مجلة الأصيل للبحوث الاقتصادية والإدارية
El - Acil Journal for Economic and Administrative Research
ISSN:2571-9866
EISSN:2661-7854
Volume: 7/N° 1/ April ,2023, PP 153-168

# Analyzing efficiency of banks in Algeria using stochastic frontier analysis

# تحليل كفاءة البنوك في الجزائر باستخدام التحليل الحدودي العشوائي

***Adel Achi**
University of Batna 1- Algeria
adel.achi@univ-batna.dz

**Boumediene Beroual**
University of Batna 1- Algeria
boumediene.beroual@univ-batna.dz

*Received:08/02/2023* *Accepted:16/04/2023* *Published: 30/04/2023*

**Abstract :**

The aim of this paper is to measure and analyze the efficiency of Algerian banks using a stochastic frontier analysis (SFA) approach and to test the potential effect of environmental variables on its efficiency over the period2014–2017. The main results indicate that there exists room (12%) to improve efficiency since its mean value is 0,878. Algerian banks enjoyed a decreasing trend of efficiency mean levels. The efficiency is affected positively by age of bank and return on assets (ROA) and negatively by size of bank.

**Keywords**: bank efficiency, determinants of efficiency, stochastic frontier analysis, Algerian banks, economic crisis.

JEL classification code : D24, G21

**Résumé:**

L'objectif de cet article est de mesurer et d'analyser l'efficience des banques algériennes en utilisant l'approche d'analyse de frontières stochastique et de tester l'effet potentiel des variables environnementales sur leur efficience durant la période 2014-2017. Les résultats empiriques indiquent qu'il existe une marge (12%) pour améliorer l'efficience puisque sa valeur moyenne est de 0.878. Les banques algériennes ont connu une tendance négative concernant les niveaux moyens d'efficience. L'efficience est affectée positivement par l'âge de la banque et le rendement des actifs et négativement par la taille de la banque.

**Mots clés** : efficience bancaire, déterminants de l'efficience, analyse de frontière stochastique, banques algériennes, crise économique.

***Corresponding author***

## 1.Introduction

One of the important ways to ensure the economic success for a bank is to efficiently use the available resources (Abu-Alkheil et al., 2018). bank's efficiency is defined as its ability to use the minimum quantity of inputs to produce given outputs or to use given inputs to produce maximum outputs. The first intervention refers to input orientation, and the second intervention refers to output orientation (Achi, 2021). Thus, it becomes indispensable to measure and analyze the efficiency of banks. Efficiency measurement is considered as one of the best ways to improve bank's efficiency by allocating and distributing resources in a better way (Mahmoud abadi and Emrouz nejad, 2019).

To examine the efficiency of banks, the analysts could use techniques that are based on the frontier of best practice. Actually, frontier efficiency is tool to assess the banks' efficiency, it shows if a bank can produce a same level of outputs by using alowest level of inputs. In benchmarking the efficiency of decision making units(DMUs), the managers of banks can use two different approaches: the parametric and the non-parametric approaches (Bogetoft and Otto, 2010; Daraio and Simar, 2007). The most non-parametric approach used in the literature is data envelopment analysis (DEA) and the most parametric approach used is stochastic frontier analysis (SFA) (Ahmad et al., 2020; Silva et al., 2017). In terms of methods, the DEA approach has its roots in linear programming, whereas the SFA approach is much more directly related to econometric theory (Bogetoft and Otto, 2010). These DEA and SFA approaches have been extensively applied to measure the efficiency of banks and of several different types of financial institutions (Silva et al., 2017).

The SFA approach has been widely used to examine the source of inefficiency in various fields since its introduction by Aigner et al. (1977), and Meeusen and van den Broeck (1977). SFA is a parametric method that applies the econometric methods to estimating various production/cost frontiers. Measuring the bank's efficiency allows to managers and policy makers to identify the source of inefficiency. According to SFA the source of inefficiency is due to two main causes. The first one is attributed to the

symmetric random shocks of production system that are not under the control of a producer. The second one is returned to factors such as managerial error and coordination failures (Bhattacharyya and Pal, 2013). SFA can also be used to make statistical inferences to further analyze banks' efficiency and associated environmental factors (Zhang et al., 2015).

