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Technical Efficiency and Productivity of Senegalese Banks : an application by the Data Envelopment Analysis method (DEA)

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Abstract : *The aim of this paper is to assess the performance of Senegalese banks in a context of financial instability and turbulence (speculative bubbles) in the financial markets. As essential components of the WAEMU financial system, banks are called upon to be efficient and productive in the allocation of resources. Methodologically, we used a non-parametric method, in this case the DEA (Data Envelopment Analysis) method to measure the level of efficiency of Senegalese banks. Using the Malmquist index, we determined the total factor productivity as well as its components at the end of highlighting the determinants of overall technical efficiency (TechE) and total productivity (TFP) of said banks. On average, over the entire period (2009-2018), the efficiency score of banks is 60% in REC and 74% in REV. Senegalese banks could increase, on average, their production by 16 to 50% with the same input volumes. This means that there is an underutilization of resources (physical capital, deposits, work) to produce the maximum number of services rendered (loans, investment securities). As for total factor productivity, it increased slightly by 3,2%, attributable to a positive change in overall technical efficiency (TE) of 7,5%. However, Technological Change (TC) saw a slight decline of 0,3%. This translates that Senegalese banks, despite their performance in terms of productivity, do not incorporate enough in their production process, technological progress in the process of better financial inclusion.*

Keywords: *Financial Reforms, Technical efficiency, Prodactivity, Data Envelopment Analysis (DEA), Malmquist Indice, Senegalease Bank Sector.*
J.E.L Classification : C14 ; D24 ; G21.

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I. Introduction

Since the 2000s, banking systems have been characterized by strong, increased and intense competition in the search for resources. Deregulation has explored the monopoly of banks and left the door open to new players who have developed a banking activity on the fringes of their activity. Banks are therefore asked to adapt to this new environment characterized by changes, reforms (Basel II and III) and new financial instruments (derivatives) that can trigger a systemic crisis[2]. More subject to this uncertain environment, banks have to improve their productive efficiency and improve their performance in order to preserve their sustainability (Diop, 2019). Senegalese banks, faced with this requirement, are obligated to strengthen the stability of the banking sector and ensure that the sector contributes more to meeting the financing needs of economic agents. According to some authors, banking efficiency makes it possible to strengthen the resilience of the financial system and even to anticipate a banking crisis (de Lima, 2012).

The efficiency of banks indicates their ability to use a minimum of resources to produce a determined level of production. In practice, there are several methods for measuring the efficiency of banks. There are the traditional tools of financial analysis (Return On Asset ROA, Return On Equaty ROE, Net banking income PNB, etc.) and efficient frontier methods (parametric and non-parametric). However, the analysis carried out through traditional tools has become insufficient today to understand the efficiency of the sector due to financial changes and innovations (Benzai, 2016). Therefore, beyond the accounting aspect, it is wise to look at economic

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[2] A systemic crisis is a financial or economic crisis triggered or provoked in a specific area or economic segment and having the capacity to spread to all economic agents on the planet.
https://www.rachatducredit.com/sous-estimation-lehman-brothers-4554333.html

performance, which highlights the efficient and effective management[3] of the resources available to banks through modern performance assessment methods. Our work is oriented in this direction.

This study focuses on assessing the technical and productive efficiency of Senegalese banks in a context of financial reform and instability. Methodologically, we used a non-parametric method, in this case the DEA (Data Envelopment Analysis) method, to measure the level of efficiency of Senegalese banks. Using the Malmquist index, we determined the total factor productivity and its components in order to highlight the determinants of the technical efficiency and overall productivity of Senegalese banks.

The rest of the paper is organized as follows: Section 2 returns to the presentation and evolution of the Senegalese banking system. Section 3 reviews the literature on theoretical and empirical studies on the performance of network institutions such as banks, as well as the various methods used to assess their productive efficiency. Section 4 presents the analytical framework of the study. The fifth section presents and discusses the results. Finally, section 6 concludes.

II. Presentation and evaluation of the Senegalese banking system

2.1. Presentation of the Senegalese banking system

The financial sector consists of the banking system, the decentralised financial system and insurance companies. The banking system consists of the Central Bank of West African States (BCEAO), secondary or commercial banks and financial institutions. The BCEAO is the common issuing institution of the eight member states of the West African Monetary Union (WAMU). Its main tasks are the issuance of money, the conduct of monetary policy, the management of payment systems and means of payment, the organization and supervision of banking activity and assistance to member states. Secondary banks, financial institutions and decentralised financial systems (DFS) - deposit-taking institutions - are mainly active in financial intermediation. In other words, they contribute to the collection of savings, the granting of credit to companies and individuals, etc. They are also involved in the provision of financial services. Their interventions in the financial sphere are supervised by the BCEAO. As for insurance companies, their main function is to offer insurance on survival or death (life insurance), accident, sickness, fire or other forms of insurance to institutional units (non-life or property insurance). Their main activity is the pooling of risks by guaranteeing the payment of compensation in the event of the occurrence of a risk. The monetary policy stance and instruments were kept unchanged throughout 2018 due to low inflation, buoyant economic activity and the generally favourable inflation and growth outlook. Thus, the minimum bid rate, the marginal lending window rate and the reserve requirement ratio remained unchanged at 2.50% (the level in force since 16 September 2013), 4.50% (the level in force since 16 December 2016) and 3.00% (the level in force since 16 March 2017)[4] respectively. For the past few years, the BCEAO has also been seeking to improve the transmission mechanisms of monetary policy and to correct market malfunctions (money market, interbank market and secondary market for public debt).

2.2. Evolution of the Senegalese banking system

Banking activity at the end of December 2019 remained dynamic with an upward trend[5]. At end-December 2019, the banking sector consisted of two financial holding companies and 29 credit institutions, including 25 active banks, of which 15 were large and 4 medium-sized and 6 small. These credit institutions are located throughout the country through a network of 572 permanent credit counters, with a higher concentration in urban centres.

Moreover, the banking sector, long regarded as one of the major challenges facing the banking system, has seen a marked improvement in activity in 2019. The number of customer bank accounts registered stood at 2,068,470 in September 2019 against 1,859,363 in December 2018, down by 11.2%. Reflecting this trend, the rate of strict bank accounts increased by 2.8 percentage points from 19.0% in December 2018 to 21.8% in September 2019. Indeed, this reflects very dynamic activity by credit institutions compared with 2018. According to provisional statistics pending the annual certified financial statements, the balance sheet total of credit institutions stood at 7,675.0 billion at the end of December 2019, an increase of 425.7 billion (+5.9%) compared to the same period in the previous year (CBWAS 2019 Report).

[3] The terms "effectiveness" and "efficiency" are widely discussed in the economic literature. Although they have a precise meaning for economists, the terms effectiveness and efficiency are often used interchangeably (De La Villarmois, 1998). According to Fare et al (1985), efficiency is defined as the quality or degree achieved in producing a set of desired effects. For an institution, it is the capacity to achieve the objectives it has set for itself with the resources at its disposal. Efficiency, on the other hand, is assessed in terms of productivity, costs and output. It measures the amount of resources used to produce a unit of goods or services at a lower cost (Johnson and Scholes, 1997).

[4] Franc Area Annual Report 2018

[5] Report of the CBWAS's quarterly meeting on the situation of banks 2019

The sector's strong performance is also reflected in a 7.0% improvement in net banking sector employment, which rose from 6,331.2 billion in December 2018 to 6,775.5 billion in December 2019, driven by credits, which rose by 356.3 billion (+8.0%) to 4,803.3 billion. The banks' portfolio is divided into short-term (47.5%), medium-term (44.4%) and long-term (8.1%) loans.

Still in this dynamic upward trend, resources were consolidated at 10.1% to reach 6,254.9 billion in December 2019, in line with the 566.4 billion (+11.7%) increase in deposits collected from customers. As regards banking conditions, base rates were within a range between 6.5% and 9.0%. The average base rate remained stable at 8.2%. The ceilings for bank debtors vary between 11.6% and 14% while the credit rates are between 1% and 8.9%.

Table 1: Simplified balance sheet of the Senegalese banking system *(in billions of FCFA)*

Assets	2015	2016	2017	Liabilities	2015	2016	2017
Treasury and interbank transactions	907	969	803	Treasury and interbank transactions	943	1 330	1 291
Customer transactions	2 965	3 323	3 989	Customer transactions	3 676	4 139	4 509
Securities and other transactions	1 195	1 587	1 590	Securities and other transactions	194	200	262
Fixed assets	322	409	406	Provisions, shareholders' equity and similar	582	620	727
Total	**5 394**	**6 289**	**6 789**	**Total**	**5 394**	**6 289**	**6 789**

Source: Authors; Commission Bancaire WAMU data.

