



# Measuring and Explaining X-Efficiency in the Saudi Banking Sector: Evidence from Data Envelopment Analysis

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## ABSTRACT

Today's financial landscape is characterized by increased volatility and heightened risk; assessing the efficiency of banking institutions is both complex and essential. Globally, banks have undergone profound changes driven by regulatory reforms, financial innovation, risk management, and the increasing digitalization of services, which has increased competition within the sector. In this context, this study aims to analyze the relationship between X-efficiency and selected financial and structural characteristics of Saudi commercial banks, including the size of institutions, profitability as measured by return on assets (ROA), and the volumes of deposits and loans. The empirical analysis is based on a panel of ten banks covering the period 2015-2024. Methodologically, technical efficiency is estimated using the Data Envelopment Analysis (DEA) method, based on linear programming, enabling the evaluation of banks' relative resource use. The results show that Saudi commercial banks have an average efficiency of 86%, reflecting an overall satisfactory performance of the Saudi banking sector. However, institutions with a score below this threshold are considered inefficient, reflecting suboptimal use of their internal resources. These results underline the importance of adopting more effective management strategies to strengthen the overall performance and competitiveness of banking institutions in a constantly changing financial environment.

**Keywords:** X-Efficiency, DEA Model, Banking Features, Cost Efficiency, Saudi Commercial Banks

**JEL Classifications:** G21, D24, C61

## 1. INTRODUCTION

In an ever-changing financial sector, it is essential to assess the efficiency of institutional costs. Improved efficiency translates into increased profitability, more competitive rates and improved quality of service. Banks must therefore optimize resource management and reduce waste, thereby reducing costs and improving performance. As a result, the analysis of costs, revenues, and revenue risks has become a priority for the banking industry.

The concept of X-efficiency, introduced by Leibenstein (1966), is based on the optimal use of resources. The term X-efficiency refers to the technical and allocative efficiencies of individual firms, distinct from the efficiency of scale and scope. Indeed, the

concept of X-efficiency measures the distance separating the firm from the most efficient cost frontier. This concept differs from economies of scale and scope in treating the productive aggregate as given. In fact, deviation from the frontier represents the degree of X-inefficiency. The opposite concept is that inefficiency X usually refers to the difference between the maximum production efficiency a firm can achieve and the actual efficiency it achieves. The more competitive pressures a company faces, the greater the risk of "super flows" within its organisation and, therefore, the higher its X-inefficiency will be.

According to Chaffai and Dietsch (2000), the concept of X-efficiency enables the measurement of an organization's performance, both productive and financial. As a result, this concept emphasizes the

quality of the organization and strategic decisions in the market. The main interest of X-efficiency is to identify the most efficient firms, given that they face the same market conditions and use the same technologies. Indeed, X-efficiency focuses attention on the one hand on the internal determinants of firms, namely, their ability to control production and distribution costs, through appropriate choices of organization, network and size, and their ability to optimize supply variables, i.e. to choose the right prices, the quality of the services offered and the scope of the skills implemented on the other hand, It represents a measure of relative performance in a group of comparable firms using the same technologies, facing the same market conditions and pursuing the same objectives.

This research is subdivided into five sections; The first presents the general framework. The second section is devoted to the review of the literature. The third section describes the technique used, and we conclude with the results.

## 2. LITERATURE REVIEW

A study of Tunisian commercial banks in Bouchaddakh and Salah (2005), covering the period 1997-2003, shows an improvement in Tunisian banking efficiency from 2000 onwards, as measured by the X-efficiency score. The average score is around 86% during the period studied. This means that banks that produce the same outputs and use more input than banks that achieve this score are considered inefficient.

For French and Spanish banks, the study by Dietsch and Lazano Vivas (2000) measures the impact of environmental variables such as income, density of deposit demand, structure, regulation, accessibility to banking services and population density on the cost efficiency of French and Spanish banks. They proposed a new method for comparing efficiency across countries. Using a parametric approach to AED. Their study shows that country-specific environmental conditions play an important role in defining and specifying the boundary, as in other countries. Regardless of environmental factors, Spanish banks' cost-efficiency scores are lower than those of French banks. However, when environmental variables are included in the model, differences in cost efficiency are reduced substantially.

Lahet (2009) used the DEA method to estimate the banking efficiency of Southeast Asian countries. It shows that ownership structure and excess risk are major factors in determining inefficiency in these countries, as it finds scores of 61% and 89% for Indonesia. Caner and Kontorovich (2004) use the stochastic frontier approach to compare the scores: 45% for Slovakia, 73% for the Czech Republic, and 61.5% for England in Western Europe. However, it did not find any macroeconomic factors or bank-specific factors that explain the difference in efficiency scores between Eastern and Western European countries. For German banks, Koetter (2006) studied 1993 to 2003 and used a stochastic frontier method, finding that cost efficiency leads to profit efficiency, with scores of 92% and 65%, respectively.