The existing studies that use SFA to measure the efficiency of Algerian banks are very limited. Moreover, most of them focus on measuring efficiency and ignore to examine the potential effect of environmental variables which play a crucial role in explaining the efficiency differences.

There fore, the main aim of this study is to measure and analyze the efficiency of Algerian banks using the SFA approach and to test the potential effect of environmental variables on its efficiency over the period of 2014–2017. In fact, this period recovers important variables which are the size of bank, the age of bank, the liquidity risk, the return on assets (ROA) and the economic crisis.

In summary, the research questions of this study are:

1. What was the efficiency mean of Algerian banks in terms of the SFA approach during the recovery period 2014–2017?

2. Did environmental variables affect the efficiency levels of Algerian banks in terms of SFA efficiency over the recovery period?

To the best of our knowledge, this paper is among the few studies that contributes to the literature by exploring the efficiency of Algerian banks and examining its determinants. In fact, limited previous researches on efficiency of Algerian banks require more and more studies to show insights and drawbacks of Algerian banks performance. This paper also attempts to show the effect of an important explanatory variable which is the national economic crisis on the efficiency of banks. Algeria witnessed this crisis after the year 2014 because of the sharp decline in oil prices that began in mid-2014.

The remainder of this paper is organized as follows. In the next section a literature review about studies that were conducted on Algerian banks efficiency using SFA, and determinants of banks

efficiency and hypotheses. Section 3 illustrates the methodology of research: data and variable and method. Section 4 is devoted to results and discussion. Finally, section 5 contains conclusions.

## 2. Literature review

### 2.1. Measurement of efficiency using SFA

Since SFA models were proposed by Aigner et al. (1977) and Meeusen and van den Broeck (1977), There has been an extensive body of studies that delt with the efficiency of banks using SFA, especially studies conducted in developed countries. On the other hand, studies conducted in developing and emerging countries remain limited and need more investigations. Studies on Algerian banks' efficiency are also very limited, in particular those carried out using SFA, as far as we know.

Studies that were conducted on efficiency of Algerian banks using SFA approach and written in English language are very limited. Benzai and Aouad (2017) used both SFA and DEA to derive the technical and cost efficiency for a sample of 14 Algerian commercial banks over the period 2003–2012, and then they further tested the robustness of the efficiency scores. They adopted the intermediation approach to select inputs and outputs. The main results indicated that a relative consistency existed between the two approaches, the efficiency was related to the size and the ownership status, and the public banks outperformed private banks in terms of cost efficiency.

Using a sample of all the commercial banks operating in Algeria over the period 2003–2016, Hamdani and Lounici (2020a) used SFA to examine the cost efficiency, scale economies, technological progress and total factor productivity growth. To select appropriate variables, the authors adopted the intermediation approach. The empirical findings suggested that banks wasted 16% of their cost of production, foreign banks of all sizes exhibited economies of scale, whereas public banks of all sizes exhibited diseconomies of scale, technological progress reduced the cost of production of banks, and bank productivity increased over the study period.

Hamdani and Lounici (2020b) used SFA to derive cost and profit efficiency for a sample of all Algerian commercial banks over the period 2003–2016. They adopted the intermediation approach to

select inputs and outputs. The main results showed that public banks were more cost efficient than foreign banks, however they were less profit efficient.

Mahdaoui and Bouchra (2022) studied the efficiency of the Algerian banking sector during the period (1975-2019) by using SFA approach. To select appropriate variables, the authors adopted the intermediation approach. The results showed that the average technical efficiency of Algerian commercial banks was estimated at 24.13%, which represented a small percentage because of the lack of optimal use of inputs (deposits).

Djaadi and Nemer (2018) investigated the operating efficiency of seven banks using SFA during period 2008-2017. The main results indicated that the Algerian small banks were more efficient than the large ones.

Concerning studies carried out on efficiency of other countries, there has been a huge number of applications in the literature. For instance, Altunbas et al. (2000), Altunbas et al. (2007), Assaf and Matousek (2013), Miyakoshi and Tsukuda (2004), and Yao (2007).