The quality of the banks' credit portfolio has improved. Gross and net delinquency rates in Senegal stood at 13.6 percent (12.9 percent in West African Monetary Union - WAMU) and 7.3 percent (5.6 percent in WAMU) in 2017. In 2018, WAMU adopted a new definition of overdue receivables. Loans that have returned to performing status will be removed from the list of delinquent loans. This new regulation could a priori enable the banking systems of Senegal and other WAMU countries to achieve better portfolio quality. However, the dynamism of banking activity has led to an increase in earnings and profitability. Indeed, the 14.8% increase in net banking income, together with growth in customer and securities transactions, led to a sharp rise in net income. All profitability indicators improved sharply between 2016 and 2017. The information is presented in Table 2 below.

Table 2: Activity indicators of Senegal's banking system *(coefficients and rates in %; amounts in millions of CFA francs (XOF))*

	2015	2016	2017
Net operating ratio ((overheads + depreciation)/GNP)	68,8	69,9	66,3
Profitability ratio (net income/equity)	5,7	7,9	16,5
Net margin rate (net income/net banking income)	10,2	13,5	28,8
Gross delinquency rate (gross overdue receivables/total gross receivables)	16,7	14,0	13,6
Net delinquency rate (net overdue receivables/total net receivables)	10,2	7,6	7,3
Provisioning rate (allowances for overdue receivables/gross overdue receivables)	43,2	49,5	49,7
Net banking income (NBI)	**298 747**	**337 033**	**387 063**
Net income	**30 414**	**45 407**	**111 308**

Source: *Commission Bancaire WAMU data.*

Table 3 shows the evolution of lending and deposit rates for all Senegalese banks. We note, first of all, an increase in lending rates of +28 basis points between the first and second quarter of 2019. For its part, the average deposit rate rose in the second quarter of 2019, reaching 5.05% compared to 5.48% in the previous quarter.

Table 3: Trends in lending and deposit rates in the Senegalese banking system

	2017				2018				2019	
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
Lending rates	**5.69**	**5.93**	**5.94**	**6.29**	**5.79**	**5.81**	**5.71**	**6.21**	**5.56**	**5.84**
Loan rates	**4.92**	**5.32**	**5.17**	**5.46**	**5.41**	**5.29**	**5.65**	**5.46**	**5.48**	**5.05**

Source*: Authors using data from the WACB 2020*

Financial inclusion, despite the notable progress made in recent years, remains insufficient in Senegal as in other WAMU countries. The percentage of the adult population over 15 years of age holding an account is around

42% (43% in Sub-Saharan Africa - SSA) according to World Bank statistics. This rate was 15% (34% in SSA) in 2014 and 6% (23% in SSA) in 2011.

III. Literature review

3.1. Concepts of efficiency and productivity

3.1.1. Productive efficiency

Early work on the effectiveness of an entity can be attributed to Koopmans (1951) and Debreu (1951). Koopmans was the first to propose a formal definition of the concept of efficiency: "a producer is technically efficient if an increase in any output requires the decrease of at least one other output or the increase of at least one input, and if a reduction in any input requires the increase of at least one other input or the reduction of at least one output". Debreu (1951) was the first to empirically measure efficiency. However, it was Farell (1957) who gave it a clear definition under the name "concept of economic efficiency". He was inspired by Koopmans' formal definition and Debreu's technical measure of efficiency (Murullo-Zamorano, 2004). It thus distinguishes between the concepts of technical efficiency and allocative efficiency (Dannon, 2009). Technical efficiency reflects a firm's ability to obtain maximum output for a given level of input. Under these conditions, allocative efficiency reflects the ability of managers to choose among technically efficient production programs, the one that ensures the highest profit, or if one prefers, the ability to choose inputs in optimal proportions (CEMAC, 2009).

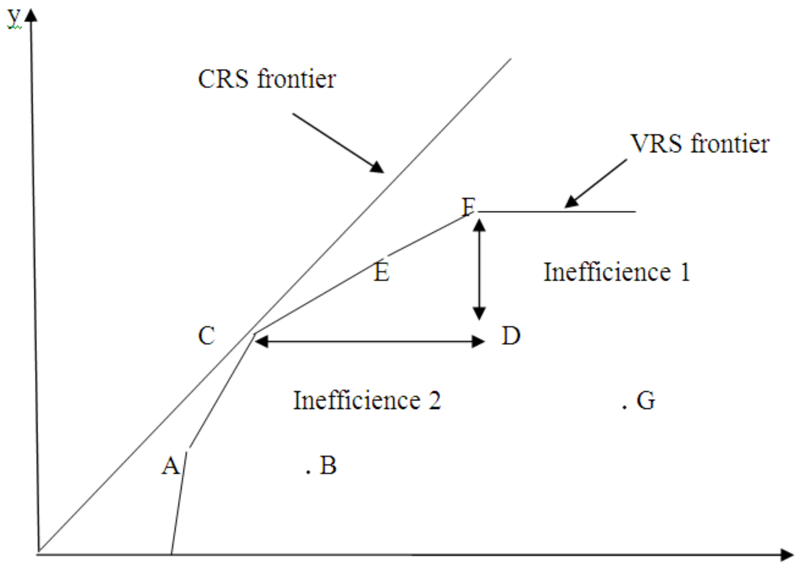
A combination of these two types of efficiencies provides a measure of economic efficiency or total efficiency (Keita, 2007). Under the cost-minimization assumption, allocative efficiency can be measured by the ratio of technical efficiency to cost efficiency.

➢ ***Input oriented measure and output oriented measure approaches***

The notion of efficiency in economics, as developed by Farell (1957), refers to minimizing the inputs used by a firm to produce a given level of output or maximizing the quantities produced by a set of inputs in a given state of technology (Toçi, 2009). According to Farell (1957), the measure of efficiency is defined as the maximum of the equiproportionate reduction of all inputs that allow for continuous production of a given output (Kablan, 2007). Thus two approaches emerge: the "output oriented measure" concept and the "input oriented measure" concept.

An input-oriented efficiency measure aims to minimise costs. Conversely, an output-oriented efficiency measure aims to maximise income (Fama, 2007). In both cases, efficiency measurement requires the comparison of observed and optimal values of production, cost, income, profit, etc. (Fama, 2007). The degree of efficiency of the production unit is given by the ratio of maximum feasible output (in the case of a production target) and this maximum feasible output is given by the production frontier (Dannon, 2007).

Figure 1 : Production frontier and Scale efficiencies[6]



Source : Dannon, 2009.

[6] Source: Dannon, 2009.

Consider the example illustrated by the diagram below, based on a simplified technology, producing an output from an input, assuming an input-oriented approach. The first hypothesis (CRS) is used to calculate the overall technical efficiency (ETG) of point A, given by the distance between points C and A. The VRS hypothesis, on the other hand, leads to the pure technical efficiency (FTE) from points B and A. Both hypotheses result in a technical efficiency due to scaling, which is the ratio between overall and pure efficiency, so that overall technical efficiency (CRS hypothesis) ultimately comprises two components, namely pure efficiency (VRS) and scaling efficiency (Chabalgoity et al, 2005).

3.1.2. Banking productivity and the Malmquist index

Productivity can be defined as the ability of a production unit to transform a given quantity of inputs into outputs. While the concept is relatively simple to define, it is not easy to concretely measure changes in productivity, which has led to a large body of economic literature (Dannon, 2009).

Productivity is usually measured as an output quantity index divided by a factor quantity index. Such indices are necessary because of the heterogeneity of goods and services, which makes it impossible to simply add up units of different product categories. A multifactor productivity index indicates the change in an index of quantity of output relative to an index of quantity of factors.

However, Malmquist indexes have proven to be the most widely used in the economic literature (Igué, 2006). There are three reasons for the preference for Malmquist indices (Grifell-Tatjé and Lovell, 1996). First, these indices require data on quantities only. This is a considerable advantage in cases where price information is not available, or where prices are influenced by distortions of competition. Secondly, they are based exclusively on the assumption of output maximisation for a given level of inputs. Finally, the advantage of this index is that it presents changes in total factor productivity in two main components: the first relates to changes in the technical efficiency of units, the second relates to technological change (Kablan, 2007; Dannon, 2009; Toci, 2009).

- ***The Malmquist Productivity Index and its components***

It is a measure of productivity change that takes into account both movements in the production frontier and the extent to which agencies or institutions are moving closer to that frontier (Dannon, 2009). Efficiency frontiers are not static over time since production technology can change, causing positive or negative changes in the practice of the best efficiency frontier (Toçi, 2009). Border shifts can result from technological progress that simplifies processes, innovations such as the introduction of new banking products and services, shocks to the economy, financial crises, changes in regulations, etc., (Dannon, 2009; Toçi, 2009). Thus, productivity is determined by both the efficiency of the production process and the type of technology used. The results of the DEA method (see Non-parametric approach) may show that there is no substantial improvement in average efficiency in the banking sector, which does not necessarily mean that productivity has declined.

