minimize cost. Additionally, in higher GDP growth, banks show higher profit efficiency but lower in cost efficiency.

Raphael (2013) investigates the determinants of bank efficiency in Tanzania from 2005 to 2008, focusing on bank-specific, industry-specific, and macroeconomic factors. The finding indicates that larger bank size positively influences efficiency, suggesting that bigger banks benefit from economies of scale. Profitability, as measured by Net Interest Margin (NIM) and Return on Average Assets (ROAA), also positively affects efficiency, highlighting that profitable banks tend to be more efficient. Capital adequacy shows a positive impact on efficiency, indicating well-capitalized banks are more efficient. However, the study found that non-performing loans, ownership, and the Consumer Price Index (CPI) do not significantly explain bank efficiency.

Adjei-Frimpong, Gan and Hu (2014) evaluates the efficiency of Ghana's banking industry from 2001 to 2010 using data DEA, focusing on how bank size, capitalization, loan loss provisions, inflation rate, and GDP growth rate impact bank efficiency through both static and dynamic panel data models. Findings suggest Ghanaian banks are generally inefficient, with well-capitalized banks showing less cost efficiency and bank size not affecting cost efficiency, indicating no cost advantage for larger banks. Moreover, the study finds no significant effect of loan loss provision ratios on bank efficiency. Interestingly, GDP growth negatively affects bank cost efficiency, indicating that in periods of economic growth, banks may prioritize expansion at the expense of cost control. In terms of inflation has a minimal and statistically insignificant effect on the cost efficiency of banks in in Ghana, suggesting that changes in inflation do not significantly impact how efficiently banks manage their costs.

3.2 Bank Risk

Bank risks come in different forms and can seriously affect a bank's financial health and stability. Banks must grasp and handle these risks well to ensure their ongoing success. The main types of bank risks in the banking sector include:

- Credit Risk is the possibility that a debtor or contractual party associated with a bank may fail to fulfill their financial obligations as stipulated in the terms of the agreement. The primary objective of managing credit risk is to, adjust for optimize the bank's return on investment by ensuring that exposure to credit risk remains within predetermined and acceptable bounds (Basel Committee on Banking Supervision, 1999). Banks mitigate loan risks through rigorous borrower verification portfolio diversification, and holding loan loss reserves, representing the role of a delegated monitor (Diamond, 1984).

- Market Risk is associated with the possibility of incurring financial setbacks within on-balance sheet and off-balance sheet portfolios due to the variability in market prices. This type of risk covers a broad range of uncertainties including changes in interest rates, currency exchange rates, stock valuations, and other factors that are affected by the constantly changing nature of market forces (Basel Committee on Banking Supervision, 2019).

- Liquidity Risk involves a bank's capacity to swiftly settle short-term liabilities without incurring losses. It happens when a bank's liquid assets do not adequately cover its immediate debts, threatening short-term cash flow stability (Basel Committee and on Banking Supervision, 2008).

-Operational Risk relates to potential losses due to internal inefficiencies or external events affecting processes, staff, or technological systems. This definition includes legal risks but excludes those associated with strategic decisions or reputational factors (Basel Committee on Banking Supervision, 2021).

3.3 Bank Capital Framework

The deliberate structuring of bank capital, integrating equity, borrowings, and various financial instruments, is crucial for enhancing operational performance and driving growth initiatives. The seminal work of Berger, Herring and Szegö (1995) casts light on bank capital's function as a cornerstone for economic equilibrium, fostering trust among consumers and investors alike. In the aftermath of the 2008 financial crisis, banking regulations, especially the Basel III accord, have seen significant revisions aimed at reinforcing capital sufficiency. These amendments, meticulously examined by Blundell-Wignall and Atkinson (2010), have introduced mechanisms like the capital conservation buffer, marking a significant shift towards ensuring greater financial system robustness and promoting responsible credit distribution.

Continuing this examination, Gambacorta and Mistrulli (2004) examined the intricate effects of heightened capital mandates on bank's lending practices, a balancing act between upholding financial solidity and ensuring credit flow during economic variances. The debate extends into the qualitative distinctions within bank capital, notably between Tier 1 and Tier 2 categories as per Basel stipulations, highlighting a discourse on the ideal capital configuration to safeguard banking stability and mitigate systemic threats (Admati *et al.*, 2013).

3.4 Bank Risk-Taking and Capital Structure

Shrieves and Dahl (1992) studies the interplay between risk and capital in commercial banks, revealing a positive correlation between changes in both variables. Contrary to only considering regulatory pressures, the findings suggest that bank manager's and owner's personal incentives significantly influence risk management, even in banks with capital ratios above the regulatory requirements. The study demonstrates the complexity of bank behavior regarding risk and capital, indicating that private incentives can effectively limit total risk exposure, aligning with theories that emphasize the cost of risk and leverage.

Jacques and Nigro (1997) explores the effect of risk-based capital standards on the capital ratios and portfolio risk of commercial banks during the initial year of implementation. The study utilized a three-stage least squares model to analyze how these standards influenced bank behavior. Findings indicate that the risk-based capital standards successfully increased capital ratios and decreased portfolio risk among commercial banks, contributing valuable insights into the impact of these regulations on banking practices.

Unlike banks in developed countries, banks in Emerging Market Economies (EMEs) have navigated through numerous phases of transformation, especially in terms of technology and regulations. Challenges such as the banking crisis and privatization processes are distinct to these markets. For a considerable period, the banking sectors in these regions were subject to strict regulation and protection, notably through interest rates and restrictions on market entry. However, the 1990s saw the beginning of deregulation, opening the door for foreign investment in these markets.

Compared to the developed countries, the relationship between bank risk-taking and capital is getting less attention in the EMEs. According to the previous research, undercapitalized banks tend to raise their capital adequacy ratios. This suggests that regulatory pressure is effective and that banks will maintain ratios above the minimum standards for safety and reputational interests.

Godlewski (2005) investigates the link between bank capital levels and credit risk in EMEs, and how this relationship is influenced by various regulatory, institutional, and legal environments. Utilizing a simultaneous equations model, it finds that capital regulations do affect bank behavior in these markets, with banks maintain higher capital ratios as a precaution or for reputational reasons. However, the impact of these regulations on bank's risk-taking activities is more complex and less direct. The research highlights the significance of a supportive and clear regulatory, institutional, and legal framework for ensuring the stability and health of banks in EMEs.

3.5 Bank Efficiency, Risk-Taking and Capital Structure Interactions

Investigating the relationship between a bank's capital management and efficiency sheds light on the intricate balance between risk management and performance optimization. Berger and Humphrey (1992) examines cost efficiency's role in a bank's competitive standing and survival. They argue that banks with operational expenses surpassing those of their competitors are more susceptible to failure, especially highlighted in their study of U.S banks from the 1980s, which showed a clear risk of failure for cost-inefficient banks.

Central to Berger and Humphrey's conclusions are a few critical insights. First, they note that in a market characterized by significant leverage and tight profit margins, minor cost increases can significantly impact a bank's profitability. High operating costs may also indicate weak management control, potentially leading to an increase in non-performing loans. Moreover, the necessity to sustain or improve returns on equity may incentivize banks to undertake higher-risk activities, a scenario often associated with moral hazard.

Eisenbeis and Kwan (1996) extended these insights using a stochastic frontier approach to analyze cost efficiency among banks of different sizes. They discovered that smaller banks typically show less efficiency and more variability in performance, with inefficiencies linked to a higher rate of problem loans and stock return volatility. However, they stopped short of determining causality in this relationship.

Altunbas *et al.* (2007) explored the dynamics among efficiency, capital, risk, and moral hazards with banks. They identified capital and efficiency as crucial factors influencing a bank's propensity for risk and susceptibility to moral hazard. Given that capital is a costly resource, banks possessing greater capital are likely to pursue higher risk levels to optimize returns, thereby achieving higher efficiency.

4 Bank Efficiency Measurement

4.1 Basic of Microeconomics

Decision-makers are empowered to critically evaluate and respond to organizational performance when they possess the tools to quantitatively assess it. Consequently, this imperative has spurred sustained interest among academics and industry managers in methodologies conducive to the quantification of performance. A prominent approach within this domain is the appraisal of a firm's economic efficiency. Economic efficiency, from a microeconomic perspective, encompasses two principal dimensions: technical efficiency and allocative efficiency. A firm attains economic efficiency when it concurrently realizes optimal levels of both dimensions.

4.1.1 Technical efficiency

Koopmans (1951) defined a firm is technically efficient if it cannot produce more without additional inputs or reduce inputs without diminishing outputs. This criterion implies that a firm achieving technical efficiency is either maximizing its output from the available inputs or using the minimum inputs to produce a specific output. The production function $y = f(x)$ represents the currently available manufacturing technology when we assume the firm generates a single output. It shows that the highest output (y) that the firm is capable of producing using the put vector (x). Because the firm generates the highest output possible given the inputs, we consider a firm technically efficient. In a broader context where a firm produces multiple outputs, the term "production set" supersedes the use of a production function to accurately represent the firm's production technology. This shift acknowledges the complexity of producing various outputs and necessitates a more comprehensive framework for analysis.

Assuming that the firm generates the outputs $y = (y_1 \ldots\ldots\ldots y_N) \in R_+^M$ using the input vector $x_1 \ldots\ldots\ldots\ldots x_N \in R_+^N$. The production set, often known as the technology set, defines the production technology as follows:

$$T = \{(y, x) : \; x \; is \; able \; to \; generate \; y\}$$

The production set is the set of all feasible input and output combinations, distinguishing it from the production function, which specifies the maximum achievable output for a given set of inputs, under the assumption of a singular output scenario. In contrast, the concept of input and output sets serves to depict the technological capabilities of an industry more comprehensively. Specifically, an input set is characterized as the aggregation of all inputs (x) capable of producing a specified output (y), thereby offering a broader perspective on the potential input-output relations within a production system:

$$L(y) = \{x : (y, x) \in T\}$$

Likewise, the output set is defined as the collection of all possible output (y) that can be generated from input (x):

$$P(x) = \{y : (y, x) \in T\}$$

Number assumptions are frequently put on input and output sets in microeconomic theory. Coelli et al. (2005) stated that the input and output sets offer different perspectives on the same underlying technology. As a result, they are connected and comprise identical data.

Shephard (1970) created distance functions, which provide a functional form for describing industrial technology and enable the measurement of technical efficiency. As with input and output sets, there are two kinds of distance functions that we need to be aware of. Either input-oriented or output-oriented distance functions exist, depending on how the analysis is conducted. The output distance functions show the greatest radial expansion in all outputs that may be obtained by a company utilizing specific inputs (x) and a given technology. The distance function can be expressed equivalently as the maximum radial reduction in all inputs that is possible given a specific technology and output (Fried, Lovell and Schmidt, 2008). The defined input distance function is:

$$D_I(y, x) = max\{\lambda : \frac{x}{\lambda} \in L(y)\}$$

When stated differently, the input distance function shows that the maximum quantity of inputs can be reduced without affecting the output quantity. For instance, a reduction factor of 1.5 demonstrates that the firm is optimizing its input level. Based on the input set terms, it is evident that the lower bound of the input distance function is 1.

The technical efficiency from an input perspective can now be depicted as a value function $TE_I(y, x)$ which is the minimum value of θ such that θ_x is within the production possibility set $L(y)$, this implies that:

$$TE_I(y, x) = \frac{1}{D_I\,(y, x)}$$

The interval $\langle 0,1 \rangle$ contains the values for this measure, with 1 denoting the most efficient firm.

Conversely, the output distance function is denoted as:

$$D_O(y,x) \ = \ min\,\{\lambda : \frac{y}{\lambda} \ \in \ P(x)\ \}$$

The technical efficiency from an output perspective can now be depicted as a value function $TE_O(y,x)$ which is the maximum value $\emptyset$ such that the production of $\emptyset$ and y is the element of the set $P(x)$. This implies that the technical efficiency is the reciprocal of the output distance function, expressed as:

$$TE_O(y,x) = \frac{1}{D_O\,(y,x)}$$

In this case, the technical efficient firm's measurement equals 1, increasing with the inefficiency levels observed.

Debreu (1951) and Farrell (1957) proposed the concept of technical efficiency measures, which are characterized by a radial expansion of outputs or a decrease in inputs. Not all of these measurements align with Koopman's definition (Fried, Lovell and Schmidt, 2008). As long as the producer satisfies Koopman's definition of technically efficient in every scenario, he also meets the technical efficiency standards of Debreu (1951) and Farrel (1957), the opposite is not true, though. Although this would not meet Koopman's definition, there may be circumstances in which Debreu's and Farrel's measures designate the firm as technically efficient.