## 2.2. Determinants of banks' efficiency and hypotheses

There have been numerous determinants of bank efficiency from the perspective of bank level. Due to the availability of data, this paper focuses on size of bank, age of bank, liquidity risk, ROA and economic crisis.

Size of the bank is widely used as an explanatory variable in banking efficiency. As a proxy for bank size, we use the natural logarithm of the value of the total assets. Empirical results from previous studies are not consensus about the relationship between bank size and efficiency. Dutta et al. (2020), Fernandes et al. (2018), Mansour and El Moussawi (2020) and Stewart et al. (2016) found a significant positive relationship between size and efficiency which means that larger banks have a higher chance of being more efficient compared to smaller ones. On the other hand, Shawtari (2015) found a significant negative relationship. On the contrary, some studies showed no significant relationship between bank size and efficiency (e.g., Assaf and Barros, 2011; Banya and Biekpe, 2018). Therefore,

the contradicting results from existing studies strengthen the need to examine the impact of bank size on efficiency of Algerian banks.

H1. *Bank size has a significant positive effect on efficiency of Algerian banks.*

Age of bank reflects the experience and learning over time. According to the literature, the influence of age on bank efficiency can be twofold. Paxton (2007) and Wijesiri et al. (2015) found a significant positive association between age and efficiency. This is due to banks in an early stage of growth may have a higher operating expense. On the other hand, Isik and Hassan (2003) and Stewart et al. (2016) reported a negative relationship between bank age and efficiency. Other studies, however, reported no significant relationship between bank age and efficiency, for example, Fukuyama and Matousek (2011). Accordingly, it is proposed that age of bank may also have significant positive effect on efficiency of Algerian banks.

H2. *Age of bank has a significant positive effect on efficiency of Algerian banks.*

Liquidity risk is defined as the ratio of total loans to total assets. It comes from the possible inability of banks to adapt to decreases in liabilities or to financial increases in assets (Banya and Biekpe, 2018). Dell'Atti et al. (2015), and Sufian and Habibullah (2010) found a positive relationship between liquidityrisk and efficiency. Thus, it is expected to find a positive relationship between liquidityrisk and efficiency of Algerian banks.

H3. *Liquidity risk has a significant positive effect on efficiency of Algerian banks.*

ROA is calculated by dividing the net profit on total assets. It represents the profitability of a bank based on total assets. It is anticipated to be associated positively with efficiency. On these grounds, the bank with a higher level of profitability is more attractive for depositors than that with lower profitability (Shawtari, 2015). Several Studies demonstrate the positive impact of ROA on bank efficiency, for example, Fernandes et al. (2018), Gulati and Kumar (2017), Mansour and El Moussawi (2020), Shawtari (2015), and Stewart et al. (2016).

H4. *ROA has a significant positive effect on efficiency of Algerian banks.*

Economic crisis is a slight national economic crisis that witnessed Algeria after the year 2014 because of the sharp decline in oil prices that began in mid-2014. The economic crisis is a variable, which usually can be modeled as either dummy or a continuous variable. In this paper, the foreign exchange reserves are used as a proxy of the national economic crisis. Dia et al. (2020) and Sufian and Habibullah (2010) prove the negative effect of the global financial crisis on bank efficiency. We expect a negative association between economic crisis and bank efficiency.

H5. *Economic* crisis *has a significant negative effect on efficiency of Algerian banks.*

## 3. Methodology

### 3.1. Data and variables

To assess the efficiency and explain its determinants, this study uses annual bank data of 13 Algerian commercial banks for the period from 2013 to 2017. The data have been obtained from published annual balance sheets and income statements in online annual reports of each individual bank. The data are measured in millions of Algerian Dinars (AD). The sample consists of eight foreign banks and five domestic banks, as can be seen in Table 1, seven banks were omitted due to the unavailability of data, consisting of five foreign ownership banks and two domestic ownership banks. It is noticed that some banks miss observations for some years. Table 1 shows name of bank, its abbreviation, type of bank and operating date.