Shephard (1970) and Fare et al. (1994) defined the output-oriented Malmquist index of change in productivity as follows :

$$M_0(Y_{t+1}, X_{t+1}, Y_t, X_t) = \left[\frac{d_{ot}(Y_{t+1}, X_{t+1})}{d_{ot}(Y_t, X_t)} * \frac{d_{ot+1}(Y_{t+1}, X_{t+1})}{d_{ot+1}(Y_t, X_t)} \right]^{1/2} \quad (1)$$

Equation (1) conceptualizes Malmquist's total factor productivity (TFP) index. It measures the change in TFP between two points by calculating the ratio of the distances of each point relative to a common technology. It can be seen that this equation is the geometric mean of the two TFP indices. The change in TFP could just as easily have been measured with reference to the technology of the period t or with reference to that of the period t+1, by making an arbitrary choice on the technology to be used. The distance function calculated from geometric averages makes it possible to take account of the technology available in the two periods respectively. The first index is calculated on the basis of the technology in period t, and the second index is calculated on the basis of the technology in period t+1. If Mo>1, there is a positive change in TFP between periods t and t+1. Conversely, if Mo<1, then there is a decline in TFP.

Equation (1) can be rewritten as follows by decomposing TFP into technological progress (TP) and overall technical efficiency (ETG)[7] :

$$M_O(Y_{t+1}, X_{t+1}, Y_t, X_t) = \frac{d_O^{t+1}(Y_{t+1}, X_{t+1})}{d^t{}_O(Y_t, X_t)} * \left[\frac{d_O^t(Y_{t+1}, X_{t+1})}{d_O^t(Y_{t+1}, X_{t+1})} * \frac{d_O^{t+1}(Y_t, X_t)}{d_O^{t+1}(Y_t, X_t)} \right]^{1/2} \quad (2)$$

[7] Coelli (1996)

The term $\frac{d_O^{t+1}(Y_{t+1}, X_{t+1})}{d_O^t(Y_t, X_t)}$ measures the relative change in technical efficiency, which is the difference between the observed output and the potential output. It is equivalent to the ratio of the measure of technical efficiency as defined by Farell (1957) in period t+1 to its technical efficiency in period t. This term represents the change in technical efficiency (TE). TE shows how far a unit is from the best practice frontier in the sample. Like Farrell, based on constant efficiency of scale, Fare et al. (1994) propose to decompose technical efficiency into "pure technical efficiency" (FTE) and "efficiency of scale" (EE). Efficiency of scale refers to the size of the production unit. Inefficiency of scale indicates an inadequate size of the production unit. Pure technical inefficiency, on the other hand, refers to the sub-optimal use of resources by the managers of the production unit. The FTE is obtained by calculating efficiency indices under the assumption of variable returns to scale (VRS). For the efficiency of scale index, it is the ratio between technical efficiency under the constant returns to scale (ROSC) assumption and technical efficiency under the variable returns to scale (VRS) assumption.

The second term in the equation $\left[\frac{d_{Ot}(Y_{t+1}, X_{t+1})}{d_{Ot+1}(Y_{t+1}, X_{t+1})} * \frac{d_{Ot+1}(Y_t, X_t)}{d_{Ot+1}(Y_t, X_t)}\right]^{1/2}$ measures technological change or innovation in the sector between the two periods. It represents the geometric mean of the technology shift (boundary shift) between periods ***t*** and ***t+1*** and is evaluated at points $\mathbf{X}_{t+1}$ and $\mathbf{X}_t$.

Similarly, the distance function can be defined with an input orientation. Always keeping the technology of period t as a reference, the Malmquist index is as follows :

$$M_I(Y_{t+1}, X_{t+1}, Y_t, X_t) = \left[\frac{d_I^t(Y_{t+1}, X_{t+1})}{d_I^t(Y_t, X_t)} * \frac{d_I^{t+1}(Y_{t+1}, X_{t+1})}{d_I^{t+1}(Y_t, X_t)}\right]^{1/2} \quad (3)$$

The decomposition of the index into technical efficiency and technological change, between the two periods, is done according to the same principle as before and the terms are interpreted in the same way.

Whether output-oriented or input-oriented, the Malmquist index includes four distance functions to be estimated (Keita, 2007, Mbaye et al, 2010) : $d_O^t(X_t, Y_t)$; $d_O^{t+1}(X_{t+1}, Y_{t+1})$; $d_O^t(X_{t+1}, Y_{t+1})$; $d_O^{t+1}(X_t, Y_t)$. Each component measures a specific relative efficiency. Two other distance functions are needed to decompose technical efficiency (BER) into pure technical efficiency (REV) and scale efficiency (Mbaye and Agbodji, 2010). These two distance functions correspond to estimate $d_O^t(X_t, Y_t)$ and $d_O^{t+1}(X_{t+1}, Y_{t+1})$ with convexity restriction to have a measure of efficiency relative to a variable efficiency of scale technology.

Several methods can be used for their empirical application and calculation of efficiency scores. We will focus here on the DEA method, which is a non-parametric approach to efficiency.

3.2 The Non-Parametric Approach to Effectiveness: An Overview of the DEA Data Envelope Methodology

The non-parametric approach includes two of the most widely used methods, which are, according to Perelma (1996), Chaffai (1997), Berger and Humphrey (1997) and de La Villarmois (2002), an extension of Farell's (1957) model: « *Data Envelopment Analysis* » **(DEA)** and « *Free Disposal Hull* » **(FDH)**. The essential characteristic of non-parametric methods is that they do not impose a particular specification of the production, cost or profit function. The literature reveals that the DEA method is the most widely used. According to Dannon (2009), this popularity stems from its versatility and ability to accommodate a range of possible technologies. We will provide an overview of this method, its advantages and limitations as well as the results of empirical studies.

3.2.1. How the Data Envelope Approach (DEA) Works

The DEA method is an extension of the work of Farell (1957) whose measurement of efficiency is therefore based on a single input and output.

Let n decision-making units (Decision Management Unit: DMU) be evaluated. Each of them consumes variable amounts of m different inputs to produce s different outputs. The $\boldsymbol{DMU_j}$ ***(j = 1,…, m)*** consumes $X\{ij\}$ number of inputs ***(i = 1,…, m)*** and produces $Y\{rj\}$ amount of outputs ***(r = 1,…, s)***. The weighting system must assign the best possible score to the under-evaluated decision unit, under the constraint that no other unit is declared over-efficient with this same weighting system, which leads to the writing of the following linear program :

$$Max_{u,v} \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}} \quad \text{s/c} \quad \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_j x_{ij}} \leq 1 \forall j \qquad (4)$$

With respectively:
s = number of outputs; ***j*** = the index of the decision units ***(1, ..., n)***, the index o corresponding to the undervalued unit; u_r = weighting coefficient of output r to be determined; y_{ro} = quantity of output r produced by the enterprise; ***m*** = number of inputs; v_i = weighting coefficient of input i to be determined; x_{io} = quantity of input i used by the enterprise; y_{rj} = the production of good ***r*** by unit ***j***; x_{ij} = the allocation of factor ***i*** to unit ***j***.

The equation below as formulated is based on constant returns to scale. The efficient frontier is thus obtained with a score equal to 1, although the weights of the input and output variables can be defined in order to determine the efficient production area from a subset of the n DMU (Dannon, 2007). To do so, four models were identified by Badillo and Paradi (1999): the CCR model (Charnes, Cooper and Rhode,), the BCC model (Banker, Charnes and Cooper,), additive models and multiplicative models. We will limit ourselves to summaries of the first two models.

The DEA method is an extension of the work of Farell (1957). The measure of efficiency as formulated by Farell (1957) is based on a single input-output (Murollo-Zamorano, 2009). It is generalized to a multiple input/output case and reformulated as a mathematical programming problem by Charnes, Cooper, and Rhodes (1978) and Banker, Charnes, Cooper (1984) (we will see how the two models work in the methodology). This method is based on the concept of production technology developed by Shephard (1970).

The aim was to represent the activity of the entities studied on the basis of the relationship between all the resources used (inputs) and all the services produced (outputs). The indicator thus calculated is the "technical inefficiency score".

3.2.2. Advantages and limitations of the method

There are a number of factors that could explain the success of the DEA method. Indeed, the DEA method has the advantage of :

- Well measuring the effectiveness of human activities beyond the limits of traditional productivity measures (Halkos and Salamouris, 2004; Hubrecht, 2005)
- Allow operationality of the results, particularly in terms of individual observations (Dannon, 2009) ;
- It is of great managerial interest because it allows a synthetic measurement of the performance of organizations that use multiple resources (input) to generate multiple results (output) (Hubrecht and Guerra, 2004);
- Identify and qualify the units of reference that define the efficiency frontier (Dannon, 2009);
- Do not impose any preconceived structure on the data when calculating efficiency scores (Berger and Humphrey, 1997; Avkiran, 1999)[8];

However, this method has some limitations that are important to note. The DEA method ignores measurement errors (Mester, 1996). It does not handle noise and does not wrap the data as in an econometric model (Kablan, 2007). One limitation of this method is that a unit is only considered efficient if it is compared to other units in the sample. Similarly, a unit deemed efficient necessarily produces, relative to others in the sector, the maximum output from a given level of input (Kablan, 2007). Thus, as Dannon (2009) points out, there may be units outside the sample that are more efficient than the best unit in the sample.