According to a study by AlKhatlan and Malik (2010), between 2003 and 2008, Saudi banks that adopted the Data Envelopment

Analysis (DEA) achieved significant efficiency, with the majority at the efficiency frontier. According to these authors, these banks play a crucial role in the financial system. Kraidi et al. (2024) state, following their study on the efficiency of the Turkish banking sector for the period 2006-2018, that the efficiency frontier is a reliable benchmark, or "benchmark", for banks seeking to improve their services, as it facilitates decision-making and promotes effective and sustainable planning. Blankson et al. (2022) examined the efficiency of Ghanaian banks by assessing technical and cost efficiency over the period 2008-2019. This study showed that these banks are not efficient. Their improvement was noticed from 2016, when the banking law came into force. According to these authors, the factors influencing bank efficiency are bank size, the rate of GDP growth, and inflation. However, ROA and provisions do not affect the determination of Ghanaian banking efficiency. Similarly, Petrović et al. (2025) found it necessary to study the efficiency of logistics companies, as the products and services they offer are intangible and require evaluation. They applied a three-phase model combining DEA and fuzzy PAH. The results show the model's reliability for measuring, evaluating, and ranking these companies based on the logistics services they offer.

Approximately 130 studies determine the efficiency frontier of financial institutions in 21 countries. The basis of this research is to determine whether there is consensus to generalize and improve the different methods adopted to reach identical conclusions (Berger and Humphrey, 1997). The study by Lozano-Vivas and Pasiouras (2010) examined a sample of 752 publicly traded commercial banks across countries and aimed to compare the impact of banking activities by characteristics such as geographic region, growth, and bank size. They employ different models by analyzing cost efficiency and profit efficiency. Their results show that the inclusion of such an off-balance-sheet activity or interest income affects banks' performance. A recent study opens a new debate on the appropriate and effective technique for the bank to choose following these upheavals and current developments. According to the results of this research, such a bank is required to apply the model appropriate to its activity to ensure its success and greater efficiency (Azzabi and Lahrichi, 2023).

Kisaka and Wafubwa (2014) and Onyango (2022) analyzed the X-efficiency of commercial banks in Kenya. According to these authors, banks are 18% efficient. Large banks are more efficient than medium-sized banks. So, they applied the stochastic boundary approach between 2000 and 2005. Onyango, on the other hand, used the DEA approach to study X-efficiency and its determinants. Second, he used the probit model to analyze the relationship between X-efficiency and banking characteristics.

## 3. DATA AND METHODOLOGY

### 3.1. Data Envelopment Analysis (DEA)

DEA is a method first introduced in the study of efficiency by Charnes et al. (1978), who built on the work of Farrell (1957). Banker et al. (1984) show that the efficiency measure described by Charnes et al. (1978) can be decomposed into two components: technical efficiency and allocative efficiency. Technical efficiency measures the ability of a unit to produce the maximum output for

a certain level of input, or, symmetrically, the ability to produce a certain level of output for the minimum input. Allocative efficiency measures a unit's ability to use optimal combinations of input given their prices. It also measures the ability to allocate inputs to the most profitable activities.

In this study, the technical efficiency of banks is estimated using the Data Envelopment Analysis (DEA) method. We consider a set of  $N$  banks, assimilated to decision units (DUs), each producing  $m$  outputs from  $n$  inputs. Let  $y_{is}$  the quantity of the  $i$ -th output produced by the  $s$ -th bank and  $x_{js}$  The amount of the  $j$ -th input used. The efficiency of a decision unit is defined as the weighted ratio of outputs to inputs:

$$h_s = \frac{\sum_{i=1}^m U_i Y_{is}}{\sum_{j=1}^n V_j X_{js}} \text{ with } \begin{cases} U_i \text{ output } i = 1, \dots, m \\ V_j \text{ output } j = 1, \dots, n \end{cases}$$

The objective is to maximize this efficiency ratio, subject to the constraint that, for all units, this ratio does not exceed 1 unit.

$$\frac{\sum_{i=1}^m U_i Y_{ir}}{\sum_{j=1}^n V_j X_{jr}} \leq 1 \text{ with } \begin{cases} U_i \geq 0, V_j \geq 0 \\ r = 1, \dots, N \end{cases}$$