Selection of input and output variables is an important step when evaluating banks efficiency. Indeed, the type and quality of these variables influence significantly the measurement's results. For this reason, this step requires paying more attention. Generally, the selection of variables depends on the availability of data and on whether to model the bank' activity as a production process or as an intermediation process. According to the intermediation approach, banks are viewed as primarily intermediary institutions between savers and investors. In this regard, deposits are considered as input. The production approach assumes that the role of banks is to use

labor and capital to attract depositors to place their funds in the bank. Thus, deposits are among the outputs (Achi, 2021). Following Berger and Humphrey (1997) and Altunbas et al. (2001), the production approach is adopted, therefore the inputs are fixed assets and operating expenses and the output is deposits.

**Table 1. Algerian banks in the study sample**.

| **Bank name** | **Abbreviation** | **Type of bank** | **Operating date** |
|---|---|---|---|
| La Banque Nationale d'Algérie | BNA | Domestic | 1966 |
| La Banque Extérieure d'Algérie | BEA | Domestic | 1967 |
| Le Crédit Populaire d'Algérie | CPA | Domestic | 1966 |
| La Banque de l'Agriculture et du Développement Rural | BADR | Domestic | 1982 |
| La Banque de Développement Local | BDL | Domestic | 1982 |
| Al Baraka Bank Algérie | Al Baraka | Foreign | 1991 |
| Arab Banking Corporation-Algeria | ABC-Algeria | Foreign | 1995 |
| Société Générale Algérie | Société Générale | Foreign | 2000 |
| BNP Paribas El Djazaïr | BNP | Foreign | 2002 |
| Gulf Bank Algeria | GBA | Foreign | 2004 |
| Trust Bank Algeria | Trust Algeria | Foreign | 2002 |
| Fransabank El-Djazaïr SPA | Fransabank | Foreign | 2010 |
| Al Salam Bank-Algeria | Al Salam | Foreign | 2008 |

### 3.2. Method

One of the main frontier approaches to examine productivity and efficiency of a cross section of banks is the SFA, which is independently proposed by Aigner et al. (1977) and Meeusen and Van den Broeck (1977) (Kumbhakar et al., 2020). The SFA is a parametric technique that is based on production function methodology. The approach explicitly recognises that production function represents technically maximum feasible output level for a given level of inputs (Mazorodze, 2020). The SFA model accounts for possible influence of measurement errors and other noise on the shape and positioning of the estimated frontier (Sakouvogui, 2020). The SFA model can be expressed as :

$$y_i = x_i\beta + v_i + u_i \qquad (1)$$

$u_i$ : is a nonnegative disturbance standing for technical inefficiency in the production function. This term is assumed to be one of the three distributions: half normal, exponential, or truncated-normal.

$v_i$ : is an idiosyncratic error term which is assumed to be normally distributed.

For SFA, a decision maker may not only desire to examine the levels of efficiency for each bank, but also the factors that can explain efficiency variation. For example, in studying the efficiency level of banks, a decision maker may want to know whether the efficiency of a bank is affected by the bank size, the experience, or the competetion. To answer these questions, we may want to estimate the relationship between the efficiency measures and the potential determinants of efficiency. To investigate such relationship between efficiency and explanatory variables, there is two approaches in the literature. The early studies adopt a two-stage procedure to investigate the relationship. In the first stage, the researcher estimates the inefficiency measures, then in the second stage, the scores of inefficiencies are regressed on vector exogenous variables. A negative coefficient of the exogenous variable in the regression indicates that banks with larger values of the variables tend to have a lower level of inefficiency. the single-stage procedure allows to estimate the inefficiency scores and parameters together (Kumbhakar et al., 2015).

The relationship between inefficiency scores and explanatory variables is modeled as follows:

$$u_i = \alpha_1 \text{bank\_size} + \alpha_2 bank\_age + \alpha_3 liquidity\_risk + \alpha_4 ROA + \alpha_5 economic\_crisis + w_i \quad (2)$$

Where $u_i$ is the estimate of banks inefficiency, obtained from Eq. (1) above, whilst $w_i$ is a random variable distributed as truncated-normal. We apply the one-stage procedure which consists of estimating Eqs. (1) and (2) simultaneously.

## 4. Results and discussion

The estimation of Algerian banks efficiency from 2013 to 2017 and SFA coefficients was conducted using Stata 17.0.