4.1.2 Cost Efficiency

Since a bank's cost efficiency is the main focus of this study, let's discuss a situation in which a producer seeks cost efficiency by attempting to minimize production costs. Cost efficiency is determined by comparing its costs to those of the best-performing bank under the same environmental conditions and producing the output (Hassan, 2005). When the non-negative vector of input prices $w \in \mathbb{R}_{+}^{M}$ is measurable, we can determine the minimum cost function as follows:

$$c(y,w) = {}^{min}_{\ x}\{w^T x \,:\, D_I(y,x) \ \geq 1\}.$$

According to the definition, the cost function specifies the lowest expenses that may be incurred by the company to create output y while dealing with prices w. To achieve these lowest costs, the firm must select the appropriate combination of inputs that corresponds to their cost. If the firm uses the input vector x to make output y, where expenses are minimized, its cost efficiency is expressed as:

$$CE(x, y, w) = \frac{C(y, w)}{w^T x} = \frac{w^T x *}{w^T x}$$

The measurement can be further divided into the measurement of allocative efficiency and technological efficiency($CE = AE_I * TE_I$). AE_I is the allocative efficiency measurement and TE_I is the indicator of input-oriented technical efficiency.

The following formats are also suitable for allocative and technical efficiencies:

$$AE_I = \frac{w^T x^*}{w^T \hat{x}}$$

$$TE_I = \frac{w^T \hat{x}}{w^T x^*}$$

where $\hat{x}$ is a technically efficient vector of inputs obtained by applying the maximum radial reduction that can be applied to the vector x without compromising the production of output y. Stated otherwise, the firm may be technically efficient while employing input $\hat{x}$, but when considering its prices, it may choose an inappropriate combination of these inputs, so unable to achieve allocative efficiency. By using the revenue and profit functions, the concepts of revenue and profit efficiency may be defined similarly when the producer aims to maximize its revenues or profit (Farrell, 1957; Färe, Grosskopf and Lovell, 1985; Coelli et al., 2005).

4.2 Estimation Methods

Prominent among non-parametric techniques in the evaluation of banking efficiency are Data Envelopment Analysis (DEA) and Free Disposal Hull (FDH). A notable drawback shared by these approaches is their lack of accommodation for stochastic discrepancies present in the data. Neither DEA nor FDH conforms to a rigid framework for establishing the optimal efficiency frontier, which some critiques have highlighted as a potential weakness. DEA, conceived by Charnes, Cooper and Rhodes (1978), was later scrutinized for how it formulates an empirical efficiency frontier using linear programming, which Coelli et al. (2005) described as a piecewise linear construct that connects observations indicative of the most effective operational practices.

DEA's methodological design does not directly capture the efficiency frontier, rather it infers it through the performance of "best practice" entities. On the other hand, FDH, which presents a variant of the DEA model, is distinct in that it abstains from enforcing a convexity constraint that is characteristic of DEA, thus offering a different perspective on efficiency by eliminating the need for predefining the functional form of the production possibility set.

Berger and Humphrey (1997) highlighted concerns with DEA and FDH regarding their oversight of measurement errors in efficiency assessments. They pointed out that these techniques do not take into account random variations that may temporarily influence a bank's operational performance. Additionally, such methods may neglect discrepancies stemming from diverse accounting practices, potentially skewing input and output data. As a result, any observed divergence from the established efficiency frontier is often too hastily ascribed to inefficiency. These oversights could lead to an under or overestimation of a unit's efficiency, particularly when anomalies appear in isolated data points.

Podpiera and Podpiera (2005) critiqued non-parametric methods for their tendency to disregard pricing information, focusing instead on the appraisal of technical efficiency. Further, Berger and Mester (1997) discussed the unsuitability of non-parametric approaches for evaluating allocative inefficiency, which arises from misaligned responses to input and output prices.

Stochastic methodologies stand as a distinguished group within the spectrum of efficiency estimation techniques. This group encompasses Stochastic Frontier Analysis (SFA), the Distribution-Free Approach (DFA), and the Thick Frontier Approach (TFA). SFA, operating within a well-defined functional framework, allows for the consideration of random errors alongside inefficiencies in efficiency estimation. According to Aigner, Lovell and Schmidt (1977), SFA operates on the premise that deviations from the efficiency frontier are composed of two parts: a symmetrically distributed random error and true inefficiencies which are treated as following an asymmetric distribution.

DFA, sharing some conceptual underpinnings with SFA, also establishes a functional form for the efficiency frontier. Its distinctive feature, as highlighted by Berger and Mester (1997), lies in its flexibility regarding the distribution of inefficiencies and random errors, allowing them to adopt nearly any forms, provided they remain non-negative. This approach is particularly advantageous for panel data analysis, as it assumes that inefficiencies are consistent over time and that the associated error components average out to zero.

The TFA also stipulates the functional form of the efficiency frontier but adopts a different approach by considering deviations only within the performance quartiles. As noted by Berger and Humphrey (1997), deviations outside these quartiles are attributed to random errors, whereas those within are deemed inefficiencies. TFA does not focus on individual efficiency scores rather, it evaluates overall efficiency within a defined cohort or population.

4.3 Data Envelopment Analysis (DEA)

4.3.1 Overview of DEA

DEA is a non-parametric technique for efficiency evaluation of Decision-Making Units (DMUs), often applied to banks. It uses linear programming to construct an efficiency frontier, benchmarking each DMU's performance (Charnes, Cooper and Rhodes, 1978). DEA's ability to handle multiple inputs and outputs makes it adaptable for different sectors (Coelli et al., 2005). For inefficient banks, DEA determines how inputs can be reduced and outputs increased to reach efficiency. DEA is particularly useful for studying efficiency in developing countries (Hassan and Mervyn, 2007) .

Despite its advantages, DEA has limitations, such as sensitivity to outliers and an inability to distinguish between noise and inefficiency. It assumes no measurement errors in the data and relies on the specific sample, limiting cross-sample comparisons. When the number of inputs and outputs is too large for the sample size, DEA's ability to discriminate between efficient and inefficient DMUs can be compromised (Hughes and Yaisawarng, 2004; Subramanyam and Reddy, 2008).

DEA scores, bounded between zero and one, measure a bank's performance relative to the efficiency frontier within the sample. A score of one indicates a bank is as efficient as the best in the sample, not necessarily the entire industry (Yudistira, 2004). Frontier construction requires total costs, input and output data for each bank, with linear programming used to compare each bank's performance against the frontier (Hassan, 2005).

4.3.2 Data requirement

To perform DEA, data on inputs and outputs for each bank within the sample are required. Inputs typically include resources like labor, capital, and operational expenses, while outputs could consist of total loan, number of transactions processed, and financial outputs like interest income. The choice of inputs and outputs should reflect the operational realities and objectives of the banks being analyzed. We will describe in more detail on selecting bank inputs and bank outputs in section 4.6.

4.3.3 DEA Model Specification

In our analysis, we focus on two fundamental DEA models to measure the efficiency of Cambodian commercial banks: the Charnes, Cooper, and Rhodes (CCR) model and the Banker, Charnes, and Cooper (BCC) model. The CCR model is built on the premise of Constant Returns to Scale (CRS) and is ideal for banks that are presumed to be operating at an optimal scale. This model is most appropriate when efficiency is to be assessed independently of the size of the bank (Charnes, Cooper and Rhodes, 1978). Conversely, the BCC model incorporates Variable Returns to Scale (VRS), making it particularly relevant for evaluating banks of various sizes by acknowledging that not all banks may experience constant scaling efficiencies (Banker, Charnes and Cooper, 1984).

In the light of the observations made by McAllister and McManus (1993), we have opted to apply the DEA model with VRS assumptions, which is more realistic for our dataset comprising banks of heterogeneous sizes. Under this assumption, the cost efficiency model is represented by the following optimization problem:

$$E_i = Min_{\lambda,x_m} w_i x_i^* \text{ subject to:}$$

$$\sum_{k=1}^{K} \lambda_j x_{jk} \leq x_i^*, j = \overline{1, N}$$

$$\sum_{k=1}^{K} \lambda_j y_{mj} \geq y_{mi}, j = \overline{1, N}$$

$$\sum_{j=1}^{K} \lambda_j = 1$$

$$\lambda_j \geq 0, \forall j$$

where k represents the banks numbered from 1,…..,k; λ denotes a vector of constants with dimensions K*1, x_i and y_j symbolize the input and output vectors, respectively; x_{ik} refers to the quantity of input that minimizes the cost for bank k at the specified price w_{ik} and for a given output amount y_{jk}. For bank k, the real cost represented as $w_{ik}x_{ik}$. To pinpoint the best value of x_{ik}^*, we solve linear programing problem number 1. Then, we figure out the Cost Efficiency (CE) of bank k by comparing the lowest possible cost to the actual cost using the following ratio:

$$CE_i = \frac{w_i x_i^*}{w_i x_i}$$

where $w_i x_i^*$ is the numerator represents the lowest possible cost for producing the given level of outputs using the optimal combination of inputs. The term w_i denotes the price or cost per unit of the inputs, and x_i^* is the optimal quantity of inputs that minimizes the total cost while still achieving the desired outputs. This optimal input combination is derived from solving the DEA model, where the goal is to reduce the input costs to the lowest feasible level given the output requirements. $w_i x_i$is the denominator representing the actual cost incurred by the bank. Similar to the numerator, w_i indicates the price per unit of inputs, and x_i is the actual number of inputs used by the bank. This value reflects the real-world expenditure of the bank to achieve its output levels.

DEA scores range from zero to one. If CE score is 1, it means that the bank's actual cost is equal to the lowest possible costs, indicating optimal cost efficiency. The bank is managing its resources as efficiently as the best performer in the sample, implying no unnecessary expenditure. However, if the CE score is less than 1, it signifies that the bank is spending more on inputs that the optimal level. The distance from 1 quantifies the proportion by which costs could be reduced to reach the efficiency frontier. For instance, a score of 0.8 suggests that the bank could potentially reduce its costs by 20 percent to achieve the efficiency of the best-performing bank.

4.4 Stochastic Frontier Analysis (SFA)

Stochastic Frontier Analysis (SFA) is a robust statistical method used to study the cost efficiency, particularly within the banking sector. This approach distinguishes itself by accounting for the randomness in data that might stem from external factors beyond the control of the banks, such as economic fluctuations or regulatory changes. By integrating a stochastic term alongside, a non-negative inefficiency term in the model, SFA allows for a deep analysis of cost efficiency, separating genuine inefficiency from random shocks.

SFA's capability to provide detailed insights into the efficiency of banks in managing their costs under varying conditions has made it a preferred tool in empirical banking research. It enables the identification of banks that operate close to the cost frontier representing the lowest possible costs for a given output level with certain inputs and technology, thereby highlighting areas for potential improvement in cost management practices (Aigner, Lovell and Schmidt, 1977b).

4.4.1 Cost Function Forms

Within the banking research, there is a notable preference for two principal forms namely the Translog form and the Fourier-Flexible form, the latter of which incorporates trigonometric components for enhanced descriptive power (Gallant, 1982; McAllister and McManus, 1993).

The Translog model, by its design as a second-order Taylor series expansion, is valued for its straightforwardness and empirical adaptability (Podpiera and Podpiera, 2005). Critics like McAllister and McManus (1993), however, have raised concerns that its effectiveness may be compromised use to its initial intent for local rather than expansive, global functional approximation.

Addressing such criticisms, an alternative has been suggested in the form of the Fourier-Flexible model. Its proponents argue for its superior data-encompassing ability, which has led to its rising adoption, especially when evidence suggests a more accurate representation of banking operations than that offered by the Translog model (Mitchell and Onvural, 1996; Berger and Humphrey, 1997b).

Despite this, not all researchers are convinced of the Fourier-Flexible model's supremacy. Altunbaş and Chakravarty (2001) propose that a model's conformity to data should not be the sole determinant of its utility, particularly in forecasting. Berger and Mester (1997) further discovered that switching from a Translog to a Flourier-Flexible model resulted in only a negligible improvement in economic significance, even though statistically the latter provided a better fit.

Furthermore, Berger and DeYoung (1997) observed that the incorporation of Fourier-Flexible terms often leads to exaggerated estimates of efficiency. Nevertheless, along with Berger and Mester (1997), they found that while the absolute efficiency estimates may vary between models, the relative efficiency rankings among banks remained consistent. This is supported by Iršová and Havránek (2010), who noted the insignificant contribution of Fourier-Flexible terms in cost functions within the context of Central European banks.