3.2.3. The results of applied studies in the banking sector

This literature review will focus on the application of the DEA method for measuring technical efficiency by distinguishing between input and output orientation. We will not fail to identify the various determinants that explain this effectiveness.

3.2.3.1. The first applications of AEDs with the CER hypothesis

The DEA method was widely used, in its early development, in efficiency studies based solely on the assumption of constant returns to scale (CRS). Several studies have been done, such as Sherman and Gold (1985) in the United States. Among them is Yue (1992), who studies the efficiency of 60 Missouri banks over

[8] Thus, the method gives the analyst the latitude to choose the variables (inputs and outputs) according to the managers' objectives. Moreover, according to Dannon (2009), these variables are generally physical quantities. From this point of view, the method has an advantage over financial measures that integrate the price of inputs and outputs, which does not always correspond to the market price.

the 1990-1994 period using the intermediation approach[9]. These results show that most of the observed inefficiencies are due to high pure technical efficiency (FTE), which is essentially a waste of resources. The same conclusions can be found in the study by Grabowski et al. (1994) on a sample of 670 U.S. banks between 1979, 1983, and 1987. Another analysis of the productivity of U.S. commercial banks with assets over US$500 million was done by Semenick (2001) between 1980 and 1989. He divides the banks studied into (i) those with a broad possibility of having U.S.-wide subsidiaries, (ii) those with limited possibility, and (iii) those with no possibility at all. Their results show that, during the 1980s, the three groups of banks had aggregate productivity growth rates of 4.6%, 3.2% and -0.3% respectively (Semenick, 2001). These results indicate that banks facing severe constraints on the establishment of subsidiaries experience lower productivity growth than those facing much more relaxed regulations in this area. These results corroborate the findings of a previous study by Tirtiroglu, Daniels and Tirtiroglu (1998) over the period 1946-1995. In that study, these authors highlighted the overall negative impact of regulation on total factor productivity growth of U.S. commercial banks (Dannon, 2009).

In Europe, Pastor et al, (1997)[10] compare the efficiency of several European banks with that of American banks over the year 2012. Using the assumption of constant returns to scale (CRS), their study shows that French banks are the most efficient (average technical efficiency estimated at 95%), followed by Spanish, then Belgian, Italian, German, American, Austrian and English banks. On the other hand, these authors underline the low productivity of French banks[11].

The latter are, in fact, in the penultimate position just ahead of the Spanish banks. Dietsch and Weill (1997) apply the DEA method to 93 French deposit banks. The outputs include staff costs, other non-financial expenses and, where appropriate, interest paid. The outputs used are loans, sight deposits, savings and time deposits and, optionally, other interest-bearing assets. They achieve an average technical efficiency of between 78% and 91% depending on the output combination selected.

Grigorian and Manole (2002) use the assumption of constant returns to scale (CRS) to assess the efficiency of banks in Eastern European transition countries following technological changes in the banking industry. They rely on the value-added approach, which considers as output any element with a substantial absolute value[12]. Their study is then used to provide answers on the effectiveness of policies to restructure the banking system in transition countries following the liberalisation of the financial system.

3.2.3.2. Recent studies using the ASR hypothesis

Kablan (2007) notes that, more recently, the assumption of variable returns to scale (VRS) has been adopted, as this is more consistent with the imperfect competitive environment in which banks operate. Similarly, Berg, Forsung, Suominen (1993)[13] study the productivity of banks in the Scandinavian countries (Finland, Sweden and Norway). They use the DEA method with successively variable (VRS) and constant (CRS) returns to scale assumptions. The first hypothesis is the most adapted to the environment in which banks operate, and therefore allows for more robust scores to the wrong specification. The second, on the other hand, makes it possible to compare large banks with smaller ones and prevent the former from appearing artificially efficient (Kablan, 2007).

In developing countries, especially African countries, the performance of the banking sector is much studied across the non-parametric boundary. Igué (2006) used the non-parametric DEA approach to measure changes in factor productivity and technical efficiency of WAEMU banks. The study period is from 1990 to 2002. The analysis of the Malmquist indexes of the evolution of productivity revealed an increase in productivity over the period. This increase is exclusively attributable to the improvement in technical efficiency in the case where "credits" are considered as the only banking output or attributable to both the increase in technical efficiency and technological progress if "investment securities" are introduced as the second output. We find that in both cases technical efficiency has improved over the period. According to Dannon (2009), this increase in technical efficiency thus invalidates the hypothesis of a deterioration in banking efficiency, which deregulation should induce.

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[9] Inputs are financial expenditure, non-financial expenditure, demand deposits and other types of deposits. Outputs are interest income, non-interest income and loans.

[10] Pastor, Pérez and Quesada (1997) and Dietsh and Weill (1997) were the first to use the DEA method on French banking data (Dannon, 2007).

[11] This study shows that French banks manage to avoid wasting resources, but their ability to transform a quantity of inputs into outputs remains low.

[12] With the value-added approach, deposits will be perceived as output, as the bank makes a net gain by collecting deposits (Kablan, 2007).

[13] Cited by Kablan (2007).

Kablan (2007), in his study on the measurement of "Performance of developing banks: the case of WAEMU", uses the Data Development Approach (DEA) to capture the technical efficiency of the union's banks between 1996 and 2004. The degrees of efficiency are of the order of 0.76 and 0.85 for the technical efficiency respectively CRS and VRS. In general, the estimated efficiency levels increase during the study period, except for Côte d'Ivoire and Burkina Faso, where divergent trends in technical efficiency are observed. A more detailed analysis (by group of banks) shows that local privately-owned banks are the most efficient, followed by foreign banks and then state-owned banks with the lowest technical levels. Overall, the results show that technical efficiency is due more to economies of scale than to the banks' incorporation of technological innovations during the study period[14]. Despite what may be considered positive about these innovations, the low degree of bankization in the countries of the region (3.02%) and its implications make the incorporation of these innovations unproductive.

Dannon (2009) also focuses on the efficiency and productivity of banks in the WAEMU zone in the context of financial reforms. He estimates the model using the DEA method over the period 1996 to 2006. The results show that pure technical inefficiencies dominate scale inefficiencies in all countries except Senegal. Thus, inefficiency is more a matter of under-utilization of inputs than of inadequate returns to scale. The study also shows that total factor productivity (TFP) has improved mainly due to positive variation in technological progress (same results for Igué, 2006; Raghui and Romdhan, 2002). It finds that financial reforms do not appear to have improved the technical efficiency of banks, as their productivity levels are explained by changes in technology rather than in efficiency. There is thus a difference between the results found by Dannon and those found by Kablan on the study of efficiency at the level of WAEMU countries.

Mbaye and Agbodji (2010), in their article "Measurement and analysis of the productive performance of banks in the WAEMU zone" between 1996 and 2007, used the REC hypothesis with an efficiency score of 80% and an average increase in productivity of around 2.3%. Contrary to previous studies, their study showed that the average increase in productivity is attributable to a 6.4% increase in technical efficiency and to a lesser extent to an increase in technology. This can be explained by the difference in approach and variables used. However, these performances noted in their study are not identical from one country to another. We will use this literature to develop the analytical framework for the study.

IV. Method of analysis

We will first present the two models concerning the DEA method (CCR and BCC) before looking at the different approaches to bank output and the choice of variables to be estimated.

4.1. The CCR model

The CCR model was developed by Charmes, Cooper and Rhodes in 1978. It is based on the Input Oriented Approach (IOA) and the returns to scale are assumed to be constant (RSC). Thus, for each unit k, the equation amounts to maximizing the efficiency ratio in the presence of ***s*** outputs and ***m*** inputs. Let the following expression of the equation be used:

$$Max_{u,v} \frac{\sum_{r=1}^{s} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}} \qquad s/c \begin{cases} \dfrac{\sum_{r=1}^{s} u_r y_{rj}}{\sum v_i x_{ij}} \leq 1 \\ u_r, v_i \geq 0 \end{cases}, \quad j=1,\dots, n \text{ (number of units)} \qquad (5)$$

To simplify the writing, let u = $\sum_{r=1}^{s} u_r y_{rk}$ and v = $\sum_{i=1}^{m} v_i x_{ik}$. We will have :

$$Max_{u,v} \ (uy_i / vx_i) \qquad s/c \begin{cases} uy_j / vx_j \leq 1 \\ u, v \geq 0 \end{cases}, \quad j = 1,\dots, n. \qquad (6)$$

Where ***u*** is a vector (M1) and ***v*** is a vector (K1).