### 4.1. Banks efficiency

Table 2 shows the statistical description of the input and output variables used for efficiency estimation. The average fixed assets

is845,881 million Algerian Dinar (AD) with a standard deviation of 709,415 million AD. The biggest bank owns as fixed assets 2277,846 million AD whereas the smallest one owns 76,706 million AD. The average operating expenses is 727,729 million AD with a standard deviation of 678,648 million AD. The average deposit is 57679,18 million AD with a standard deviation of 75155,33 million AD. On average, an Algerian bank uses 845,881 million AD in fixed assets and spends 727,729 million AD as operating expenses to collect 57679,18 million AD in deposits.

**Table 2: Descriptive statistics of input and output variables**

| **Variable** | **Obs** | **Mean** | **Sta.Dev.** | **Min** | **Max** |
|---|---|---|---|---|---|
| Fixedassets | 60 | 845,88 | 709,41 | 76,70 | 2277,84 |
| Operatingeexpenses | 60 | 727,729 | 678,648 | 63,838 | 2278,73 |
| Deposits | 60 | 57679,1 | 75155,3 | 1155,61 | 250936,09 |
| Unit : million AD | | | | | |

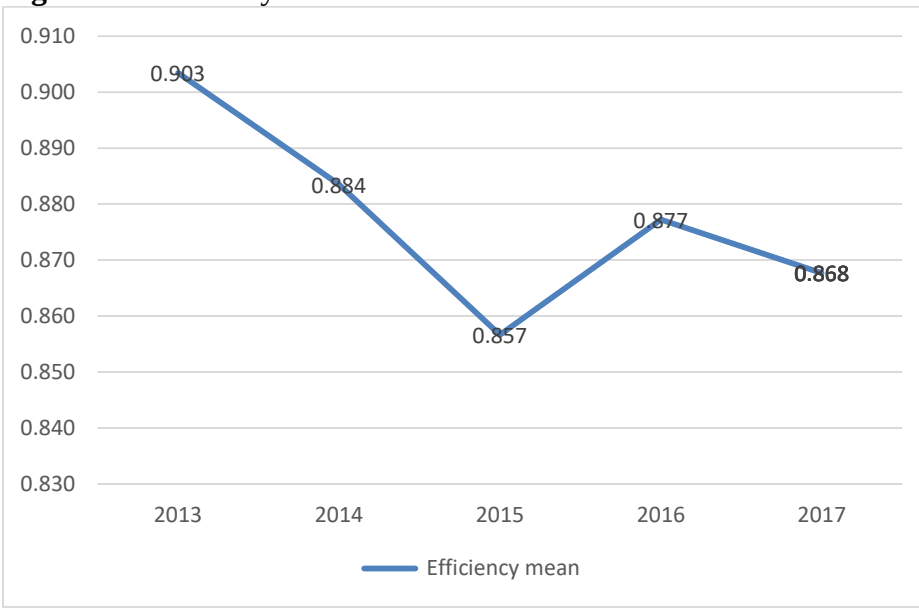
Table 3 presents mean, minimum and maximum of efficiency scores of pooled data. The mean of efficiency equals 0,878, implying that, on average, the Algerian banks produce 87.8% of the maximum output, or that they lost about 12% of the potential output due to technical inefficiency. The lowest efficiency level is 0,466 and the highest one is 0,999.

| **Table 3** : Statistics of efficiency | | | | | |
|---|---|---|---|---|---|
| **Variable** | **Obs** | **Mean** | **Sta.Dev.** | **Min** | **Max** |
| Efficiency | 60 | 0,878 | 0,179 | 0,466 | 0,999 |

Figure 1 shows efficiency mean scores estimated for the sample banks from 2013 to 2017. The figure shows that the mean of scores decreased from 0,903 in 2013 to 0,857 in 2015, in 2016, it recorded an increase estimated by 1,23%, and then it recorded a slight decrease estimated by 1%. Figure 2 represents also the trend of efficiency mean scores. It is noticed that the trend was negative, which means that the levels of efficiency mean of Algerian banks was falling over (2013–2107) period. The efficiency mean shifted from 0.903 in 2013 to 0.868 in 2017. The highest mean (0,903) was observed in 2013 and the lowest average (0,857) was observed in 2015. This result indicates that the Algerian banks experienced a

continuous deterioration in overall efficiency during the period 2013–2017.