Drawing from these discourses, the suitability of a functional form is intricately tied to the research objectives at hand. Should a study necessitate an overall efficiency assessment, a Fourier-Flexible model is preferable due to its comprehensive scope (Berger and DeYoung, 1997). On the contrary, if the goal is to evaluate relative efficiency or to explore the effect of efficiency on other variables, the Translog model may be adequate due to its simplicity and lower data requirements (Iršová and Havránek, 2010b). Moreover, studies with extensive data sets might profit more from the Fourier-Flexible model, which can handle global approximations effectively, while smaller data sets may be better served by the less complex Translog function due to its lower parametric burden.

4.4.2 Stochastic Cost Function

When the costs of inputs are known, it is possible to calculate the cost efficiency using a stochastic cost function approach. With the assumption that banks are minimizing costs while utilizing N inputs to generate M outputs, we establish a cost function in a log-linear format as following:

$$lnTC_i \geq c(w_{1i}, w_{2i}, \ldots., w_{Ni}, y_{1i}, y_{2i}, \ldots., y_{Mi}) + \varepsilon_i$$

where TC_i denotes the total cost incurred by the i-th bank, w_{Ni} represents a set of prices for N inputs, and y_{Mi} is the set of M outputs produced. The cost function is denoted by c(.). The random error component ε_i consists of an inefficiency term (u_i), which is strictly non-negative and assumed to follow an independent and identically distributed (iid) normal distribution with zero and variance σ_u^2 and a random noise (v_i), also iid normally distributed with mean zero and variance σ_v^2. Moreover, v_i is presumed to be uncorrelated with the explanatory variables, and $u_i$is independent of v_i (Coelli et al., 2005; Fiorentino, Karmann and Koetter, 2006).

Fiorentino, Karmann and Koetter (2006), to estimate cost efficiency accurately, it is essential to define the appropriate functional form of the cost function. In this study, we use the transcendental logarithmic (translog) model, which is the predominant functional form in bank efficiency studies.

In this study, we operationalize the estimation of cost efficiency within the Cambodian commercial banking sector by employing a transcendental logarithmic (translog) cost function, a widely endorsed form in the field of banking efficiency research. This translog model, representative of the stochastic cost frontier, is given by the equation:

$$\begin{aligned} lnTC_{it} = \alpha_0 + \sum_j \alpha_j lny_j \\ + \sum_l \beta_l lnw_l + \frac{1}{2}\sum_j \sum_k \gamma_{jk} lny_j lny_k \\ + \frac{1}{2}\sum_l \sum_m \delta_{lm} lnw_l lnw_m + \sum_l \sum_j \rho_{lj} lnw_l lny_j + u_i + v_i \end{aligned}$$

where TC represents the total cost of i-th bank, $j, k, m = 1, \ldots, 3$ and $\alpha_0$is the intercept. We add the inefficiency term (u_i) because inefficiency causes the expenses to be greater than optimal cost. We estimate the efficiency scores for each bank in the sample using this translog function. The selection of specific input and output variables adheres to the intermediary technique and is in line with DEA.

In estimating the SFA scores, we acknowledge that the inefficiency effect (u_i) in the stochastic frontier model represents the discrepancy between observed and optimally minimal costs due to inefficiency, which invariably inflates the expenditure above the cost frontier. Conversely, v_i denotes the stochastic error term that accounts for random noise beyond the bank's control. Based on Battese and Coelli (1988), the method for calculating the cost efficiency score (CE_{it}) leverages the conditional distribution of the inefficiency term, given the combined error and is expressed by:

$$CE_{it} = E[\exp(-u_{it})\,|\varepsilon_{it}] = \left[\frac{1-\Phi(\sigma_* - \frac{\varepsilon_{it}\gamma}{\sigma_*})}{1-\Phi(-\frac{\varepsilon_{it}\gamma}{\sigma_*})}\right].exp\left\{-\varepsilon_{it}\gamma + \frac{1}{2}\sigma_*\right\}$$

where $\Phi(.)$ represents the standard cumulative distribution function. The calculations for $\sigma = \sqrt{\sigma_v^2 + \sigma_u^2}$, $\sigma_* = \sigma_v^2\sigma_u^2/\sigma^2$; and $\gamma = \sigma_u^2/\sigma^2$ with its value ranking from 0 to 1. A γ value of one suggests that deviations from the efficiency frontier are entirely due to cost inefficiency (u_{it}), whereas a γ of zero implies that such deviations are fully attributable to statistical noise (v_{it}). The inefficiency is considered valid for range of $[1, \infty)$ and achieves a value of one when the bank operates at peak efficiency.

A score of 1 $(CE_{it}) = 1$ implies that the bank is operating at the frontier of cost efficiency, indicating no discernible in efficiency. Scores less than 1 denote cost inefficiency, with the distance from 1 quantifying the potential reduction in costs that could be realized if the bank operated at the frontier. Thus, higher efficiency scores are indicative of better performance, where a bank's costs are closely aligned with the best practice frontier established by the translog cost function.

4.5 Comparative Analyses of DEA and SFA

The assessment of bank performance has been a significant topic in the financial services literature, with numerous studies employing both parametric and non-parametric methods to measure efficiency. The emergence of comparative studies in the 1990s initiated a critical examination of the reliability between DEA and SFA when applied to identical datasets.

Ferrier and Lovell (1990) developed this comparative approach by examining the cost efficiency of a sample of U.S banks. They found that while DEA and SFA provided a consensus on the average levels of cost efficiency, the individual efficiency rankings derived from each method did not correspond closely. This suggest that while the methods may agree broadly, details in their methodological frameworks lead to significantly different outcomes when applied to individual entities. This finding demonstrates a notable lack of strong linear correlation between DEA and SFA efficiency scores, implicating a discrepancy in individual performance assessment.

Bauer *et al.* (1998) extended this analysis, employing various frontier techniques to explore the consistency in banking efficiency of 683 U.S banks from 1977 to 1988. Their results showed higher efficiency scores for parametric methods over non-parametric methods, with a relatively low correlations (10%) between DEA and parametric scores. This divergence is indicative of the inherent differences between the analytical approaches, highlighting the need for a careful selection of the method based on the study's objective.

Drake and Weyman-Jones (1996), in their examination of British building societies, and Weill (2004), in his analysis of banks across five European countries, both concluded that DEA and SFA tend to agree on the average efficiency scores. However, both studies also reported a poor correlation in rankings, underlining the importance of recognizing that the agreement on aggregate levels does not necessarily extend to the micro-level assessment of individual institutions.

The work of Delis *et al.* (2009), studying 28 Greek banks, revealed that the individual results can be influenced by factors such as the size of the institution. Their research noted a positive size-efficiency correlation and reported conflicting results concerning the influence of ownership status on efficiency between the two methods.

These studies collectively indicate that while DEA and SFA are both valid and frequently utilized methods for efficiency measurement, their application can yield divergent results, particularly when ranking individual institutions. This is significant in practical terms, as the selection of an efficiency measurement approach can have implications for policy-making and strategic decisions within the banking sector.

4.6 Specifying Bank Inputs and Outputs

This section provides describes about the four main techniques most frequently used in bank efficiency studies to identify both input and output elements for banks. Those four main techniques include the intermediation, production, user cost, and value-added approaches.

4.6.1 Intermediation Approach

Sealey and Lindley (1977) recognized intermediation approach, evaluates banks' efficiency by simulating them as profit-maximizing firms, focusing on the transformation of inputs into valuable outputs. Inputs are transformed into outputs in the banking process by channeling funds from surplus entities to deficit ones, aiming to produce outputs with higher market value (Frisch, 1964).

In practice, the approach measures inputs and outputs in monetary terms rather than account quantities. The monetary value of intermediated funds is more significant than the number of accounts (Benston, Hanweck and Humphrey, 1982; Kolari, 1987). Berger and Humphrey (1997) recommended the intermediation approach for its robustness in institutional performance evaluation.

However, this approach has limitations. It overlooks the role of deposit services in the output process and their operational costs as well as the distinctive functions of banks in the national payment system and the economy's money supply expansion (Berger and Humphrey, 1992). Moreover, it generally neglects non-interest activities and risk management, thus focusing narrowly on deposit issuance and loan provision while ignoring the comprehensive role of banks as risk managers and liquidity insurers (Allen and Santomero, 2001).

4.6.2 Production Approach

Benston (1965) was the first to propose a production approach, it is grounded in an operational perspective, focusing on the banking services. Originating from a cost study by the First Federal Reserve District, this approach sees banks as entities seeking to minimize operational expenses through efficient transaction processing and service provision. It considers inputs such as labor, infrastructure, and technology that contribute to operational costs, excluding interest expenses. Outputs are defined by the financial services that incur operational costs, including various types of deposits and loans. This method emphasizes operational procedures rather than financial intermediation.

Most of the bank’s operational costs come from the processing of loan and deposit documents and transactions. The intermediation approach distinguishes itself by assessing the monetary values of loans and deposits, while the production strategy focuses on the quantity of processed documents or transactions. Although the monetary value of documents can influence operational costs, it is not the sole factor. Moreover, relying solely on financial value measurements might lead to a misleading representation of operational efficiency, particularly if a bank processes a large number of accounts with relatively lower costs per monetary unit (Benston, 1972; Humphrey, 1985).

When deposits are considered part of the output, it emphasizes their importance in banking. Deposit services, including security and liquidity, are valued by customers who pay through interest spreads. Deposits also require significant labor and physical resources (Benston, 1965; Bell and Murphy, 1968; Longbrake, 1974). Baltensperger (1980) supports this view, highlighting the importance of tangible inputs like labor in banking. Financial contracts, transactions, and risk management demand substantial resources, especially in labor-intensive industries like banking. This approach is favored for evaluating bank branch efficiency as it focuses on operational costs

4.6.3 User Cost Approach

Hancock (1985, 1986, 1991) developed the user cost approach, which offers a framework for analyzing bank financial service production by treating financial assets and liabilities as inventory managed over time. This model calculates user costs as the net cost of maintaining a unit of currency for a period, facilitating the analysis of bank operations across time intervals.

Christensen and Jorgenson (1970); Diewert (1980); Fixler and Zieschang (1992) have refined this approach, which views banks as entities aiming to optimize their economic returns through the management of user costs. At its core, the approach assesses opportunity costs associated with holding financial assets or liabilities, considering factors like interest rates, reserve requirements, and deposit insurance premiums.

Hancock (1991) distinguishes between financial products that are inputs (with positive user costs) and outputs (with negative user costs) based on their economic roles, providing a clear framework for measuring banking efficiency. However, the complexity of calculating user costs and the need for detailed financial data make the approach challenging and sensitive to data fluctuations (Berger and Humphrey, 1992).

4.6.4 Value-Added Approach

The value-added approach was developed by Berger, Hanweck and Humphrey (1987) and further elaborated by Berger and Humphrey (1992), offers a method for assessing banking efficiency by recognizing the economic value generated by various banking activities. Unlike traditional models that strictly classify bank products as inputs or outputs, this approach considers all assets and liabilities as contributing to a bank's output to different extents. It emphasizes enhancing economic value to maintain competitive advantage, focusing on the role of operational expenses in evaluating banking activities' value addition. This methodology assesses the significance of different types of deposits and loans, prioritizing those with higher value-added contributions while viewing non-loan investments as less critical.

Grigorian and Manole (2002) highlighted its effectiveness in analyzing banking operations by utilizing readily available accounting data, although it lacks a clear framework for distinguishing between inputs and outputs, replicating Porter's (1985) the value chain concept in its inclusive view of organizational activities.

5 Empirical Analysis

The empirical analysis in this chapter is split into two segments. The first segment focuses on the estimation of the cost efficiency of Cambodian commercial banks by using DEA and SFA. Subsequently, the second segment focuses on the relationship between cost efficiency, risk-taking, and capital position in Cambodian commercial banks.

5.1 Cost Efficiency Estimation

5.1.1 Data and Variables

In this section, we evaluate the cost efficiency of commercial banks in Cambodia using DEA and SFA. Our analysis employs quarterly panel data extracted from the balance sheets and income statements of Cambodian commercial banks for the period from 2012 to 2022. This dataset was officially obtained upon request from the NBC. Due to the dynamic nature of the banking industry, where certain banks commenced operations post-analysis period and few banks consolidated through mergers within the study timeframe, we carefully selected our sample to minimize estimation bias and the influence of outliers. Our study includes only those commercial banks that have complete data available for the entire duration of the study period. This criterion ensured the integrity and comparability of our analysis. As a result, our final dataset comprises data from thirty commercial banks across forty-four quarters, resulting in a total of 1,320 observations. The total assets of these thirty commercial banks amount to 207,494,817.70 million KHR, which represents 76.85 percent of the total assets held by the commercial banks in Cambodia.