This implies finding the values of u and v, such that the measure of the efficiency of the i^{ème} firm is maximized, under the constraints that all efficiency measures are less than or equal to 1. A problem with this particular ratio

[14] According to Dannon (2009), these technological changes should logically allow banks in these countries to increase in speed, quality and access to services.

formulation is that there are infinite solutions (Mbaye and Agbodji, 2010)[15]. To avoid this, we can pose $vx_i = 1$, which gives :

$$Max_{u,v}\ (uy_i) \quad \text{s/c} \begin{cases} vx_i = 1 \\ uy_j - vx_j \leq 0\ , \quad j = 1,\ldots, \\ u, v \geq 0 \end{cases} \tag{7}$$

4.2. The BCC model

The BCC model (Banker, Charnes, and Cooper 1984) focuses on returns to variable scales. It introduces new variables into the BCC model, allowing a distinction to be made between scale efficiency and technical efficiency (Dannon 2009). The formulation of the model is as follows:

$$Max_{u,v}(uy + c_k) \ \text{s/c} \begin{cases} vx_i = 1 \\ uy_j - vx_j - c_0 \leq 0\ ,\ j = 1,\ldots, n. \\ u, v \geq \varepsilon \end{cases} \tag{8}$$

The form shown above, whether the CCR or BCC model, is known as the "multiplicative form" of linear programming. By using the dual form of linear programming, an equivalent form can be derived from this wrapping problem (Mbaye and Agbodji, 2010) :

$$Max_{\theta,\lambda}\theta \quad \text{s/c} \begin{cases} -x_{io} + X\lambda \geq 0 \\ \theta y_r - Y\lambda \geq 0 \\ \lambda \geq \varepsilon \end{cases} . \tag{9}$$

Where is θ a scalar and λ is a vector of constants.

The value obtained θ will be the degree of efficiency of the $i^{ème}$ firm. To account for variations in economies of scale (BCC model), the convexity constraint N1' $\lambda = 1$ (or $\sum_{j=1}^{n} \lambda_j = 1$) can be added to give the following program :

$$Max_{\theta,\lambda}\theta \quad \text{s/c} \begin{cases} -x_{io} + X\lambda \geq 0 \\ \theta y_r - Y\lambda \geq 0 \\ N1'\lambda = 1 \\ \lambda \geq \varepsilon \end{cases} \tag{10}$$

Where N1 is a dimensional unit vector (N*1).

In our model, we will estimate technical efficiency across a non-parametric frontier (DEA) oriented towards output maximization and under the assumption of constant and variable returns to scale (Kablan, 2007). The choice in favour of this type of model is justified by the fact that the assumption of variable returns to scale[16] is indisputably the most appropriate assumption in the case of banks (Hubrecht et al, 2005; Kablan, 2007; Keita, 2007). In terms of the output maximization orientation, this choice has the advantage of generating the maximum output for the available resources. Indeed, Senegal's economy is marked by a financing deficit of small and medium enterprises, but also by a low bank rate of 19% (Hubrecht et al, 2005; Kablan, 2007; Keita, 2007). With regard to the output maximisation orientation, this choice has the advantage of generating the maximum output for the available resources. Indeed, Senegal's economy is marked by a financing deficit for small and medium-sized enterprises, but also by a low bank penetration rate of 19%[17]. We therefore find it more plausible to assume that domestic banks should seek to maximize the supply of services rather than seek to minimize the resources available to them. Moreover, in the particular context of the WAEMU, where the financial market is not too developed (10 per cent of the zone's GDP), the collection of savings is proving to be

[15] Indeed, if (u*, v*) is one solution, then (au*, av*) is another solution.

[16] The hypothesis of variable returns to scale requires the acceptance of a long-term vision where the size of the decision units evaluated can be modified. In contrast, under constant returns to scale, the reasoning takes place in the short term, and the size of the entities studied is assumed to be fixed (Hubrecht, Dietsch and Guerra, 2005, p18).

[17] Information note 4th quarter 2018, No. 56 - CBWAS.

of great importance for banks in granting credit. It is therefore not strategic for them to seek to reduce this activity.

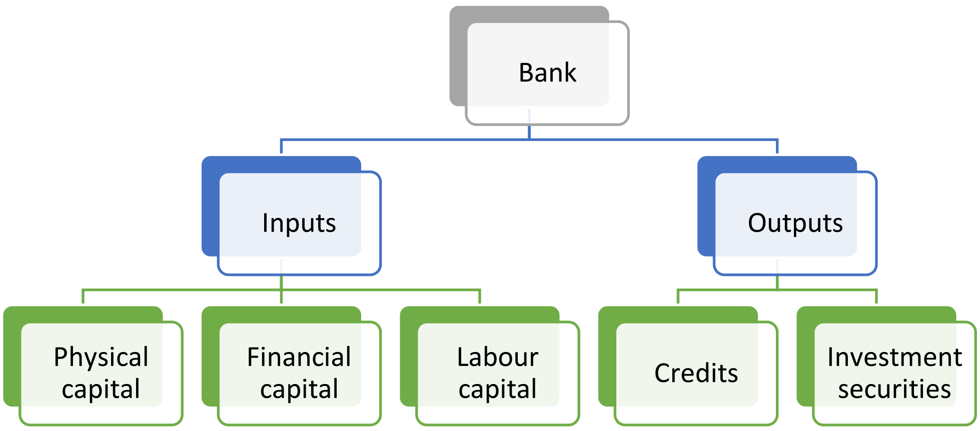
4.3. Presentation choice of variables and data sources

In the banking production process, the choice of variables and their measurement poses a complex problem. The definition of inputs and outputs depends on the approach chosen. The literature identifies three main approaches to defining banking production: the production approach, the intermediation approach and the value added approach. It should be noted, however, that the first two approaches are the most discussed and their main difference lies in the classification of deposits into inputs or outputs. For the value added approach, it can be associated with one of these two approaches. In our study, we will use the intermediation approach.

It characterizes the bank as a financial intermediary whose role is to use capital, labour and deposits to provide loans and investments. Developed by Sealey and Lindlay (1977), the intermediation approach takes into account the financial dimension of the bank's operations. The bank's operations are viewed from a more financial perspective. From this perspective, banks are seen as financial intermediaries and not simply as producers of loan and deposit services.

With this approach, deposits form a basis for production, as they are necessary for the granting of loans. Therefore, these deposits are inputs while the value of loans granted and other assets represent outputs.

Figure 2: Presentation of Inputs and Outputs according to the intermediation approach



4.3.1. Inputs used by all banks

The three inputs we selected to evaluate the banks represent the traditional factors of production for any production unit (PU), namely :

- Physical capital: this can be measured by net fixed assets and leasing transactions or other fixed assets. It can also be approximated by the real estate area of branches and by the costs of supplies or by the net book value of machinery and equipment. For our part, we estimate physical capital through net tangible and intangible fixed assets;
- Financial capital: various indicators have been used to measure the financial capital of banking institutions. Some authors have measured it through the funds collected, including term and savings deposits, while others have used demand and term deposits, both bank and non-bank. It is also possible to use financial charges ;
- Labour capital: as it is difficult to access data on staff costs for all the banks in the sample, we have chosen general operating expenses to introduce this factor. Since a large proportion of these expenses is made up of staff costs, we have chosen general operating expenses to introduce this factor.

4.3.2. Outputs produced by all banks

According to the intermediation approach, banking output can be broken down into two primary activities: credit distribution and portfolio investment (Leighter and Lovell, 1998; Rouabah, 2002). Some authors (Weill, 2006; Gutierriez-Nieto et al., 2007) use the number of borrowers or the volume of loans measured by average gross credit outstanding as output variables. The latter can also be defined by the income statement: net financial income (Yue, 1994; Tripe, 2004). In this case, business volume is expressed in terms of turnover measured in the banking sector by interest and commission income or, in a broad sense, by total operating income (Sturm and Williams, 2005; Wélé, 2008).

For our model, we have retained in the credit item, loans to bank and non-bank customers (Avkiran, 2006; Kablan, 2007) and investment securities are measured by the securities of other credit and non-bank institutions, i.e. companies and individuals (Kablan, 2007; Mbaye and Agbodji, 2010).
The presentation of the descriptive values of inputs and outputs is presented in the appendix.

4.3.3. Source of data

To carry out our study on the technical efficiency of Senegalese banks from 2009 to 2018, we used accounting data from the publishable balance sheets of 17 banks in the official gazette, various issues of the "Balance sheets of WAMU banks and financial institutions", reports of the WAMU banking commission and the Central Bank's statistical yearbooks. For this purpose, we used the data available on the CBWAS website, but also from the Research and Statistics Department of the CBWAS Agency in Dakar. The use of these different sources of data is justified by their complementarity, but also to make up for shortcomings in the time series of banking variables.