**Figure 1** : Efficiency mean scores over time




### 4.2. The influence of explanatory variables on banks efficiency

Table 4 presents the parameters estimation results. The value of Lambda equals 0,124 and is statistically significant at 5% level, which means that the deviation from the frontier do not depend entirely on random noise, but also on technical inefficiency. As can be seen from Table 4, most of parameters are statistically significant. The influencing variables on Algerian banks efficiency are bank size, bank age and ROA. The remaining two variables are statistically insignificant.

Concerning the bank size, the coefficient equals 0.672 which manifests that this variable negatively affects the efficiency of banks, and that its influence is strong in comparison to other factors. This result does not confirm our expectation (H1) that larger banks have a higher chance of being more efficient compared to smaller ones. However, it is consistent with the study of Shawtari (2015).

The coefficient of bank age equals -0.062 which manifests that bank age has a positive influence on the efficiency of Algerian banks. It means that the old banks have higher efficiency. It is noticed that the coefficient value of bank age is the smallest one. The result supports

our hypothesis (H2) and the view of some studies such as Paxton (2007) and Wijesiriet al. (2015). This might be because banks in an early stage of growth have a higher operating expense.

The coefficient estimate of liquidity risk equals 0.672 which shows that this variable is negatively related to the efficiency of banks. Noticeably, the parameter is statistically insignificant, which indicates that no relationship exists between liquidity risk and efficiency of Algerian banks. This result does not support our hypothesis (H3) and other results reached by Dell'Atti et al. (2015), and Sufian and Habibullah (2010).

**Table 4: Maximum-likelihood estimates for parameters of the stochastic frontier**

| Variable | Coefficient | Standard deviation | P |
|---|---|---|---|
| Size | ,672*** | ,263 | 0,010 |
| Age | -,062*** | ,019 | 0,001 |
| Liquidity_risk | ,672 | ,988 | 0,497 |
| ROA | -29,810** | 14,826 | 0,044 |
| Economic crisis | -,0014 | ,002 | 0,529 |
| Constant | -11,481*** | 4,429 | 0,010 |
| Sigma_u | ,033 | ,0481 | 0,486 |
| Sigma_v | ,271*** | ,0251 | 0,000 |
| Lambda | ,124** | ,054 | 0,023 |
| Number of observations | 60 | | |
| Wald chi2(2) | 1642,21 | | |
| Prob > chi2 | 0.0000 | | |
| Log likelihood | -6,6616 | | |

***: significant at 1%, **: significant at 5%

Concerning the influence of ROA on the bank efficiency, the coefficient is negative and significant indicating a strong positive relationship between profitability and bank efficiency. This suggests that higher levels of profitability ratio increase the ability of Algerian banks to be more efficient. This confirms our expectations (H4) which support the results of several empirical studies (e.g.Fernandes et al., 2018; Gulati and Kumar, 2017; Mansour and El Moussawi, 2020; Shawtari, 2015; Stewart et al., 2016).

The coefficient associated with economic crisis is -0,0014 and it is statistically insignificant which means that the Algerian banks efficiency is not affected by a slight national economic crisis resulting from a decline in oil prices. This finding conflicts with our presumption (H5) and evidence reported in previous studies. For instance, Dia et al. (2020) and Sufian and Habibullah (2010) prove the negative effect of the global financial crisis on bank efficiency.

## 5. Conclusion

This paper adds to the literature of limited studies dealing with the bank's efficiency and its determinants in the Algerian context, and fills the gap of the lack of research on the influencing variables in developing and emerging countries by using the SFA approach. The results on efficiency measurement reveal that the efficiency mean of Algerian banks is 0,878, implying that, on average, the Algerian banks produce 87,8% of the maximum output, or that they lost about 12% of the potential output due to technical inefficiency. The Algerian banks enjoys a decreasing trend of efficiency mean levels over the period 2013–2017.

The findings of examining the determinants of Algerian banks efficiency over the period 2013–2017 reveal that the factors of bank age and ROA affect positively Algerian banks efficiency, whereas the bank size negatively relate to efficiency.