In measuring bank cost efficiency, we define three input and output categories by the literature review in section 4.5. The three input elements are fixed assets (x_1) expressed as total fixed assets, labor (x_2) expressed as personnel expense and capital (x_3) expressed as total sources of funds. Each bank's input prices (w_n) are calculated as follows: price of capital (w_1) equals depreciation divided by total fixed assets, price of funding (w_2) equals interest expense divided by total sources of funds, and price of labor (w_3) equals personnel expense divided by total assets. For the outputs, we design the total loans (y_1), total deposits (y_2) , and interest income (y_3).

Table 5.1: Variables used in DEA and SFA models

	Variables	Descriptions (In Million KHR)
Dependent Variable		
TC	Total Cost	Interest Expenses + Operating Expenses + Provision Expenses
Inputs		
x_1	Fixed Assets	Total Fixed Assets
x_2	Labor	Personnel Expenses
x_3	Capital	Total Sources of Funds (Locally Collected)
Outputs		
y_1	Total Loans	Total Loan (to advance customer)
y_2	Total Deposits	Total Deposits
y_3	Interest Income	Total Interest Income
Input Prices		
w_1	Price of Capital	Depreciation divided by total fixed assets
w_2	Price of Labor	Personnel expense divided by total asset
w_3	Price of Funding	Interest Expense divided by total source of funding.

Table 5.2: Descriptive Statistics of Variables used in DEA

Variables	Obs.	Mean	Median	St.Dev	Min	Max
Fixed Assets (x_1)	1320	41,084.10	9,843.69	84,346.78	5.68	710,657.04
Labor (x_2)	1320	23,931.10	6,991.18	58,763.16	121.49	630,851.34
Capital (x_3)	1320	2,623,874.06	948,823.99	4,810,731.89	935.70	57,173,629.89

Total Loans (y_1)	1320	2,190,973.48	1,072,405.16	3,684,709.36	0.00	26,780,302.17
Total Deposits (y_2)	1320	2,319,312.54	767,681.68	4,212,087.14	935.70	29,687,496.02
Interest Income (y_3)	1320	128,836.35	39,747.28	264,757.98	2.11	2,493,054.81
Price of Capital (w_1)	1320	0.25	0.12	1.08	0.00	36.16
Price of Labor (w_2)	1320	0.01	0.00	0.00	0.00	0.03
Price of Funding (w_3)	1320	0.02	0.01	0.11	0.00	2.40

Table 5.3: Descriptive Statistics of Variables used in SFA

Variables	Obs.	Mean	Median	St.Dev	Min	Max
Total Cost (TC)	1320	102,900.6	34,941.97	208,222	410.6448	2,228,025
Total Loans (y_1)	1320	2,190,973	1,072,405	3,684,709	0	26,780,302
Total Deposits (y_2)	1320	2,319,313	767,681.7	4,212,087	935.70	29,687,496
Interest Income (y_3)	1320	128,836.4	39,747.28	264,758	2.10	2,493,055
Price of Capital (w_1)	1320	0.25	0.12	1.07	0	36.16
Price of Labor (w_2)	1320	0.006	0.004	0.004	0.0002	0.03
Price of Funding (w_3)	1320	0.02	0.01	0.10	0.0000007	2.40

5.1.2 Cost Efficiency Estimation in DEA

Cost efficiency is about bank's efforts to minimize the costs of inputs while achieving a specific output level. When banks modify their production processes, they need to consider the costs of inputs to reduce expresses effectively. Thus, cost efficiency is determined by assessing both the input-oriented technical efficiency and the efficiency in allocating costs for inputs (Nguyen and Pham, 2020).

We used R to calculate the cost efficiency of Cambodian commercial banks using the DEA. To accurately measure cost efficiency, it is essential to identify the inputs and their associated costs, along with the outputs, which is specified in the Table 5.2.

In Table 5.4 presents the average efficiency scores of Cambodian commercial banks as computed via DEA spanning the period from 2012 to 2022. These results represent aggregate averages derived from quarterly data, reflecting the cost efficiency of the banks within the Cambodian sector for each respective year.

The efficiency scores are quantitative expressions ranging from 0 to 1. A score of 1 denotes a bank's operation on the efficiency frontier, indicating that it is performing at maximum potential efficiency given the inputs. Conversely, scores less than 1 point to inefficiencies, where a bank's operational performance needs to improve their performance relative to the most efficient bank.

An upward trend in efficiency scores is observable over the decade, indicating a general improvement in the operational performance of these banks. The year 2012 starts with an efficiency score of 0.694, implying that on average, banks could potentially improve their operational efficiency by approximately 30.6 percent to reach the efficiency frontier. An upward trajectory is observed in subsequent years, with scores increasing to 0.719 in 2013 and continuing to ascend steadily to 0.856 by 2021. The consistent score of 0.856 in both 2021 and 2022 indicates a stabilization at a higher efficiency level. On average, banks have sustained improvements and are operating closer to their full efficiency potential.

Table 5.4: Cambodian Annual Average Commercial Bank Efficiency Score in DEA from 2012-2022

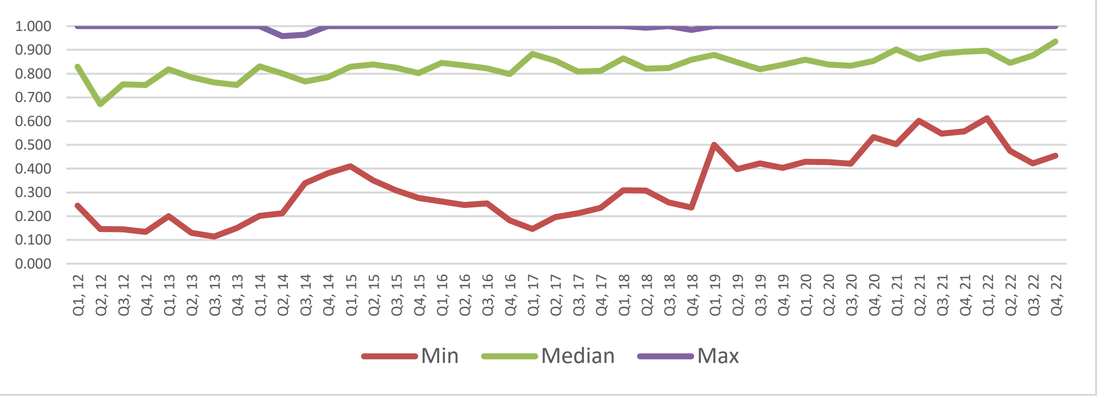
Year	Average
2012	0.694
2013	0.719
2014	0.730
2015	0.778
2016	0.776
2017	0.791
2018	0.788
2019	0.810
2020	0.823
2021	0.856
2022	0.856

Source: Author's Calculation

Based on Figure 5.1, it appears to display stability in the median DEA cost efficiency scores for Cambodian commercial banks, suggesting that from 2012 to 2022, the central tendency of bank efficiency does not exhibit dramatic changes. The stability of the median might indicate that despite variations among individual banks, the overall banking sector's efficiency is relatively steady.

The minimum efficiency scores show more volatility, which could imply that some banks may have struggled with certain operational inefficiencies or that the sector might have seen new entrants who took time to reach the efficiency levels of established banks. These fluctuations could be reflective of diverse strategies, management effectiveness, or perhaps external economic impacts that affect banks differently. The maximum efficiency scores are consistently high, pointing towards a presence of top-performing banks that set the benchmark for efficiency within the sector. Their performance may drive competitive pressures and sector-wide advancements in operational practices.

Figure 5.1: Trend of DEA Cost Efficiency for Cambodian Commercial Banks (Min, Median, Max), Quarterly Data 2012-2022



Source: Author's Calculation

5.1.3 Cost Efficiency Estimation in SFA

Unlike the DEA, estimating bank cost efficiency in SFA does not require the quantity of inputs. We use total costs as the dependent variable and outputs and the price of inputs as the independent variables as mentioned in the Table 5.3. To make it comparable to DEA, we also employed a panel dataset to estimate bank cost efficiency in SFA. The analysis was conducted in R, which utilized Maximum Likelihood Estimator (MLE) to calculate the efficiency scores (Coelli, 1996).

In the Table 5.5, show the annual average efficiency scores for Cambodian Commercial banks from 2012 to 2022. These efficiency scores are calculated using SFA and are derived from quarterly data, offering a yearly snapshot of the bank's operational performance. The scores indicate how closely each bank approaches optimal efficiency, with the figures representing an aggregation of the quarterly scores into an annual average. The results indicates that the performance of Cambodia banks has fluctuated over the years, reflecting a dynamic interplay of factors influencing bank performance. For example, the average efficiency score in the year 2012 was 0.700 indicating that, on average, banks could potentially improve their efficiency by 30 percent. Observing the trends, there appears to be a peak in efficiency in 2013 with a score of 0.764, whereas a relative trough is observed in 2018 with a score of 0.643. Such patterns underscore the temporal shifts in operational efficiency and may hint at underlying economic, regulatory, and institutional changes impacting the banking industry over the assessed period.

Table 5.5: Cambodian Annual Average Commercial Bank Efficiency Score in SFA from 2012-2022

Year	Average
2012	0.700
2013	0.764
2014	0.741
2015	0.762
2016	0.768
2017	0.727
2018	0.643
2019	0.759
2020	0.697
2021	0.698
2022	0.649

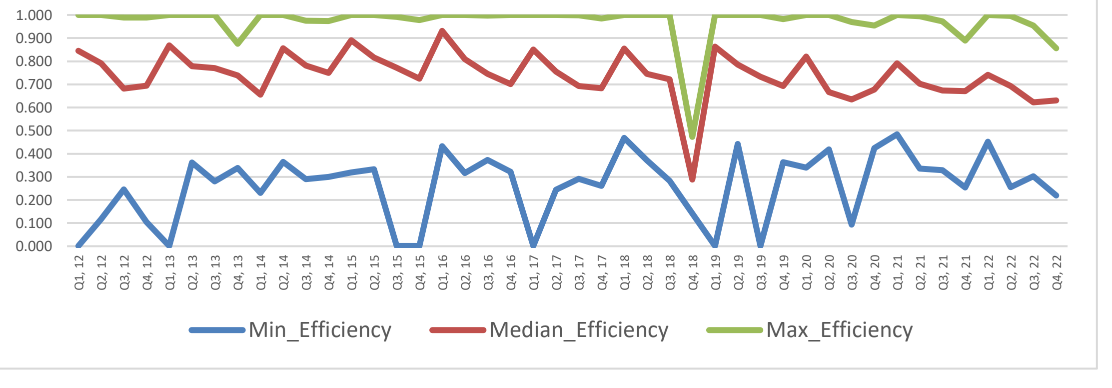
Source: Author's Calculation

Figure 5.2 illustrates the trend of cost efficiency calculated through SFA for Cambodian commercial banks, using quarterly data from 2012 to 2022. The figure shows three statistical measures of efficiency such as the minimum, median, and maximum efficiency scores observed each quarter within the specified time frame.

The graph indicates a relative constancy in the median efficiency level, suggestive of a sustained typical performance across the banks throughout the period. This measurement offers insight into the central tendency of the sector's cost efficiency, largely underpinned by outliers. Contrastingly, the minimum efficiency scores demonstrate considerable variability, with discernible dips and peaks. Such fluctuation could reflect either the operational inconsistencies of certain banks or broader sectoral shifts impacting the least efficient banks more acutely. The maximum efficiency scores maintain a position close to the optimal efficiency score of one, indicating that the best-performing banks consistently operate near the efficiency frontier. The peaks in maximum efficiency scores suggest period where top-performing banks may have achieved notable operational milestones or benefited from favorable market conditions.

There is a notable drop of median and maximum score in the fourth quarter of 2018, where efficiency sharply declines before quickly rebounding to previous levels. Such a dip might be influenced by various strategic decisions that might not immediately result in high efficiency but are expected to enhance the bank's stability and performance in the long run. For example, in November 2018, the global credit rating firm Standard & Poor's updated the economic risk outlook in its Banking Industry Country Risk Assessment (BICRA) for Cambodia from "negative" to "stable." Nonetheless, the firm cautioned that the banking sector still presents a "high risk" profile, attributed to rapid expansion in lending (Admin, 2019). In this regard, the banks might have adjusted their operations to prepare for more sustainable growth, which could affect their cost efficiency. Towards the end of the observed period, there is a slight downward trend, showing a decrease in efficiency in the recent quarter. This downturn could be linked to the global disruptions caused by the COVID-19 pandemic, which has impacted financial institutions worldwide through economic contractions, shifts in consumer behavior, and the increased need for loan provisions due to economic uncertainty.