V. Estimation and discussion of results

In this section, we analyze the efficiency and productivity results obtained by the application of the DEA technique. We will first analyze the technical efficiency levels of Senegalese banks over the entire study period. Secondly, using the Malmquist Index, we will analyze the total factor productivity and its components according to the banks, but also its evolution over time. Finally, we will determine the internal, external and macroeconomic factors in technical efficiency.

5.1. Analysis of the technical efficiency scores of Senegalese banks

The technical efficiency of Senegalese banks over the period 2009 to 2018 is analyzed under the assumption of constant returns to scale (CRS) and under the assumption of variable returns to scale (VRS), which is more in line with the environment in which the banks operate. Table 3 summarises the scores obtained by banks in the zone under the two assumptions respectively.

Table 4: Technical efficiency levels under the CSR and VSR assumptions between 2009 and 2018

Year	Technical efficiency in CSR	Technical efficiency in VSR
2009	0.603	0.714
2010	0.509	0.596
2011	0.621	0.729
2012	0.602	0.721
2013	0.625	0.735
2014	0.647	0.766
2015	0.576	0.719
2016	0.587	0.757
2017	0.646	0.840
2018	0.614	0.824
Average	**0.603**	**0.740**

Source : *Calculated by the authors from the estimates provided by Stata 14 (Cf. Annex)*

On average, over the whole period, the efficiency score of banks in the zone is 60% in BER and 74% in REV. Average efficiency scores range from 50% to 84%. In other words, Senegalese banks could increase, on average, their output by 16 to 50% with the same volumes of inputs. The efficiency scores under the REV hypothesis appear higher than those under the REC hypothesis over the entire period. Over the study period, there is also an upward trend from 2010 in the evolution of efficiency levels in REC and REV, which decreases from 2014 and increases from 2016.

Table 5: Level of technical efficiency according to banks under the BER and REV assumptions

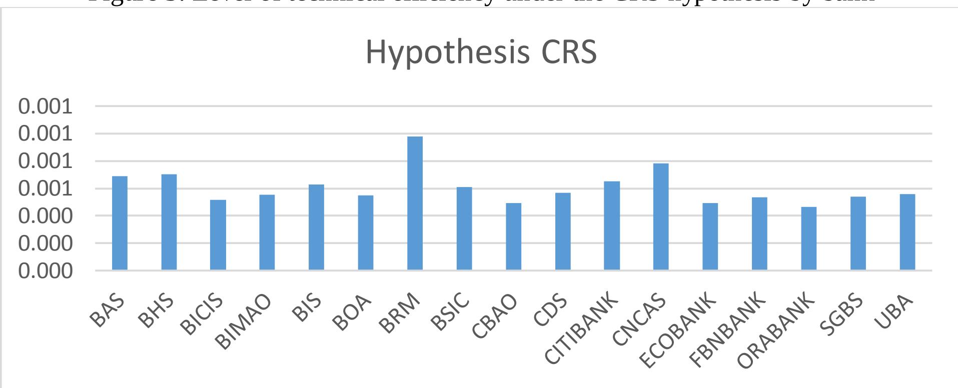
Bank	Constant return to scale (CRS)	Variable return to scale (VRC)
BAS	0.688	0.763
BHS	0.701	0.868
BICIS	0.517	0.742

BIMAO	0.556	0.646
BIS	0.629	0.743
BOA	0.547	0.646
BRM	0.980	0.990
BSIC	0.608	0.653
CBAO	0.491	0.878
CDS	0.570	0.611
CITIBANK	0.650	0.696
CNCAS	0.784	0.850
ECOBANK	0.494	0.783
FBNBANK	0.535	0.683
ORABANK	0.466	0.512
SGBS	0.540	0.939
UBA	0.558	0.648
Average	**0.607**	**0.744**

Source: *By the authors based on the results provided by Stata 14.*

According to the banks, there is an average heterogeneity in efficiency levels. Indeed, the BRM presents the highest scores over the whole period with 98% and 99% respectively in CRS and VRS, ORABANK the lowest scores with 46.6% and 51.2 respectively in CRS and VRS.

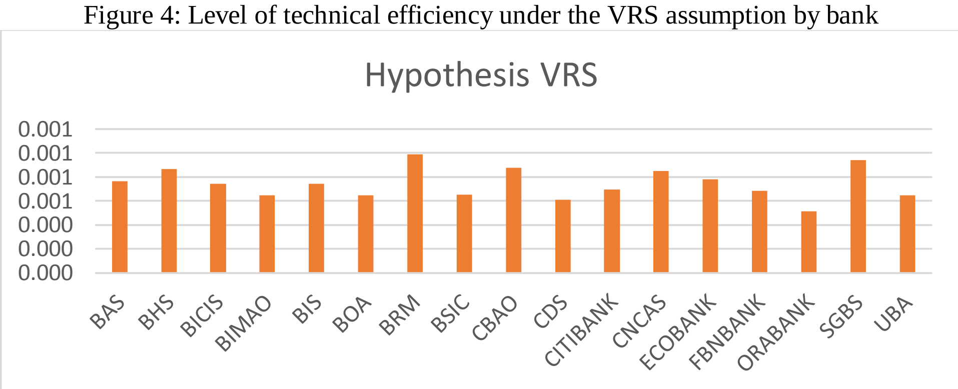
Figure 3: Level of technical efficiency under the CRS hypothesis by bank



Source : Auteurs

The hypothesis under the constant return to scale shows us the BRM with the score of 98%, followed by the CNCAS with 78.4% and the BHS with 70.1% thus holding the highest scores. The lowest scores are held by ECOBANK with 49.4%, CBAO with 49.1% and ORABANK with 46.6%.

Figure 4: Level of technical efficiency under the VRS assumption by bank



Source : Authors

Analysis under the variable return to scale hypothesis shows BRM leading with a score of 99%, followed by SGBS with 93.9% and CBAO with 87.8%. The lowest scores are recorded by BIMAO with 64.6%, BOA and ORABANK with 51.2%. These results under the VRS hypothesis reflect the reality and performance of Senegalese banks more than under the CRS hypothesis.

After calculating the technical efficiency scores, one should look up the Malmquist Productivity Index to see the decomposition of overall technical efficiency and total factor productivity.

5.2. Analysis of total factor productivity and its components by country

Table 4 provides the results, by country, of the overall technical efficiency (OTE) relative to the model and the associated productivity measures: the Malmquist index (PGF), pure technical efficiency (PTE), the efficiency of scale (ES) and technological progress (TP). Values greater than unity indicate an improvement in productivity or efficiency, while values below unity indicate deterioration.

Referring to Table 5, it appears that overall technical efficiency (OTE) increased slightly by 7.5 per cent for all banks over the study period. This growth is attributable to scale efficiency (SE), which increased by 6.3 per cent. This means that Senegalese banks were able to exploit economies of scale during the study period.

The total factor productivity (TFP) index rose by 3.2%. This increase is due more to overall technical efficiency (OTE) than to the incorporation of technological change (TC). In fact, technological change fell slightly by 0.3% over the entire period, with several banks accounting for this decline (8 banks out of 17). This shows that the level of productivity of Senegalese banks is explained by technical efficiency and not by technological change. Thus, the financial reforms applied in the Senegalese banking sector have improved the technical efficiency of its banks.

Table 6: Total factor productivity (TFP) and its components according to Senegalese banks.

Banks	TFP	OTE	TC	PTE	SE
BAS	0.951	0.962	0.994	0.955	1.009
BHS	1.006	1.024	0.985	1.000	1.024
BICIS	0.990	0.967	1.012	0.988	1.007
BIMAO	1.321	1.379	1.071	1.000	1.181
BIS	0.945	0.966	1.014	0.952	1.017
BOA	1.004	1.049	0.957	1.007	1.052
BRM	1.008	1.053	0.957	1.022	1.040
BSIC	1.008	1.053	0.999	1.076	1.014
CBAO	1.003	1.021	0.999	1.000	1.016
CDS	1.001	1.013	1.023	1.000	1.017
CITIBANK	0.961	1.041	0.911	1.016	1.037
CNCAS	1.017	1.017	1.003	1.000	1.017
ECOBANK	1.033	1.024	1.009	0.991	1.035
FBNBANK	1.228	1.257	1.001	0.995	1.263
ORABANK	1.055	1.073	1.013	0.993	1.292
SGBS	1.022	1.022	1.022	0.999	1.021
UBA	0.986	1.352	0.979	1.284	1.031
Average	**1.032**	**1.075**	**0.997**	**1.016**	**1.063**

Source: *By the authors based on estimates provided by stata 14.*

The results show that, over the entire period, total factor productivity of Senegalese banks increased by 3.2%. This growth is attributable to a positive change in overall technical efficiency (7.5%). However, technological changes experienced a slight decline of 0.3%. This reflects the fact that Senegalese banks, despite their performance in terms of productivity, do not sufficiently incorporate technological progress into their production process. This can be explained by the low rate of bancarisation (19% in 2018) and the failure to incorporate new transaction and information technologies (mobile banking, electronic money, popularisation of points of interaction).