The primal problem can be reformulated in its dual form into a program for minimizing a scalar  $\beta_s$ , representing overall technical efficiency, subject to production constraints.

$$\sum_{r=1}^N \varphi_r y_{ir} \geq y_{is}; i = 1, \dots, m$$

$$\beta_s X_{js} - \sum_{r=1}^N \varphi_r X_{jr} \geq 0; j = 1, \dots, n; \varphi_r \geq 0 \text{ and } \beta_s \text{ free}$$

The variable  $\beta_s$  ranges from 0 to 1, where 1 indicates an efficient bank on the production frontier, while values  $<1$  indicate inefficiency. In the simplified case of a bank with a single input and a single output, the efficiency frontier is the envelope of the best-observed returns.

In the simplified case of a bank with a single input and a single output, the efficiency frontier is the envelope of the best-observed performance. A bank below this boundary is inefficient, and its efficiency is measured by the beta sub  $s$  ratio, which indicates the proportion of input reduction required to achieve the output level of an efficient bank. Overall technical efficiency  $\beta_s$  is measured by the ratio  $\frac{K_f}{K_s} \leq 1$ .

### 3.2. Model Specification

To identify the determinants of x-efficiency, an econometric analysis was conducted using a panel-data multiple linear

regression model. This model examines the relationship between the efficiency score (dependent variable) and bank-specific characteristics (explanatory variables). The model specification is as follows:

$$EffX_{it} = \beta_0 + \beta_1(\log TA)_{it} + \beta_2(TCRD / TA)_{it} + \beta_3(DP / TA)_{it} + \beta_4(BN / TA)_{it} + \varepsilon_{it}$$

Where:

- $i$  represents the bank
- $t$  represents the observation period
- $\beta_0$  is the constant
- $\beta_k$  are the coefficients to be estimated
- $\varepsilon_{it}$  is the error term

This model allows assessing the impact of bank size, profitability, deposits, and loans on bank efficiency.

### 3.3. Variables

In this study, the dependent variable is the X-efficiency of banks, measured from an efficiency score that reflects the ability of banks to optimize the use of their resources. The explanatory variables include several key financial indicators. The size of the bank is measured by the natural logarithm of total assets ( $\log(TA)$ ), which helps capture size effects and economies of scale. Profitability is measured by return on assets (ROA), defined as net profit divided by total assets ( $BN/TA$ ), and reflects the bank's ability to generate profits. In addition, total deposits, expressed as a ratio to total assets ( $DP/TA$ ), include sight deposits, savings deposits, and term deposits, and enable assessment of the weight of the resources collected in banks' financial structures. Finally, total loans ( $TCRD/TA$ ), also related to total assets, represent all financing granted to the economy and reflect the role of bank intermediation. The sample used in this study comprises a panel of data spanning 2015–2024 and ten Saudi commercial banks. These banks are classified by size, based on their total assets, to analyze potential differences in efficiency between institutions.

### 3.4. Conceptual System Framework for X-Efficiency Analysis

Figure 1 shows the study's structure. It uses bank-specific characteristics as inputs in the Data Envelopment Analysis (DEA) framework to estimate X-efficiency scores. The feedback loop highlights that banking performance is dynamic, since efficiency results can affect future strategic and operational decisions.

The DEA framework works as an evaluation tool that turns inputs into X-efficiency scores. Feedback loops show how efficiency results can affect later financial decisions. Solid arrows stand for strong empirical relationships, while dashed arrows show weaker ones. Thicker arrows mean a factor is more important. The feedback loop shows how banks adjust their characteristics in response to efficiency outcomes.

## 4. EMPIRICAL RESULTS

According to Table 1, the model's quality, as measured by  $R^2$ , indicates acceptable explanatory power. Indeed, the model used