Figure 5.2: Trend of SFA Cost Efficiency for Cambodian Commercial Banks (Min, Median, Max), Quarterly Data 2012-2022



Source: Author’s Calculation

5.1.4 Comparing results from DEA and SFA

While there are relative few studies that contrast the outcomes of DEA and SFA, the findings among these studies do not always align. For instance, the efficiency scores derived from DEA and SFA are closely aligned in the research by Wadud and White (2000) and Weill (2004). However, this consistency does not extend to the findings of Fiorentino, Karmann and Koetter (2006) and Delis *et al.* (2009), where the efficiency scores diverge significantly between the two methodologies.

Table 5.6 shows several key differences emerge when examining the cost efficiency scores calculated through DEA and SFA from 2012 to 2022. DEA results indicate a mean efficiency score of 0.783, whereas SFA results exhibit a slightly lower mean of 0.7183. The minimum efficiency scores reported by DEA and SFA are 0.113 and 0.001, respectively, suggesting that the SFA approach identifies a broader range of inefficiency among the evaluated banks. The maximum efficiency score for both DEA and SFA is 1. This denotes that, according to both methodologies, there are entities that are deemed to be operating at peak efficiency, thus serving as benchmarks within the respective analyses.

Skewness in the DEA scores is -0.926, which reveals a leftward asymmetry in the distribution and indicates a predominance of entities with higher efficiency scores. The SFA scores also exhibit leftward skewness at -0.698, albeit to a lesser extent than DEA. This means that according to SFA, not as many banks are grouped at the higher efficiency levels compared to what DEA shows. In terms of kurtosis, the DEA scores have value of 0.169, reflecting a flatter distribution that the normal curve, which implies fewer outliers. In contrast, the SFA scores have a kurtosis of 0.687, indicating a more peaked distribution that is more sharply pointed around the mean with fatter tails, implying a greater likelihood of observing extreme values.

The analysis reveals distinct distributional features of cost efficiency scores when employing the two methodologies. Such variations could stem from the unique underlying assumptions inherent to each method (Weill, 2004). Nevertheless, these discrepancies should not be overly concerning when choosing a preferred technique.

Table 5.6: Descriptive Statistics of Cost Efficiency based on the DEA and SFA

	DEA	SFA
Mean	0.783	0.718
Min	0.113	0.001
Max	1	1
Skewness	-0.926	-0.698
Kurtosis	0.169	0.687

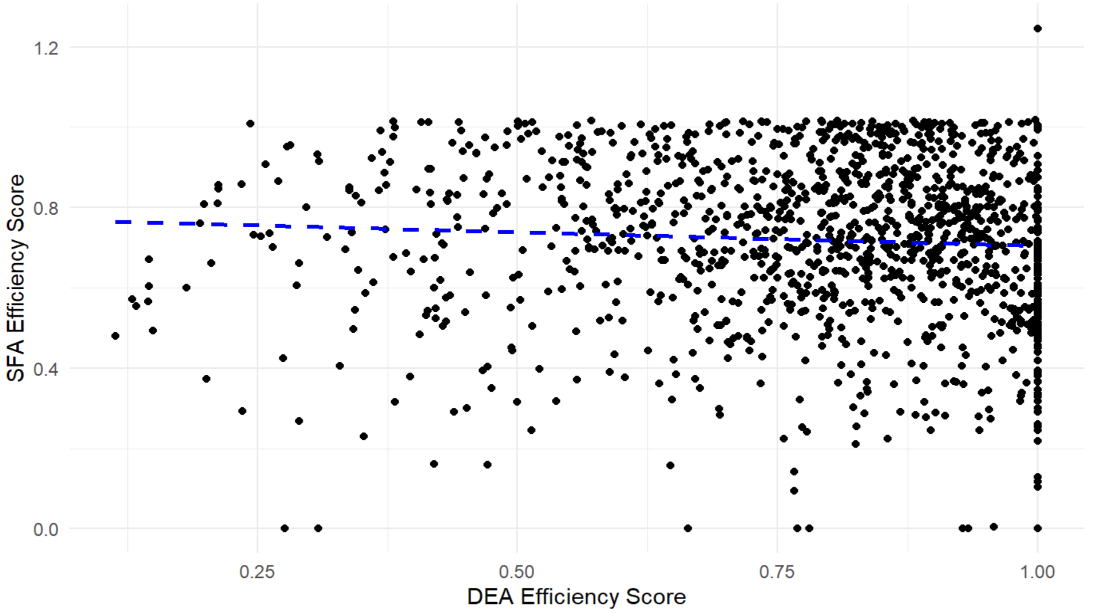
Source: Author’s Calculation

In Figure 5.3, the scatterplot shows the relationship between the DEA efficiency scores and the SFA efficiency scores for Cambodian commercial banks. Each point represents a bank, with its DEA score determining its position along the horizontal axis and its SFA scores determining its position along the vertical axis. The result illustrates a positive correlation, as higher efficiency scores obtained through DEA are generally mirrored by commensurate scores in SFA, and conversely for lower scores. This correlative trend suggests that both methods yield a consensus on the relative efficiency standings of the banks, affirming their utility in performance assessment.

Despite the general agreement between the two methods, the scatterplot also reveals some differences in how individual banks are rated by DEA and SFA. This is evident from the distribution of points relative to the blue dashed line which signifies the linear regression fit to the data. Certain banks exhibit a disparity in their DEA and SFA scores, with some achieving higher efficiency ratings under one method over the other. Such variances may stem from the distinct analytical frameworks and computational assumptions underpinning each method. The plot further indicates a clustering of data points in specific regions, denoting a higher density of banks whose DEA and SFA scores are closely aligned. For example, a concentration of points near the coordinate (0.8, 0.8) would indicate a substantial number of banks consistently rated with efficiency scores around 0.8 across both methods, potentially reflecting a sector-wide operational norm.

Moreover, outlier observations are discernible as points that diverge significantly from the main concentration of data. The presence of these outliers suggests that certain bank's efficiency levels are appraised quite differently by the DEA and SFA approaches. Such discrepancies could be attributed to unique operational characteristics of the individual banks, or to the inherent methodological differences between DEA and SFA, including how each method accommodates variations in operational scale, technology, and external influences.

Figure 5.3: Scatterplot of DEA and SFA Efficiency Scores



Source: Author own's calculation based on R

5.2 Determinants of Bank Cost Efficiency in Cambodia

5.2.1 Data and Models

This section examines the determinants of bank cost efficiency in Cambodian commercial banks. We used balanced panel data spanning from 2012 to 2022, which was collected on a quarterly basis. The dataset, obtained from the NBC, comprises comprehensive records from thirty commercial banks across forty-four quarters, resulting in a total of 1,320 observations. The selection criteria ensured inclusion only of banks that had complete data available throughout the study period to mitigate estimation biases and the influence of outliers.

The analysis was conducted using panel data techniques to capitalize on the data structure and enhance the robustness of the findings. Both fixed effects and random effects models were estimated using the plm package in R, depending on the outcome of the Hausman specification test. The Fixed Effects (FE) model was applied to control for unobserved heterogeneity by assuming time-invariant characteristics that differ across banks but are constant over time, while the Random Effects (RE) model was utilized where the Hausman tests indicated that the unique errors were uncorrelated with the regressors across all banks and time periods.

We conducted a Hausman test to compare FE and RE models. The result shows that the model with the dependent variables "CE_DEA" and "CE_SFA" favored the

FE model with a p-value of 1.976e-05 and 7.404e-05 (lower than significant level p-value = 0.05) respectively. Since we already calculated the cost efficiency score from both DEA and SFA, now the panel data based on the FE estimator has the following form:

$$CE\_DEA_{it} = \beta_1 RISK_{it} + \beta_2 CAP_{it} + \beta_3 ln\_SIZE_{it} + \beta_4 NIM_{it} + \beta_5 rGDP_{it} + \beta_6 INF_{it} + u_{it} \quad (1)$$

$$CE\_SFA_{it} = \beta_1 RISK_{it} + \beta_2 CAP_{it} + \beta_3 ln\_SIZE_{it} + \beta_4 NIM_{it} + \beta_5 rGDP_{it} + \beta_6 INF_{it} + u_{it} \quad (2)$$

5.2.2 Variables Description

In this section outlines the variables used in the regression analysis. The dependent variables in this analysis were cost efficiency scores derived from DEA (CE_DEA) and SFA (CE_SFA). The independent variables included bank-specific risk levels (RISK), capital adequacy ratio (CAP), size of the bank (SIZE), and net interest margin (NIM). Additionally, we considered macroeconomic indicators such as real GDP growth (rGDP) and inflation rate (INF), which were expected to influence the bank's efficiency. A concise description of these variables is provided in the Table 5.7 below.

Table 5.7: Description of Independent Variables

Variables	Description	Expected sign
Cost Efficiency (CE_DEA_{it})	Cost Efficiency Score that calculated from DEA	
Cost Efficiency (CE_SFA_{it})	Cost Efficiency Score that calculated from SFA	
Credit RISK ($RISK_{it}$)	Non-Performing Loan Ratio, measured by total of non-performing loan divided by total loan	(-)
Capital Adequacy Ratio (CAP_{it})	Capital Adequacy Ratio, measured by Tier 1+Tier 2 divided by Risk Weighted Assets	(+/-)

SIZE (ln_SIZE_{it})	Natural Logarithm of Total Assets in million KHR	(+)
NIM (NIM_{it})	Net Interest Margin, measured by interest income minus interest expense divided by total assets	(+/-)
Real GDP ($rGDP_{it}$)	Real GDP growth rate	(+/-)
Inflation rate (INF_{it})	Inflation rate, measured by Consumer Price Index (CPI)	(+)

***Note: Wooldridge (2013) advised to convert variables with a broad span of values into their natural logarithmic form like total assets, total equities. This transformation can reduce the likelihood of distortions within the regression. Taking the logarithm typically compresses the variability, which in turn diminishes the influence of outliers. This process also helps to stabilize variance and to transform data distributions that are skewed into more normally distributed forms.

- CE_DEA_{it} *and* CE_SFA_{it} : are the dependent variables. The efficiency scores are ranking from 0 to 1, where bank with efficiency score 1 represent the most efficient bank.

- $RISK_{it}$: Eisenbeis and Kwan (1996); Berger and DeYoung (1997) and Berger and Mester (1997) suggest that credit risk is a substantial part of the risk faced by commercial banks, directly tied to their core banking activities. Given that credit risk from loan portfolios constitutes a significant chunk of risk for commercial banks, we opted to use amount of non-performing to signify the bank's asset risk (Altunbas *et al.*, 2007). Therefore, in our study, bank risk is quantified by Non-Performing Ratio.

- CAP_{it} : is measured by Capital Adequacy Ratio (CAR). CAR known as the total capital to risk weighted assets ratio. It represents the bank's overall capital indicator. This ratio determines a bank's capacity to meet short-term commitments as well as various hazards, including credit operating and market risk. Additionally, it determines the capital utilized to support the bank's riskier assets (Al-Hares and Saleem, 2017). Hafez and El-Ansary (2015) stated that the formula is used to calculate CAR: Core Capital (Tier 1) + Supplement Capital (Tier 2) / Risk Weighted Assets (RWA) * 100.

- ln_SIZE_{it} : bank size is measured by natural logarithm of total assets. It is hypothesized that there is a positive relationship between the size of a bank and its cost efficiency, which suggest that larger banks may benefit from economies of scale and therefore operate more efficiently (Halkos and Salamouris, 2004; Hassan, 2005). However, this view is not universal, there is certain studies point out that the relationship between cost efficiency and bank size is negative, where increase in bank size could potentially lead to decreases in efficiency (Rahman and Rosman, 2013).

- NIM_{it}: is measured by the interest income minus interest expense divided by total assets. Estrada, Gómez-González and Orozco-Hinojosa (2006) highlights the opposite direction between bank efficiency and Net Interest Margin (NIM). Bank that are less efficient tend to have higher NIM because these banks often offset their higher operating costs by charging more for loans.

- $rGDP_{it}$: is the real GDP growth rate. This variable is commonly used for control macroeconomic factors (Salas and Saurina, 2003).

- INF_{it} : is measured by Consumer Price Index (CPI). Similar to real GDP, this variable is popular used for control macroeconomic factor (Girardone, Molyneux and Gardener, 2004; Semih Yildirim and Philippatos, 2007).