VI. Conclusion

The objective of this study was to assess the technical and productive efficiency of Senegalese banks in a context of financial reforms and instability. To this end, we used a non-parametric method, in this case the Data Envelopment Analysis (DEA) method, to measure the level of efficiency of Senegalese banks. Thus, using the Malmquist index, we determined total factor productivity and its components in order to highlight the determinants of technical efficiency and overall productivity of Senegalese banks.

There is a link between banking efficiency and productivity. It emerges from the theoretical investigation that the measure of efficiency is defined as the maximum of the equiproportionate reduction of all inputs that allow a continuous production of a given output, whereas productivity can be defined as the ability of a production unit to transform a given quantity of inputs into outputs. Productivity is usually measured as an output quantity index divided by a factor quantity index. Thus, productivity is determined by both the efficiency of the production process and the type of technology used. Moreover, stylized facts show that Senegal's economy is characterized by a financing gap for small and medium-sized enterprises, but also by a very low rate of bankization. It therefore seems more plausible to assume that the country's banks should seek to maximize the supply of services rather than seek to minimize the resources available to them.

In our model, we estimate technical efficiency across a non-parametric frontier (DEA) oriented towards output maximization and under the assumption of constant and variable returns to scale. The results show that there is no substantial improvement in average efficiency in the banking sector, which does not necessarily mean that productivity has declined.

The technical efficiency of Senegalese banks over the period 2009-2018 is analyzed under the assumption of constant returns to scale (CRS) and under the assumption of variable returns to scale (VRS). The results show that, on average, over the entire period, the efficiency score of banks in the zone is 60% in CRS and 74% in VRS. This means that Senegalese banks could increase, on average, their output by 16 to 40% with the same volumes of inputs.

For the total factor productivity (TFP) index, it increases by 3.2%. This increase is due more to overall technical efficiency (OTE) than to the incorporation of technological change (TC). In fact, technological change fell slightly by 0.3% over the entire period, with several banks accounting for this decline (8 banks out of 17). This shows that the level of productivity of Senegalese banks is explained by technical efficiency and not by technological change. Thus, we confirm that the financial reforms applied in the Senegalese banking sector have improved the technical efficiency of its banks. This important result provides an alternative to the econometric approach that does not take into account production technology and thus the "technical inefficiency score". This reflects the fact that Senegalese banks, despite their performance in terms of productivity, do not sufficiently incorporate technological progress into their production process. This can be explained by the low rate of bancarization (6 percent) and the non-incorporation of new transaction and information technologies (mobile banking, electronic money, popularization of Points of Interactions).

Thus, in terms of outlook, it would be interesting to consider the "Electronic Banking" dimension in explaining the relationship between bank efficiency and productivity.

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Appendices

Table 1: Average values of variables used in millions of FCFA (except number of employees)

Banque	Immobilisations nettes	Effectif du personnel	Dépôts	crédits	Titres de placement
B.A.S.	117788	1641	1167879	1316692	352090
B.H.S.	77335	2022	1944439	2050804	1258311
B.I.C.I.S.	109320	4579	2991933	2469604	189541
B.I.M.A.O.	15029	303	214957	165960	854
B.I.S	44641	1342	1584589	1397749	9334
B.O.A.	139929	2078	1779648	1509779	627556
B.R.M	22617	619	773828	964883	1168381
B.S.I.C.	76688	1523	409722	395222	157197
C.B.A.O.	493390	10004	5891822	4734120	1340119
C.D.S.	28603	1359	1155513	958783	334388
CITIBANK	3366	326	562439	354980	108913
C.N.C.A.S.	57460	2713	1416625	1801888	40935
ECOBANK	197759	3358	3708147	2617502	1068083
FBNBANK	5368	635	147370	90544	115678
ORABANK	10541	1098	482082	394228	83458
S.G.B.S.	180665	7793	5452571	4557239	943069
U.B.A.	15434	1283	946513	584025	453440
Total	1595933	42676	30630077	26364002	8251347
Moyenne	93878	2510	1801769	1550824	485373

Source: *Based on the balance sheets of the CBWAS and the the banking commission.*

Credits = Credits to banking and non-banking customers; **Investment securities** = Securities from other credit and non-banking institutions; **Deposits** = bank and non-bank sight and term deposits; **Physical capital** = tangible and intangible fixed assets; **Human Capital** = number of staff (executives and employees).

Tableau 2 : Malmquist productvity index OUTPUT Oriented DEA Results:

Periode	dmu	PTF	EG	CT	EP	EE
2009-2010	BAS	1,00622	0,752123	1,33784	0,816086	0,921622
2009-2010	BHS	1,39873	1,10399	1,26698	1	1,10399
2009-2010	BICIS	1,09843	0,81995	1,35109	1,03072	0,788764
2009-2010	BIMAO	1,56259	1,1132	1,40369	1	1,1132
2009-2010	BIS	0,611598	0,475841	1,2853	0,500904	0,949964
2009-2010	BOA	1,13435	0,965302	1,17513	0,86582	1,11489
2009-2010	BRM	0,741214	1	0,741214	1	1
2009-2010	BSIC	2,18252	1,62365	1,34421	1,83625	0,884221
2009-2010	CBAO	1,20785	0,95638	1,31913	1	0,915638
2009-2010	CDS	0,96273	0,690204	1,39485	0,647867	1,06535
2009-2010	CITIBANK	0,894786	1	0,894786	1	1
2009-2010	CNCAS	1,35872	1	1,35872	1	1
2009-2010	ECOBANK	1,21965	0,913091	1,33573	0,923755	0,988456
2009-2010	FBNBANK	0,906408	0,832364	1,08896	1,04978	0,792897
2009-2010	ORABANK	0,911696	0,673844	1,35298	0,635409	1,06049
2009-2010	SGBS	0,928426	0,667547	1,3908	1	0,667547
2009-2010	UBA	0	3,70771	0	3,5319	1,04978
2010-2011	BAS	0,722017	0,810813	0,890485	0,8046	1,00767
2010-2011	BHS	0,970205	1,18619	0,817915	1	1,18619

2010-2011	BICIS	0,978631	1,13703	0,860693	1,0966	1,03687
2010-2011	BIMAO	0,600309	0,680929	0,881602	1	0,680929
2010-2011	BIS	0,792469	1	0,792469	1	1
2010-2011	BOA	1,01014	1,19841	0,842906	1,26762	0,945398
2010-2011	BRM	0,604777	1	0,604777	1	1
2010-2011	BSIC	0,402041	0,462473	0,869329	0,425824	1,08607
2010-2011	CBAO	0,982417	1,11896	0,877972	1	1,11896
2010-2011	CDS	0,865927	0,985242	0,878897	1,03269	0,954052
2010-2011	CITIBANK	0,989477	1,4805	0,668338	1,45781	1,01557
2010-2011	CNCAS	0,846672	1	0,846672	1	1
2010-2011	ECOBANK	0,843588	0,964156	0,874949	0,867243	1,11175
2010-2011	FBNBANK	0,839899	0,882291	0,951951	0,901808	0,978358
2010-2011	ORABANK	1,34316	1,55819	0,862002	1,65246	0,942949
2010-2011	SGBS	0,9349981	1,06643	0,876737	1	1,06643
2010-2011	UBA	0,258493	0,269708	0,958416	0,283133	0,952584
2011-2012	BAS	0,794137	0,906668	0,875885	0,91967	0,985862
2011-2012	BHS	0,960543	1,0947	0,877452	1,00862	1,08534
2011-2012	BICIS	0,982878	0,996128	0,986698	1,00779	0,988426
2011-2012	BIMAO	0,726033	0,851341	0,852811	1	0,851341
2011-2012	BIS	1,24813	1,36205	0,916359	1,11085	1,22613
2011-2012	BOA	0,85427	0,993535	0,859829	0,899953	1,10399
2011-2012	BRM	1,11248	1	1,11248	1	1
2011-2012	BSIC	1,16485	1,1284	1,0323	1,2255	0,92768
2011-2012	CBAO	0,931971	0,934596	0,997191	1	0,934596
2011-2012	CDS	1,09069	1,26874	0,859664	1,092557	1,16124
2011-2012	CITIBANK	0,795705	0,94451	0,841614	0,68596	1,37829
2011-2012	CNCAS	1,06837	1,04298	1,02434	1	1,04298
2011-2012	ECOBANK	0,950275	1,06048	0,89608	0,992934	1,06803
2011-2012	FBNBANK	1,08076	1,25093	0,863968	1	1,25093
2011-2012	ORABANK	1,51966	1,55413	0,977821	1,11105	1,3988
2011-2012	SGBS	0,939513	0,982532	0,956216	1	0,982532
2011-2012	UBA	2,78617	2,70933	1,02836	2,35125	1,15229
2012-2013	BAS	0,897234	0,998481	0,8986	1	0,998481
2012-2013	BHS	0,828296	0,890096	0,931693	0,991451	0,897772
2012-2013	BICIS	0,960704	1,06954	0,898243	0,951314	1,12427
2012-2013	BIMAO	1,28711	1,29473	0,994112	1	1,29473
2012-2013	BIS	0,908849	0,981457	0,92602	1,12339	0,873659
2012-2013	BOA	0,746039	0,807488	0,823901	0,854712	0,944749
2012-2013	BRM	0,683935	1	0,683935	1	1
2012-2013	BSIC	0,685034	0,81083	0,844856	0,685134	1,18346
2012-2013	CBAO	0,921827	1,08829	0,847039	1	1,08829
2012-2013	CDS	1,06557	1,11837	0,952794	1,19239	0,937919
2012-2013	CITIBANK	0,963309	1,08561	0,887348	1	1,08561
2012-2013	CNCAS	0,911995	1,00705	0,905614	1	1,00705
2012-2013	ECOBANK	0,950596	1,02404	0,928278	1	1,02404
2012-2013	FBNBANK	0,98127	1,00718	0,974275	1	1,00718