Finally, there are limitations of this study, which could serve as fruitful avenues for further researches. For instance, the five explanatory variables may be not enough to accurately explain the differences in Algerian banks' efficiency levels. In addition, the study can be carried out over a longer period of time.

## 6. Bibliography List

Abu-Alkheil, A., Khartabiel, G., & Dali, N. R. S. M. (2018). A two-stage parametric stochastic frontier analysis (SFA) of the efficiency performance of Shari'ah compliant banks: a global evidence. *American Journal of Finance and Accounting*, *5*(2), 85-110.

Achi, A. (2021). Efficiency and its determinants in the Algerian banks: network data envelopment analysis and partial least squares regression. International Journal of Productivity and Performance Management. https://doi.org/10.1108/IJPPM-07-2021-0407

Ahmad, N., Naveed, A., Ahmad, S., & Butt, I. (2020). Banking sector performance, profitability, and efficiency: a citation-based systematic literature review. *Journal of Economic Surveys*, *34*(1), 185-218.

Aigner, D., Lovell, C. K., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of econometrics*, *6*(1), 21-37.

Altunbas, Y., Carbo, S., Gardener, E. P., & Molyneux, P. (2007). Examining the relationships between capital, risk and efficiency in European banking. *Europeanfinancial management*, *13*(1), 49-70.

Altunbas, Y., Liu, M. H., Molyneux, P., & Seth, R. (2000). Efficiency and risk in Japanese banking. *Journal of Banking & Finance*, *24*(10), 1605-1628.

Assaf, A. G., Barros, C. P., &Matousek, R. (2011). Technical efficiency in Saudi banks. *Expert systems with Applications*, *38*(5), 5781-5786.

Assaf, A. G., Matousek, R., &Tsionas, E. G. (2013). Turkish bank efficiency: Bayesian estimation with undesirable outputs. *Journal of Banking & Finance*, *37*(2), 506-517.

Banya, R., &Biekpe, N. (2018). Banking Efficiency and its determinants in selected Frontier African Markets. *Economic Change and Restructuring*, *51*, 69-95.

Benzai, Y. & Aouad, H. S. (2017). Measuring cost efficiency in the Algerian banking system : A comparison of parametric and non-parametric frontier methodologies. *AL-MOASHEER Journal of Economic Studies*, *1*(2), 139-158.

Berger, A. N., & Humphrey, D. B. (1997). Efficiency of financial institutions: International survey and directions for future research. *European journal of operational research*, *98*(2), 175-212.

Bhattacharyya, A., & Pal, S. (2013). Financial reforms and technical efficiency in Indian commercial banking: A generalized stochastic frontier analysis. *Review of Financial Economics*, *22*(3), 109-117.

Bogetoft, P., & Otto, L. (2010). *Benchmarking with dea, sfa, and r* (Vol. 157). Springer Science & Business Media.

Daraio, C., & Simar, L. (2007). *Advanced robust and nonparametric methods in efficiency analysis: Methodology and applications*. Springer Science & Business Media.

Dell'Atti, S.Pacelli, V., &Mazzarelli, G.(2015).The efficiency of the European banking groups and its determinants. *Managerial Finance*, *41*(7), 734-751.

Djaadi, C., &Nemer, M. E. (2019). Measurement of operating efficiency using stochastic cost frontier model to a sample from banks which deal with Algeria in the period 2008 to2017. *Dirassat Journal Economic Issue*, 10(2), 267-284.

Dutta, P., Jain, A., & Gupta, A. (2020). Performance analysis of non-banking finance companies using two-stage data envelopment analysis. *Annals of Operations Research*, *295*, 91-116.

Fernandes, F. D. S., Stasinakis, C., &Bardarova, V. (2018). Two-stage DEA-Truncated Regression: Application in banking efficiency and financial development. *Expert Systems with Applications*, *96*, 284-301.

Fukuyama, H., &Matousek, R. (2011). Efficiency of Turkish banking: Two-stage network system. Variable returns to scale model. *Journal of International Financial Markets, Institutions and Money*, *21*(1), 75-91.

Gulati, R., & Kumar, S. (2017). Analysing banks' intermediation and operating efficiencies using the two-stage network DEA model: The case of India. *International Journal of Productivity and Performance Management*.*66* (4), 500-516.