Table 5.8 shows the descriptive statistics of independent variables used in this analysis for 30 Cambodian commercial banks from 2012 to 2022. The variables include ln_SIZE, which are expressed in million KHR, alongside RISK, CAP, NIM, rGDP and INF, which are reported as ratios. The table consists the number of observations, the mean, standard deviation, minimum and maximum values for each variable.

Table 5.8: Descriptive Statistics of Independent Variables

Variable	N	Mean	St.Deviation	Min	Max
CE_DEA	1,320	0.784	0.188	0.114	1
CE_SFA	1,320	0.719	0.200	0.001	1
RISK	1,320	0.027	0.037	0.000	0.569
CAP	1,320	0.392	0.468	0.135	11.070
SIZE	1,320	3,667,001	5,749,858	149,501.700	37,052,231
NIM	1,320	0.020	0.019	-0.001	0.407
rGDP	1,320	0.004	0.067	-0.434	0.071
INF	1,320	2.967	1.488	0.699	7.809

Source: Author's Combination based on R

In order to test the correlation between correlation between dependent and independent variables, we use Spearman rank correlation. Spearman's rank correlation is a nonparametric test, intended to measure the monotonic relationship between two variables (Spearman, 1904). There is no statistical distribution of variables assumed in the test. The formula calculated for value of two variables X and Y in Spearman's correlation has the following form:

$$\rho_{spearman} = 1 - \frac{6\sum_i (x_i - y_i)^2}{n(n^2 - 1)}$$

where x_i and y_i are the sample's ranks for the values Y_i and X_i. These two variable independences are the test's null hypothesis.

In the Table 5.9 provides the Spearman rank correlation coefficients among dependent and independent variables. The results shows that the cost efficiency score derived from DEA and SFA, reveal a negative correlation between the two methodologies, with a coefficient of -0.13. This suggests that banks ranked as more efficient under DEA are not consistently ranked the same under SFA. The risk of the banks (RISK), exhibits a very slight negative correlation with both CE_DEA and CE_SFA. It is indicating that higher efficiency scores do not strongly correlate with lower bank risk. Bank capital (CAP) shows a moderately strong negative correlation with CE_DEA at -0.4, pointing towards a potentially inverse relationship where banks with higher capital might not be the most efficient as per DEA. Its correlation with CE_SFA is near negligible. Bank size (SIZE) displays a notable positive correlation of 0.6 with CE_DEA, suggesting that larger banks tend to have higher efficiency scores in DEA.

However, SIZE is negatively correlated with CE_SFA, which may imply that SFA does not consistently associate larger size with higher efficiency. NIM has a negligible correlation with both DEA and SFA scores, RISK, and CAP. The marginal positive correlation between NIM and SIZE suggests that larger banks might have a slightly higher net interest margin, although its relationship is not substantial. Moreover, NIM also has the weak relationship with rGDP and INF.

The real GDP growth (rGDP), show a negligible correlation with both CE_DEA and CE_SFA, indicating that the broader economic growth context may not have a direct association with bank efficiency as measured by these methods. Last but not least, the inflation rate (INF) has a weak positive correlation with CE_DEA and a negligible one with CE_SFA, hinting that inflation has little to no impact on the efficiency scores of banks in Cambodia as determined by DEA and SFA.

Table 5.9: Correlation of independent variables using Spearman

Variables	CE_DEA	CE_SFA	RISK	CAP	SIZE	NIM	rGDP	INF
CE_DEA	1							
CE_SFA	-0.13	1						
RISK	-0.06	-0.15	1					
CAP	-0.40	0.07	-0.04	1				
SIZE	0.60	-0.13	0.06	-0.76	1			
NIM	-0.04	-0.01	0.04	-0.12	0.09	1		
rGDP	-0.06	0.07	-0.02	-0.01	-0.07	0.02	1	
INF	0.03	-0.06	0.07	-0.03	0.06	0.09	-0.14	1

Source: Author's own calculation from R

5.2.3 Empirical Results

In the regression analysis, fixed effects models were estimated to ascertain the impacts of the independent variables on cost efficiency. We did the diagnostic test to assess whether the assumptions underlying the statistical models are valid. These tests are crucial because most statistical methods rely on certain assumptions, and violations of these assumptions can lead to invalid or misleading results. The Breusch-Pagan was applied to the FE model of both CE_DEA and CE_SFA to detect heteroscedasticity. As a result, the p-value of CE_DEA and CE_SFA are 2.2e-16 and 2.895e-05 respectively, which is lower than significant level p-value = 0.05 indicating the evidence of heteroscedasticity in the residuals.

Additionally, the Breusch-Godfrey test was employed to assess the presence of autocorrelation in the error terms of the models. The FE model of CE_DEA and CE_SFA exhibited substantial autocorrelation, as indicated by an LM test statistic of 429.25 with the p-value 2.2e-16 and LM test 216.78 with the p-value 2.2e-16.

To address the presence of heteroscedasticity and autocorrelation identified in the diagnostic tests, this study employed robust standard errors using the Arellano method, specifically the HC1 type variance-covariance matrix. This approach adjusts the standard errors of the regression coefficients allowing for heteroscedasticity and autocorrelation across panels, thus providing more reliable statistical inference. Additionally, to avoid the endogeneity, we also lagged all the explanatory variables by one quarter.

In assessing the determinants of bank cost efficiency, two distinct methodologies, DEA and SFA were employed. The ensuing regression analyses, encompassing both Pooled Ordinary Lease Squares (POLS) and Fixed Effects (FE) models, yielded insightful findings on the effects of risk-taking, capital adequacy, bank size, net interest margins, real GDP growth, and inflation rate on cost efficiency.

Table 5.10 shows that the capital adequacy ratio (lag_CAP) appeared a divergent impact under both DEA and SFA models. With the POLS framework, a significantly positive coefficient (0.105***) indicates a direct relationship between prior-period capital adequacy and DEA-based cost efficiency. Conversely, the FE model completed this relationship statistically insignificant, thus reducing the evidence for the influence of capital adequacy on cost efficiency in the fixed effects context.

Bank size (lag-SIZE), in both POLS and FE models, exhibited a significantly positive correlation with DEA-based cost efficiency, with coefficients of 0.097*** and 0.076***, respectively. These results suggest economies of scale, where larger banking entities may be realizing operational efficiencies.

Real GDP growth in the preceding period (lag_rGDP) consistently exhibited a negative association with DEA-based cost efficiency across both regression models, at coefficients of -0.136***(POLS) and -0.202*** (FE). This potentially indicates that in periods of economic expansion, banks may engage in growth strategies that do not translate into immediate efficiencies.

Inflation rate (lag_INFL) showed a robust negative correlation with DEA-based cost efficiency in both models, with coefficients of -1.907*** (POLS) and -1.876*** (FE). This result suggests that higher inflation rates may adversely affect the operational efficiency of banks, possibly due to increased cost pressures.

Table 5.11 indicates that risk-taking behavior in the previous period (lag_RISK) revealed a negative impact on SFA-based cost efficiency in the FE model, significant at the 5 percent level with a coefficient of -0.578**. This shows that higher prior risk-taking may lead to reduced current efficiency, aligning with the premise that increased risk can lead to inefficiencies. However, in the DEA model, the FE model for SFA-based efficiency demonstrated a significantly negative relationship between bank size (lag-SIZE) and cost efficiency, with a coefficient of -0.058***. This suggests the presence of diseconomies of scale within the SFA framework, where larger banks may encounter operational inefficiencies.

Furthermore, the net interest margin of the prior period (lag_NIM) exhibited a negative correlation with SFA-based cost efficiency in the FE model, significant at the 5 percent level with a coefficient of -1.838. The implication here is that higher net interest margins might not be conducive to efficiency, possibly indicative of an operational focus on high-margin, yet less efficient, financial products.

Table 5.10: Determinants of bank cost efficiency in DEA in Cambodia

	Dependent variable: CE_DEA	
	Pooled OLS	Fixed Effects
	(1)	(2)
lag_RISK	-0.577	-0.303
	(0.373)	(0.380)
lag_CAP	0.105***	0.014
	(0.029)	(0.017)
lag_SIZE	0.097***	0.076***
	(0.018)	(0.018)
lag_NIM	-1.584***	-0.318
	(0.460)	(0.319)
lag_rGDP	-0.136***	-0.202***
	(0.039)	(0.036)
lag_INF	-1.907***	-1.876***
	(0.395)	(0.430)
Constant	-0.547**	
	(0.268)	
Observations	1,290	1,290
R2	0.321	0.134
Adjusted R2	0.317	0.109
F Statistic	100.865*** (df = 6; 1283)	32.218*** (df = 6; 1254)
Note:		*p<0.1; **p<0.05; ***p<0.01

Source: Author Estimation, results obtained from R

Table 5.11: Determinants of bank cost efficiency in SFA in Cambodia

	Dependent variable: CE_SFA	
	Pooled OLS	Fixed Effects
	(1)	(2)
lag_RISK	-0.428	-0.578**
	(0.369)	(0.284)
lag_CAP	-0.046	0.018
	(0.028)	(0.022)
lag_SIZE	-0.023	-0.058***
	(0.017)	(0.019)
lag_NIM	-0.503	-1.838**
	(0.712)	(0.795)
lag_rGDP	-0.099	0.061
	(0.085)	(0.081)
lag_INF	0.282	0.662
	(0.495)	(0.500)
Constant	1.081***	
	(0.225)	
Observations	1,290	1,290
R2	0.031	0.083
Adjusted R2	0.026	0.057
F Statistic	6.746*** (df = 6; 1283)	18.798*** (df = 6; 1254)
Note:		*p<0.1; **p<0.05; ***p<0.01

Source: Author Estimation, results obtained from R

5.2.4 Results and Discussion

In analyzing, the relationship between previous period risk-taking and current period cost efficiency, our results reveal that both CE_DEA and CE_SFA exhibit negative and statistically significant coefficients for lag_RISK. This evidence supports our first hypothesis, firmly establishing that banks that have engaged in higher risk-taking behaviors in the preceding period are likely to incur reduced cost efficiency in the subsequent period. This negative association confirms the theory that heightened risk exposure can adversely affect bank efficiency, possibly due to the escalated expenses associated with risk mitigation strategies and the requisite capital reserves to support risky activities. The alignment of this finding across both DEA and SFA methodologies lends additional proof to the argument that risk-taking is inversely proportional to efficiency in the banking sector.

When examining the capitalization aspect, the FE model for CE_DEA shows a non-significant positive coefficient for lag_CAP, thus failing to uphold our second hypothesis. Similarly, the CE_SFA model, under the FE specification, presents a positive but statistically insignificant lag_CAP coefficient, implying that with this modeling framework, the hypothesis that elevated capital levels in the previous period led to improved cost efficiency in the current period is not substantiated by the empirical evidence. These findings indicate that the data does not affirm the proposed beneficial impact of higher capital buffers on cost efficiency within the banking institutions.

The analysis of bank size effects, as depicted by the coefficients for lag_SIZE in the FE models, delivers contrasting results. A significant positive relationship with CE_DEA suggests that larger banks may benefit from economies of scale, thereby endorsing the third hypothesis for the DEA-based efficiency measure. Conversely, the SFA model reveals a significant negative association between lag_SIZE and CE_SFA, hinting at possible diseconomies of scale where increased bank size could introduce inefficiencies, potentially as a consequence of more complex of bank structure.

This opposition in findings underscores the complex nature of bank efficiency and the influence of size, which may appear differently across efficiency measurement frameworks. Notably, these results align with the divergent outcomes reported in the comparative literature, such as Ferrier and Lovell (1990) and Bauer *et al.* (1998), which observed differences in individual rankings and correlations between DEA and SFA scores, respectively. Furthermore, the varied impact of bank size on efficiency reflects the complex inferences drawn by Delis *et al.* (2009), who observed differential effects of size on cost efficiency across DEA and SFA. Along with the current finding, this body of evidence highlights the need for a sophisticated interpretation of the sized-efficiency relationship and raises the possibility that the particulars of the banking environment and the efficiency dimensions being examined will determine how reliable each measure is in comparison to the other.