2012-2013	ORABANK	1,59153	1,68457	0,944773	0,439646	3,83165
2012-2013	SGBS	1,07546	1,13472	0,94777	1	1,13472
2012-2013	UBA	0,906616	0,865659	1,04731	0,792204	1,09272
2013-2014	BAS	1,22305	1,14061	1,07228	1,0105	1,12876
2013-2014	BHS	1,00341	0,994979	1,0048	1	0,994979
2013-2014	BICIS	1,12833	1,08972	1,03543	1,02815	1,05989
2013-2014	BIMAO	0,720022	0,772361	0,932235	1	0,772361
2013-2014	BIS	1,20231	1,18534	1,01432	1,13283	1,04635
2013-2014	BOA	0,924644	0,853315	1,08359	0,87165	0,978966
2013-2014	BRM	1,04209	1	1,04209	1	1
2013-2014	BSIC	0,876004	0,819841	1,06851	0,970891	0,844421
2013-2014	CBAO	1,0207	0,93418	1,09262	1	0,93418
2013-2014	CDS	1,07951	1,05628	1,022	1,12185	0,941544
2013-2014	CITIBANK	1,30361	1,37573	0,947577	1	1,37573
2013-2014	CNCAS	1,02083	0,977136	1,04472	1	0,977136
2013-2014	ECOBANK	1,11529	1,12804	0,988696	1	1,12804
2013-2014	FBNBANK	0,835476	0,825322	1,0123	1	0,825322
2013-2014	ORABANK	0,22817	0,230921	0,988089	1,38052	0,16727
2013-2014	SGBS	1,13799	1,15217	0,987689	1	1,15217
2013-2014	UBA	0,901042	0,913107	0,986787	1,11244	0,820814
2014-2015	BAS	1,10448	1,01457	1,08862	1,10278	0,920012
2014-2015	BHS	0,945675	0,867802	1,08974	1	0,867802
2014-2015	BICIS	1,0316	0,953046	1,08931	0,936593	1,01757
2014-2015	BIMAO	3,21462	1,78354	1,80238	1	1,78354
2014-2015	BIS	1,01892	0,946517	1,0765	0,735149	1,28752
2014-2015	BOA	1,24065	1,14355	1,08491	1,14762	0,996454
2014-2015	BRM	2,70939	1	2,70939	1	1
2014-2015	BSIC	1,06637	1	1,06637	1	1
2014-2015	CBAO	1,00463	0,922727	1,08876	1	0,922727
2014-2015	CDS	1,10879	1,00683	1,10126	0,970268	1,03768
2014-2015	CITIBANK	1,15055	0,478349	1,40525	1	0,478349
2014-2015	CNCAS	1,04929	0,974364	1,0769	1	0,974364
2014-2015	ECOBANK	1,1263	1,02965	1,09387	1	1,02965
2014-2015	FBNBANK	1,39285	1,33795	1,04103	1	1,33795
2014-2015	ORABANK	1,17427	1,02912	1,14105	0,900775	1,14248
2014-2015	SGBS	1,25022	1,06998	1,16845	1,03192	1,03688
2014-2015	UBA	0,857066	0,466949	1,83546	0,4826	0,96757
2015-2016	BAS	0,914106	1,11418	0,820427	1,00486	1,1088
2015-2016	BHS	0,934247	0,923521	1,01161	1	0,923521
2015-2016	BICIS	0,829258	0,723208	1,14664	0,838797	0,862197
2015-2016	BIMAO	1,0215	1,21905	0,837952	1	1,21905
2015-2016	BIS	0,949338	0,68776	1,38032	0,962224	0,71477
2015-2016	BOA	1,13703	1,30128	0,873776	0,926252	1,40489
2015-2016	BRM	1,11305	1	1,11305	1	1
2015-2016	BSIC	1,11436	1,29426	0,860999	1,12436	1,15111
2015-2016	CBAO	1,06864	1,12335	0,951298	1	1,12335

2015-2016	CDS	0,952482	0,7059	1,34932	0,734438	0,961143
2015-2016	CITIBANK	0,769501	1	0,769501	1	1
2015-2016	CNCAS	0,97943	1	0,97943	1	1
2015-2016	ECOBANK	1,20783	1,14932	1,05091	1	1,14932
2015-2016	FBNBANK	1,34038	1,13764	1,17821	1	1,13764
2015-2016	ORABANK	0,77755	0,700193	1,11048	0,804155	0,870719
2015-2016	SGBS	1,07066	0,899061	1,19087	0,96066	0,92776
2015-2016	UBA	1,18448	1	1,18448	1	1
2016-2017	BAS	1,13285	1,00702	1,12495	1,10964	0,907516
2016-2017	BHS	0,992703	1,0581	0,938196	1	1,0581
2016-2017	BICIS	0,86819	1,02142	0,849984	1	1,02142
2016-2017	BIMAO	1,27122	1,1814	1,07603	1	1,1814
2016-2017	BIS	0,82366	1,08304	0,760505	1	1,083304
2016-2017	BOA	0,916476	0,870432	1,0529	1,17263	742293
2016-2017	BRM	0,96067	1	0,96067	1	1
2016-2017	BSIC	0,985422	0,881972	1,11729	0,90518	0,974361
2016-2017	CBAO	0,87071	0,887649	0,986957	1	0,887649
2016-2017	CDS	1,00729	1,2707	0,792706	1,28235	0,990917
2016-2017	CITIBANK	0,532774	1	0,532774	1	1
2016-2017	CNCAS	0,912378	1	0,912378	1	1
2016-2017	ECOBANK	0,711899	0,796834	0,893409	1,03011	0,77344
2016-2017	FBNBANK	0,738511	0,733659	1,00661	1	0,733659
2016-2017	ORABANK	0,872824	1,06506	0,819509	1,00995	1,05456
2016-2017	SGBS	0,784163	0,919837	0,852502	1	0,919837
2016-2017	UBA	0,940976	1,14794	0,819709	1	1,14794
2017-2018	BAS	0,765927	0,91637	0,835828	0,830513	1,10338
2017-2018	BHS	1,02374	1,10002	0,93066	1	1,10002
2017-2018	BICIS	1,02865	1,16026	0,886566	1	1,16026
2017-2018	BIMAO	1,48715	1,3446	0,857416	1	1,73446
2017-2018	BIS	0,953439	0,974468	0,978421	1	0,974468
2017-2018	BOA	1,06866	1,3113	0,814959	1,05752	1,23998
2017-2018	BRM	1,17472	1	1,17472	1	1
2017-2018	BSIC	1,28527	1,62509	0,790892	1,51098	1,07552
2017-2018	CBAO	1,0203	1,22271	0,834455	1	1,22271
2017-2018	CDS	0,873789	1,0172	0,859012	0,922754	1,10235
2017-2018	CITIBANK	1,24764	1	1,24764	1	1
2017-2018	CNCAS	1,0063	1,14817	0,876437	1	1,14817
2017-2018	ECOBANK	1,16755	1,14835	1,01672	1,10339	1,04075
2017-2018	FBNBANK	2,93434	3,30142	0,8881	1	3,30142
2017-2018	ORABANK	1,07488	1,16248	0,924647	1,0021	1,16004
2017-2018	SGBS	1,07528	1,3055	0,82365	1	1,3055
2017-2018	UBA	1,04153	1,09129	0,954404	1	1,09129

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