Figure 1: System-Based Conceptual Framework for X-efficiency analysis using DEA

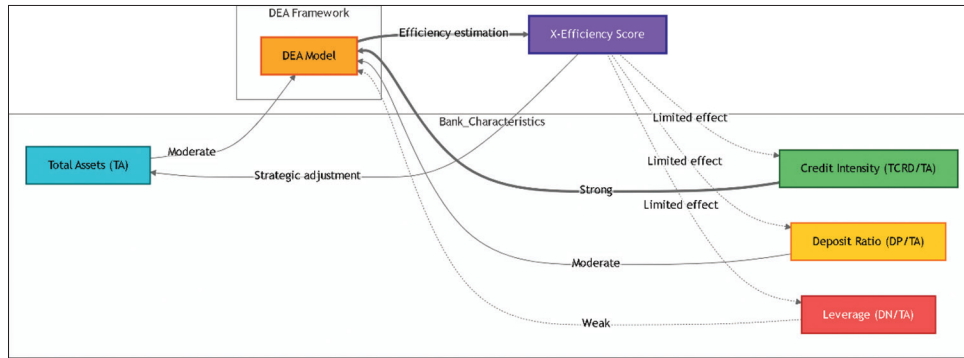


Table 1: Estimation des résultats

Coefficient–(Variable)	Total banks	High banks	Mean banks
$\beta_0$ - (Constant)	0.23155 (0.5645)	0.5633* (0.054)	-0.23156 (0.6532)
$\beta_1$ - (TA)	0.14584*** (0.0000)	0.4568*** (0.000)	0.25689** (0.0456)
$\beta_2$ - (TCRD/TA)	0.58484*** (0.0000)	0.6548*** (0.0000)	0.35487** (0.0356)
$\beta_3$ - (DP/TA)	-0.25875 (0.2135)	-0.18575 (0.4548)	-0.32655 (0.3645)
$\beta_4$ - (DN/TA)	0.87547*** (0.0000)	0.36548** (0.0487)	0.45665* (0.0545)
R-square	0.75612	0.56423	0.68754
Durbin -Watson	1.85474	1.85474	1.75894

\*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5% and 1% thresholds, respectively. Brackets represent the 95% P values for the total sample, high banks, and mean banks

Table 2: Estimated efficiency score -X for each bank and for each year

Bank name	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	Average
NCB	0.747	0.838	0.522	0.847	0.552	1.000	1.000	1.000	1.000	1.000	0.851
SAMBA	0.835	0.812	0.883	0.612	0.637	0.623	1.000	0.637	0.836	1.000	0.788
SABB	0.823	0.835	0.615	0.640	0.788	0.807	0.895	0.910	1.000	0.932	0.788
BSF	0.822	0.977	0.918	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.972
SAIB	0.462	0.761	0.618	0.704	0.678	0.960	0.943	1.000	1.000	0.960	0.809
SHB	0.764	0.657	0.846	0.874	0.757	0.799	0.776	0.873	0.869	0.893	0.836
RIB	0.839	0.751	0.967	0.993	0.912	0.903	0.943	0.932	0.955	0.905	0.910
ANB	0.938	0.895	0.896	0.661	0.836	0.835	0.993	0.907	0.949	0.941	0.885
AJB	0.949	1.000	0.981	0.993	0.996	0.832	0.948	0.887	0.989	1.000	0.958
BAJ	0.854	0.779	0.859	0.778	0.920	0.749	0.721	0.895	0.774	0.709	0.804
Average	0.808	0.649	0.811	0.810	0.808	0.851	0.922	0.904	0.937	0.934	0.859

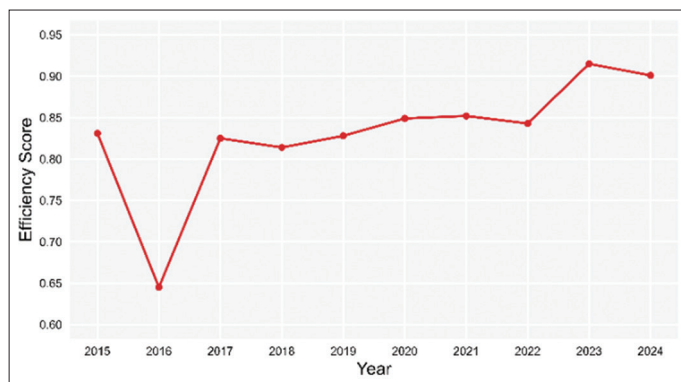
For the complete bank name, Appendix 1

explains 75%, 56% and 68% of the variation in the dependent variable for the three subsamples, respectively. The Durbin-Watson test ( $D-W \approx 2$ ), therefore, does not show autocorrelation of errors. The parameter  $\beta_1$  is significantly positive for all three subsamples, suggesting that X-efficiency increases with size for Saudi deposit-taking banks. So, the big banks are more efficient than the average bank. This result contradicts the economies-of-scale observed for medium-sized banks in the study using the nonparametric method. However, Berger et al. (1992) explained this phenomenon by noting that output inefficiencies dominate input inefficiencies and that large banks, which are best able to achieve an optimal composition of output baskets while maintaining high quality, will therefore become the most efficient.

The total credit-to-total asset ratio (TCRD/AT) coefficient  $\beta_2$  is significantly positive across all three levels, indicating that

banks that extend more credit are associated with higher levels of X-efficiency. This result is consistent with the findings of Nasir et al. (2024) and Allen and Rai (1996), which suggest that banks engaged in high-intensity lending activities tend to be more operationally efficient.