The two scatter plots in Figure A.1 and Figure A.2 illustrate the relationship between the cost to income ratio and efficiency scores determined by DEA and SFA methods, respectively. In Figure A.1, the scatter plot of the cost to income ratio versus DEA efficiency Score shows a clear negative trend, as indicated by the fitted dashed line. The majority of data points seem to cluster in a pattern that descends from left to right, suggesting that as the cost to income ratio increases, the DEA efficiency score tends to decrease. This indicates that banks with higher costs relative to their income are generally less efficient according to DEA. The strength of this relationship appears relatively pronounced, pointing to DEA's sensitivity in capturing the impact of cost management on efficiency. In Figure A.2 presents the scatter plot pf the cost to income ratio versus SFA efficiency score. While there is also a negative trend indicated by the fitted dashed line, the data points are more vertically spread across all levels of cost to income ratio. This distribution suggests a weaker correlation between cost to income ratio and SFA efficiency scores compared to the DEA plot. The spread of data points, especially at lower levels of cost to income, indicates that SFA may be less sensitive to changes in cost efficiency or that other factors are influencing SFA efficiency scores more significantly that they do DEA scores.

Based on visual interpretation of the scatter plots, the DEA method shows a stronger and more coherent negative relationship with the cost to income ratio that the SFA method. This implies that DEA may be more effective in reflecting the impact of cost control on banking efficiency in this particular dataset. The tighter clustering of points along the trend line in the DEA plot suggests that the DEA efficiency score is more consistently influenced by variations in cost to income ratios.

6 Conclusion

This thesis assesses the determinants of cost efficiency in Cambodia commercial banks from 2012 to 2022 in the quarterly basis, employing both DEA and SFA. By analyzing data from thirty commercial banks, this study sought to determine how bank risk-taking, capital adequacy, and bank size influence cost efficiency. Three hypotheses were tested: higher risk-taking negatively affects bank cost efficiency, higher capital levels improve cost efficiency, and larger banks exhibit greater cost efficiency.

The findings from the DEA and SFA models provided substantial evidence supporting the hypothesis that higher risk-taking by banks leads to lower cost efficiency. Both models consistently demonstrated a significant negative relationship between risk-taking and bank efficiency, validating the premise that higher risk levels compromise bank performance. This aligns with the broader banking literature suggesting that excessive risk-taking, often due to aggressive growth strategies, can erode operational efficiency by increasing the probability of non-performing loans and capital adequacy pressures.

Contrary to the expectation that higher capital levels would uniformly enhance bank efficiency, the results were more complicated. While the SFA model found no significant impact of capital on efficiency, the DEA analysis suggested that only in the context of variable returns to scale does capital have a modest effect on efficiency. This implies that while capital adequacy is crucial for sustaining bank operations and absorbing risks, its role in driving operational efficiency is complex and possibly contingent on other factors like management practices and market conditions.

The hypothesis that larger banks are inherently more efficient was not fully supported by the empirical evidence. In the DEA model, larger bank size was associated with higher efficiency scores, suggesting that economies of scale and possibly better access to technological resources play a role in enhancing efficiency. However, the SFA results indicated that size alone does not guarantee superior efficiency. These mixed fundings underscore the challenges larger banks face in managing their extensive operations and the potential for inefficiencies that can arise from complex bank structures.

Moreover, the study expanded its analysis by incorporating other variables such as NIM, which was found to have a weak negative correlation efficiency score. This suggests that while NIM is a critical profitability measure, its direct impact on operational efficiency is limited.

This thesis contributes to the limited but growing body of literature on banking efficiency in emerging markets, particularly within the Cambodian context. By employing robust analytical techniques and a comprehensive dataset, it provides valuable insights into the operational dynamics of Cambodian commercial banks. The findings highlight the importance of prudent risk management, the complicate role of capital adequacy, and the complex implications of bank size on efficiency.

For policymakers and bank management, these insights underscore the need for balanced growth strategies that not only aim for expansion but also prioritize operational efficiency and risk control. Additionally, the findings advocate for continuous improvement in regulatory frameworks to ensure that capital adequacy requirements align with the bank's operational needs and risk profiles.

In conclusion, while the Cambodian banking sector continues to evolve amid economic and regulatory changes, the principles of effective risk management, capital adequacy, and scale of operations remain central to enhancing bank efficiency. This study lays a foundation for future research to explore deeper into the strategic decisions that influence bank efficiency and to expand the analysis to other performance metrics within the Cambodian banking sector.

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Appendix A: Additional Estimation Results

Figure A.1: Comparison Cost to Income Ratio and DEA Scores

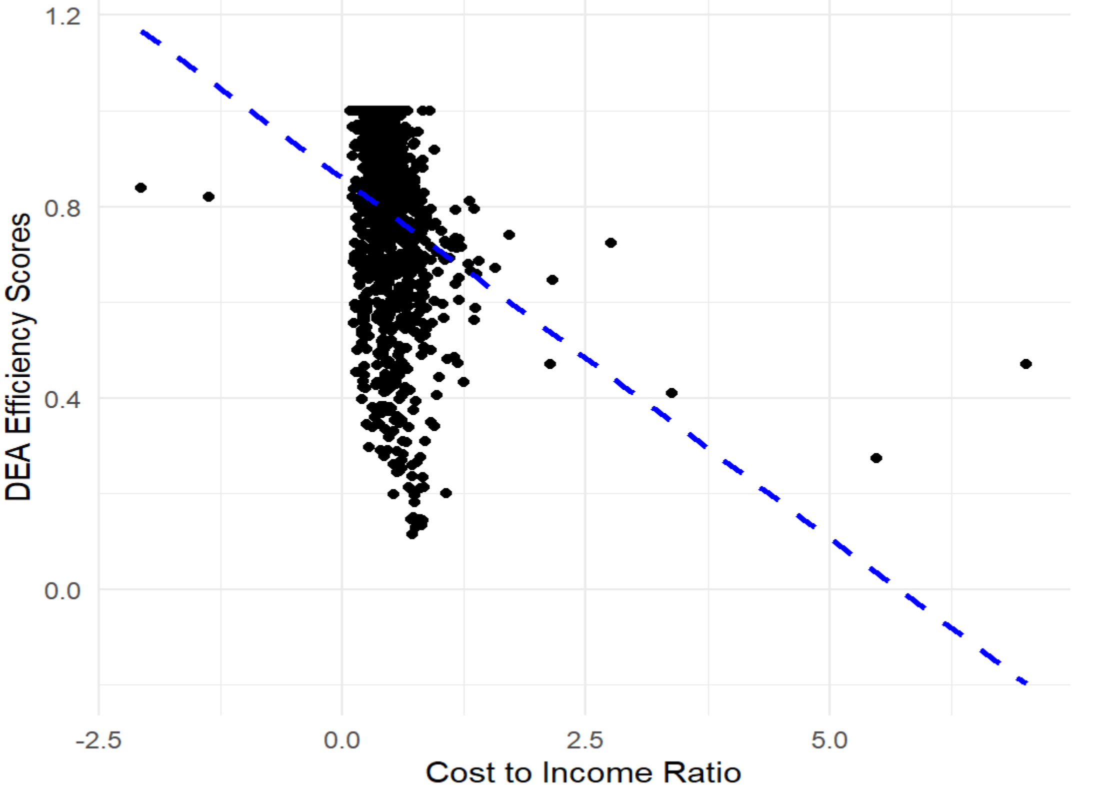
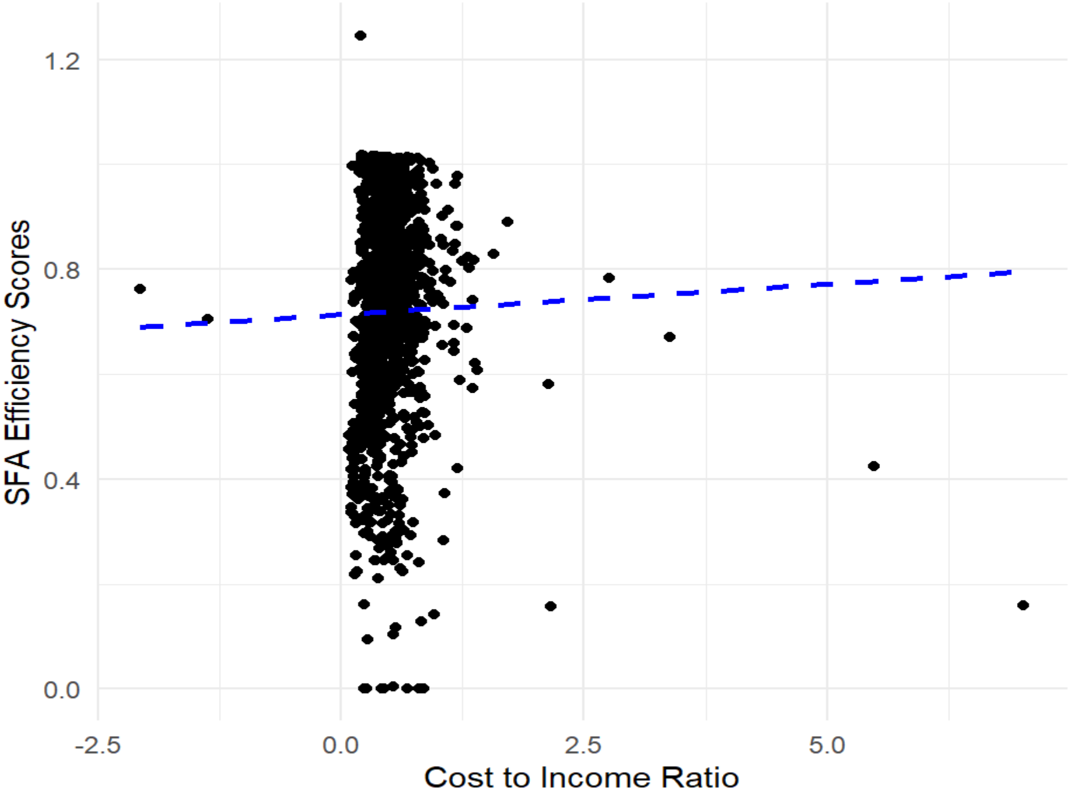


Figure A.2: Comparison Cost to Income Ratio and SFA Scores



Appendix B: Supplementary Information

Figure B.1: Cambodian Map

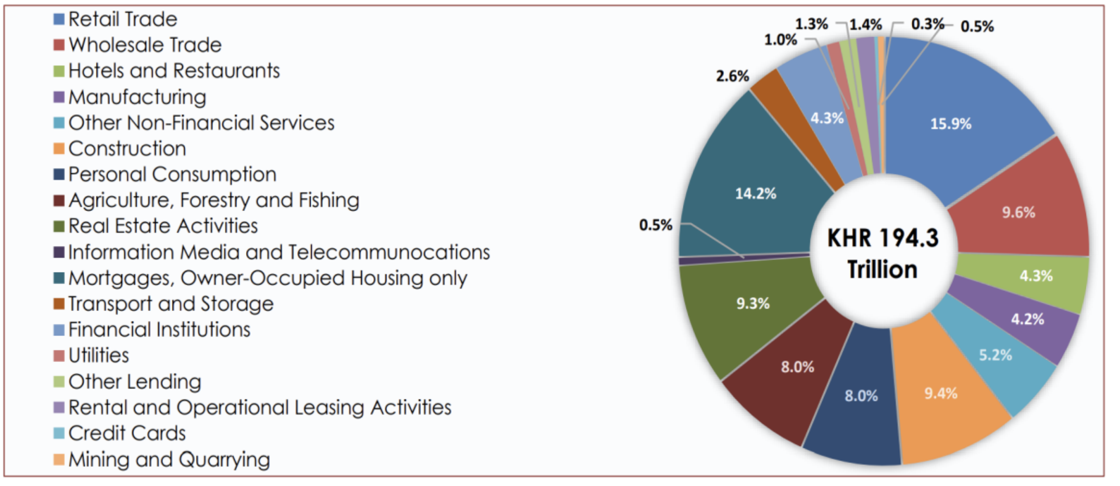
Source: WorldAtlas, available at: https://www.worldatlas.com/maps/cambodia