Hamdani F.&Lounici, N. (2020a). An investigation into the cost efficiency, scale economies, technological progress and productivity of Algerian banks. *Finance & Markets Review*, 7 (2), 1-18.

Hamdani F.&Lounici, N. (2020b). The role of ownership structure in explaining differences in efficiency: Evidence from the Algerian banking sector. *Economic and Management Research Journal*, *14* (05), 259-278

Isik, I., & Hassan, M. K. (2003). Efficiency, ownership and market structure, corporate control and governance in the Turkish banking industry. *Journal of Business Finance & Accounting*, *30*(9-10), 1363-1421.

Kumbhakar, S. C., Wang, H., &Horncastle, A. P. (2015). A practitioner's guide to stochastic frontier analysis using Stata. Cambridge University Press.Kumbhakar, S. C., Parmeter, C. F., &Zelenyuk, V. (2020). Stochastic frontier analysis: Foundations and advances I. *Handbook of production economics*, 1-40.

Mahdaoui, M. &Bouchra, A. (2022). Measuring the technical Efficiency in Algerian commercial banks: from a mediation approach by using Stochastic frontier analysis. Journal of Economic Integration, 10 (02), 553-565.

Mahmoudabadi, M. Z., &Emrouznejad, A. (2019). Comprehensive performance evaluation of banking branches: A three-stage slacks-based measure (SBM) data envelopment analysis. *International Review of Economics & Finance*, *64*, 359-376.

Mansour, R., & El Moussawi, C. (2020). Efficiency, technical progress and productivity of Arab banks: A non-parametric approach. *The Quarterly Review of Economics and Finance*, *75*, 191-208.

Mazorodze, B. (2020). Trade and efficiency of manufacturing industries in South Africa. *The Journal of International Trade & Economic Development*, *29*(1), 89-118.

Meeusen, W., & van Den Broeck, J. (1977). Efficiency estimation from Cobb-Douglas production functions with composed error. *International economic review*, 435-444.

Miyakoshi, T., &Tsukuda, Y. (2004). Regional disparities in Japanese banking performance. *Review of Urban & Regional Development Studies*, *16*(1), 74-89.

Paxton, J. (2007). Technical efficiency in a semi-formal financial sector: The case of Mexico. *Oxford Bulletin of Economics and Statistics*, *69*(1), 57-74.

Sakouvogui, K. (2020). A comparative approach of stochastic frontier analysis and data envelopment analysis estimators: evidence from banking system. *Journal of Economic Studies*, *47*(7), 1787-1810.

Shawtari, F. A., Ariff, M., & Abdul Razak, S. H. (2015). Efficiency assessment of banking sector in Yemen using data envelopment window analysis: A comparative analysis of Islamic and conventional banks. *Benchmarking: An International Journal*, *22*(6), 1115-1140.

Silva, T. C., Tabak, B. M., Cajueiro, D. O., & Dias, M. V. B. (2017). A comparison of DEA and SFA using micro-and macro-level perspectives: Efficiency of Chinese local banks. *Physica A: Statistical Mechanics and its Applications*, *469*, 216-223.

Stewart, C., Matousek, R., & Nguyen, T. N. (2016). Efficiency in the Vietnamese banking system: A DEA double bootstrap approach. *Research in International Business and Finance*, *36*, 96-111.

Sufian, F., & Habibullah, M. S. (2010). Bank-specific, industry-specific and macroeconomic determinants of bank efficiency: Empirical evidence from the Thai banking sector. *Margin: The Journal of Applied Economic Research*, *4*(4), 427-461.

Wijesiri, M., Viganò, L., &Meoli, M. (2015). Efficiency of microfinance institutions in Sri Lanka: a two-stage double bootstrap DEA approach. *Economic Modelling*, *47*, 74-83.

Yao, S. (2007). On the efficiency of Chinese banks and WTO challenges. *Applied Economics*, *39*(5), 629-643.

Zhang, Q., Xu, Z., Feng, T., & Jiao, J. (2015). A dynamic stochastic frontier model to evaluate regional financial efficiency: Evidence from Chinese county-level panel data. *European Journal of Operational* Research, *241*(3), 907-916.