Regarding the TDP/TA ratio  $\beta_3$  has no effect on the performance of Saudi banks, which can be explained by their negligence regarding their assets. This result contrasts with that of Nasir et al. (2024), who report that this ratio is positively significant, which they attribute to large banks' very large deposits and their access to a stable deposit base. It seems that the BN/AT ratio BN/AT ( $\beta_4$ ) is significantly positive. This leads us to conclude that an improvement in efficiency can be explained in large part by an increase in its profit. In fact, improved profitability helps increase Saudi Arabia's banking efficiency score.

**Figure 2:** Evolution of average X-efficiency scores of Saudi banking sector, 2015-2024

Analysis of these results indicates an improvement in the X-efficiency of the Saudi banking sector. This improvement is evolving from year to year. It has increased from 0.807 in 2015 to 0.934 in 2024. This confirms the adoption of financial technology and good management of the financial system. The average bank efficiency score is around 86%. This means that Saudi banks are 14% inefficient due to inadequate resource management. To reduce the gap with the efficiency frontier, these banks are called upon to optimize their management.

According to Table 2, efficiency levels vary across banks. BSF achieved a very high level of efficiency (0.9717). This means it is well-managed in terms of its internal resources. AJB and RIB also have high levels. This reflects their performance and ability to manage their resources. On the contrary, BHJ, considered to be an average bank, has an average level of efficiency. This allows us to conclude that bank size is a crucial factor in bank performance.

In some years, some banks have reached the efficiency frontier (100%). This shows that they practice optimal management and adaptability of operational practices, which allows them to optimize the allocation of internal resources and reach the efficiency frontier.

Figure 2 illustrates the evolution of the banks' average X-Efficiency score over the period 2015-2024. In 2015, banks recorded an efficiency level of around 83%. This was followed by a remarkable 65% drop in 2016. This decline can be explained by inadequate resource management. The period 2017-2022 is gradually improving. From 2022 onwards, there has been an upward trend in the X-efficiency score, indicating an orientation towards a new operational policy that can be understood in the integration of technology (FinTech) and good cost control.

## 5. CONCLUSION AND RECOMMENDATION

Our study aims to analyze the relationship between X-efficiency and selected banking characteristics such as size, profitability (ROA), total credit-to-asset ratio, and total deposit-to-asset ratio, in Saudi Arabia between 2015 and 2024. To this end, a multiple linear regression was conducted to determine which of these characteristics contributes to improving the efficiency of the banking sector. The Data Envelopment Approach (DEA) was used

to determine each bank's efficiency score.

Our results show an average X-Efficiency score of 86%. This reveals that some Saudi banks are not making optimal use of their internal resources. So, they record an inefficiency of about 14%. They are called upon to improve their management in order to reach the efficiency level (100%).

The results also show that bank size has a positive and significant effect on efficiency. From this result, we can see that the large banks are performing better than the small ones. This can be explained by the employability of technology, which promotes better use of resources.

The ratio of loans granted by the bank also positively affects efficiency. In fact, the more loans a bank grants, the better its performance. Similarly, profitability as measured by ROA plays a central role in improving the efficiency of the banking sector. This means that every profitable bank can manage its resources optimally.

In contrast, the deposit-to-asset ratio has no significant effect on bank efficiency, which may be explained by its modest role compared to other bank assets.

In light of these results, Saudi commercial banks are called upon to master their strategies for managing resource allocations. By integrating technology (FinTech) to optimize their management. This policy aims to reduce the gap with the efficiency frontier.

Some banks have reached the efficient frontier, including NCB Bank, which was on this frontier between 2020 and 2024. In addition to other banks that are distinguished by inefficiency, whose scores do not reach 100%, they had to adopt management policies similar to those of efficient banks.

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## APPENDIX 1

The main commercial banks in Saudi Arabia

Number	Code	Description	Size <sup>a</sup>
1	NCB	National Commercial Bank	Large
2	SAMBA	Samba Financial Group	Large
3	SABB	Saudi Arabia British Bank	Large
4	BSF	Bank Saudi Fransi	Large
5	SAIB	Saudi Investment Bank	Large
6	SHB	Saudi Hollandi Bank	Medium
7	RIB	Riyath Bank	Large
8	ANB	Arab National Bank	Large
9	AJB	Al Rajhi Bank	Large
10	BAJ	Bank Aljazeera	Medium

<sup>a</sup>Size is based on annual bank report