Figure: B.2: List of Commercial Banks as of December 2022

No.	Name of Institutions	Address	Contact Number
1. Commercial Banks			
1	ACLEDA BANK Plc.	#61, Preah Monivong Blvd., Sangkat Srah Chork, Khan Daun Penh, Phnom Penh	023 998 777
2	ADVANCED BANK OF ASIA LIMITED	Building N°141, 146, 148, & 148 ABCD, & 162 A Preah Sihanouk Blvd., N°15 & 153 ABC Street 278, N°171 Street Preah Trasak Paem , Phum Phum 4, Sangkat Boeng Keng Kang Ti Muoy, Khan Boeng Keng Kang, Phnom Penh	023 225 333
3	AGRICULTURAL AND RURAL DEVELOPMENT BANK	No 9-13, Street No 7, Sangkat Chakto mukh, Khan Doun Penh, Phnom Penh	023 220 810-220 811
4	Alpha Commercial Bank Plc.	The Gateway Building, Ground & 33rd Floor, Russian Federation Blvd., Sangkat Phsar Depou Ti Bei, Khan Tuol Kouk, Phnom Penh	023 88 66 88
5	Asia- Pacific Development Bank Plc.	No C20, C21, C22, C23, D32, D33 & D33A, One Park, Street No R8, Sangkat Srah Chak, Khan Doun Penh, Phnom Penh.	098 399 888
6	B.I.C (Cambodia) Bank Plc.	No 462, Street 93, Sangkat Tonle Bassac, Khan Chamkarmon, Phnom Penh	023 901 338
7	Bangkok Bank Public Company Limited, Cambodia Branch	#344 (1st, 2nd floor), Mao Tse Toung Boulevard, Sangkat toul Svay Prey Ti Muoy, Khan Khan Boeng Keng Kang, Phnom Penh	023 224 404
8	BANK FOR INVESMENT&DEVELOPMENT OF CAMBODIA Plc.	#235, Preah Norodom Blvd., Phum Phum 13, Sangkat Tonle Basak, Khan Chamkar Mon, Phnom Penh	023 210 044
9	BANK OF CHINA (HONG KONG) LIMITED PHNOM PENH BRANCH	Canadia Tower (315) 1st- 2nd Floor, Preah Monivong Blvd, Sangkat Wat Phnom, Khan Don Penh, Phnom Penh	023 988 886
10	BOOYOUNG KHMER BANK	# 86-88, Preah Norodom Blvd, Sangkat Chaktomuk,Khan Daun Penh, Phnom Penh	023 952 888
11	Branch of Industrial Bank of Korea "Phnom Penh"	No S2-23 The Olympia City, Preah Monireth Blvd (No 217), Sangkat Veal Vong, Khan Prampir Meakkakra, Phnom Penh	023 964 202 / 012 608 898
12	Branch of Kasikorn Bank Public Company Limitted (Phnom Penh)	#45, Preah Sihanouk Blvd, Corner of street No.59, Phum 6, Sangkat Chaktomuk, Khan Daun Penh, Phnom Penh	077 555 366 / 023 214 998-214 999
13	Branch of Mizuho Bank, Ltd.	No 132, Samdach Sothearos Blvd, Sangkat Tonle Basak, Khan Chamkar Mon, Phnom Penh	023 964 490
14	BRED Bank (Cambodia) Plc	#30, Preah Norodom Blvd, Sangkat Phsar Thmey 3, Khan Daun Penh, Phnom Penh	092 233 850 / 023 999 222
15	BRIDGE BANK PLC.	No 46Eo, Street No 41, Sangkat Chey Chumneah, Khan Doun Penh, Phnom Penh	023 213 111 / 023 222 068
16	CAMBODIA ASIA BANK LTD	No 75C,036, Preah Sihanouk Street, Sangkat Veal Vong, Khan Prampir Meakkakra, Phnom Penh	023 980 000
17	CAMBODIA MEKONG BANK PUBLIC LIMITED.	#445, Preah Monivong Blvd., Sangkat Srah Chak, Khan Daun Penh, Phnom Penh (moved to temporary location: Regency, Building 298, Mao Tse Toung Blvd., Sangkat Tomnub Tuek, Khan Chamkar Mon, Phnom Penh	023 430 980
18	CAMBODIA POST BANK PLC.	#265-269 Ang Duong Street, Sangkat Wat phnom, Khan Daun Penh, Phnom Penh	023 260 888
19	CAMBODIAN COMMERCIAL BANK PLC.	#26, Preah Monivong Blvd, Sangkat Phsar Thmey 2, Khan Daun Penh, Phnom Penh	023 426 145
20	CAMBODIAN PUBLIC BANK Plc.	#23, 114 St., Sangkat Phsar Thmey 2, Khan Daun Penh,Phnom Penh	023 222 880 / 222 881 / 222 882
21	CANADIA BANK PLC.	#315, Preah Ang Duong Street, Sangkat Wat Phnom, Khan Daun Penh, Phnom Penh	023 868 222
22	Cathay United Bank (Cambodia) Corp. Ltd.	#48, Samdech Pan St.(214), Sangkat Boeung Raing, Khan Daun Penh, Phnom Penh	023 211 211-222 438
23	CCU COMMERCIAL BANK PLC.	#15, Preah Monivong Blvd., Phum Phum 5, Sangkat Boeng Trabaek, Khan Chamkar Mon, Phnom Penh	099 333 878
24	Chief (Cambodia) Commercial Bank Plc.	#C01, St. R11 corner St. 70, Phum 1, Sangkat Sras Chork, Khan Daun Penh, Phnom Penh	023 900 878
25	Chip Mong Commercial Bank Plc.	Building No 174 (1st, 3rd & 4th Floor), Czech Republic Blvd. Corner Street No 164, Sangkat Veal Vong, Khan Prampir Meakkara, Phnom Penh	081 811 911
26	CIMB Bank PLC.	#20A/B, Preah Norodom Blvd Corner of Street 118, Sangkat Phsar Chas, Khan Daun Penh, Phnom Penh	023 988 388
27	DGB Bank Plc.	No 689B, Kampucheakrom Blvd., Sangkat Tuek L'ak Ti Muoy, Khan Tuol Kouk, Phnom Penh	023 999 990
28	FIRST COMMERCIAL BANK PHNOM PENH BRANCH	# 66, Preah Norodom Blvd., Sangkat Chey Chumneas,Khan Daun Penh, Phnom Penh	070 600 098 / 023 220 773-220 772
29	FOREIGN TRADE BANK OF CAMBODIA	#33 C-D, Cheque Slovakia blvd, Khan 7 Makara, Phnom Penh	023 724 466-725 266-722 466
30	Hattha Bank Plc.	#606, St. 271, Sansam Kosal 3 Village, Sangkat Boeng Tumpun 1, Khan Mean Chey, Phnom Penh	023 999 266
31	HENG FENG (CAMBODIA) BANK PLC.	#242, Preah Monivong Blvd., Corner Street No 288, Phum 4, Sangkat Boeng Keng Kang Ti Muoy, Khan Boeng Keng Kang, Phnom Penh	088 8666 988
32	Heng He (Cambodia) Commercial Bank Plc.	Building No 64, Preah Norodom Blvd., Corner Street No 178, Sangkat Chey Chumneah, Khan Doun Penh, Phnom Penh	023 997 777
33	Hong Leong Bank (Cambodia) PLC	#28, St. 214 Corner St. 51, Sangkat Beoung Raing, Khan Daun Penh ,Phnom Penh	023 999 711
34	ICBC Limited Phnom Penh Branch	Exchange Square (Ground Floor) No. 19 and 20, Street 106, Phum Pir, Sangkat Voat Phnom, Khan Doun Penh, Phnom Penh	023 955 880
35	J Trust Royal Bank Plc.	#20FE-E0 E1 E2 E3 & 20 HG-E0 E1 E2 E3, Corner of Kramoun Sar and St. 67, Sangkat Phsar Thmey 1, Khan Daun Penh, Phnom Penh	023 999 000
36	KOOKMIN BANK CAMBODIA PLC.	#55, 214 St. Sangkat Boeung Raing, Khan Daun Penh, Phnom Penh	023 999 300
37	KRUNG THAI BANK PUBLIC CO., LTD PHNOM PENH BRANCH	# 149, 215 Road, Sangkat Phsar Depo1, Khan Toulkork, Phnom Penh	023 882 959
38	MAYBANK (Cambodia) Plc.	#43, Preah Norodom Blvd, Sangkat Psar Thmei3, Khan Doun Penh, Phnom Penh	023 210 255-210 123
39	MB BANK (CAMBODIA) PLC.	#146, Preah Norodom Blvd, Sangkat Tonle Basak, Khan Chamkar Mon, Phnom Penh	023 964 666
40	Mega International Commercial Bank Co., Ltd Phnom Penh Branch	No. 139, Street 274 corner street No. 41, Phum Phum 5, Sangkat Boeung Kengkang Ti Muoy, Khan Boeng Keng Kang, Phnom Penh	023 988 101 / 023 218 540
41	ORIENTAL BANK PLC.	Building No 101, Preah Norodom Blvd. Comor Samdach Pan Ave. (214), Sangkat Boeng Reang, Khan Doun Penh, Phnom Penh	023 920 222 / 023 920 111
42	PANDA Commercial Bank Plc.	#31, Mao Tsetoung Blvd 245, Sangkat Boeng Keng Kang Ti Muoy, Khan Boeng Keng Kang, Phnom Penh	018 282 8416/023888801
43	Phillip Bank Plc.	No 27DEFG, Preah Monivong Blvd., Phum 6, Sangkat Srah Chak, Khan Doun Penh, Phnom Penh	086 930 000 / 089 989 818
44	PHNOM PENH COMMERCIAL BANK PLC.	#217, Preah Norodom Blvd, Sangkat Tonle Basak, Khan Chamkamom, Phnom Penh	023 999 500
45	PRINCE BANK PLC.	No175ABCD, Mao Tse Toung Blvd., Phum Phum 5, Sangkat Tuol Svay Prey Ti Muoy, Khan Boeng Keng Kang, Phnom Penh	1800 20 8888 / 023 991 168
46	RHB BANK (CAMBODIA) PLC.	Building 1st, M, 2nd and 9th Floor, Street 110 Corner Street 93, Phum 3, Sangkat Srah Chak, Khan Doun Penh, Phnom Penh	023 992 833
47	RUI LI (CAMBODIA) BANK PLC.	Building No 635&637, Preah Monivong Blvd, Sangkat Boeng Keng Kang Ti Bei, Khan Boeng Keng Kang, Phnom Penh	081 292237/023 989736
48	Saigon Thuong Tin BANK (Cambodia) Plc.	#60, Preah Norodom Blvd, Sangkat Chey Chumnas, Khan Daun Penh, Phnom Penh	023 223 422
49	Saigon-Hanoi Bank Cambodia Plc.	#107, Preah Norodom Blvd, Sangkat Beoung Reang, Khan Doun Penh, Phnom Penh	023 221 900
50	SATHAPANA BANK Plc.	Sathapana Tower, Preah Norodom Blvd., Corner Street No 172 and Street No 174, Phum phum 14, Sangkat Phsar Thmei Ti Bei, Khan Doun Penh, Phnom Penh	023 999 010/081 999 010
51	SBI Ly Hour Bank Plc.	No 219, Street 128 Corner Street 169, Sangkat Mittapheap, Khan Prampir Meakkakra, Phnom Penh	023 980 888/ 023 999 368
52	SHINHAN BANK (CAMBODIA) PLC.	Vanda Tower No 79, Kampuchea Krom Blvd, Sangkat Monourom, Khan Prampir Meakkakra, Phnom Penh	023 727 380
53	Small and medium enterprise bank of Cambodia Plc. "SME Bank"	MEF Business Development Center, # 5, OCIC Street, Phum Kien Khleang, Sangkat Chraoy Chongvar, Khan Chraoy Chongvar, Phnom Penh	096 811 1118 \ 012 868 887
54	Taiwan Cooperative Bank, Phnom Penh Branch	#171, Preah Norodom Blvd at corner of St322, Beoung Keng Kang 1, Khan Chamkamom, Phnom Penh	023 430 800
55	UNION COMMERCIAL BANK PLC.	No 441, Preah Monivong Blvd., Sangkat Boeng Proluet, Khan Prampir Meakkakra, Phnom Penh	023 212 357-427 995
56	VATTANAC BANK	#66, Preah Monivong Blvd., Sangkat Wat Phnom, Khan Daun Penh, Phnom Penh	023 963 999
57	Vietnam Bank for Agriculture and Rural Development Cambodia Branch	N° 364, Preah Monivong Blvd, Sangkat Boeung keng kang1, Khan Chancarmon,Phnom Penh	023 223 750
58	Wing Bank (Cambodia) PLC	#721, Preah Monivong Blvd., Phum Phum 9, Sangkat Boeng Keng Kang Ti Bei, Khan Boeng Keng Kang, Phnom Penh.	023 999 989
59	WOORI BANK (CAMBODIA) PLC.	No 398, Preah Monivong Blvd, Phum Phum 1, Sangkat Boeng Keng Kang Ti Muoy, Khan Boeng Keng Kang, Phnom Penh	023 969 269

Source: NBC, Annual Supervision Report (2022)

Figure: B.3: Banks-Credit Classified by Industries



Source: NBC, Annual Supervision Report (2022)