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Measuring the X-Efficiency of Saudi Banks: Case Study Pre and Post-Coronavirus Crisis

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Abstract

By specifying a translog cost function and applying the DFA (Data Frontier Approach) model, the objective of this paper was to determine the x-efficiency, economies of scale and economies of scope for Saudi banks during the period 2017-2022. Subsequently, the model compares bank efficiency before and after corona pandemic. The empirical results indicate that the measure of x-inefficiency (around 7% to 19% of costs) dominates scale inefficiency (around 5% of costs), moreover, there is no difference in efficiency before and after the coronavirus pandemic.

Keywords

Cost Function, X-Efficiency, Economies of Scale, Economies of Scope, Coronavirus Pandemic

1. Introduction

According to the globalization movement, financial institutions (in particular banks) are operating in an increasingly competitive environment, where competition may come from foreign banks as well as from non-banking firms. To cope with this, banks need to further improve the performance of their operations. If they become more efficient, then one can expect large amounts of funds intermediated in the market, good product quality and favorable prices in favor of customers, and higher profitability which can be used to strengthen capital against risks.

In practice, however, the production plans of banking firms do not perfectly follow efficient and rational decisions, which can cause differences in efficiency between banks and can cause the actual data to deviate away from the optimum. Therefore, it was necessary to make a precise and clear estimate of the efficiency of banks in order to be able to identify the best and the bad banks in an industry.

In the literature, the operational efficiency of banks has generally been studied from two perspectives. One perspective examines output efficiency, i.e. the full exploitation of economies of scale and scope. The other concerns input efficiency (x-efficiency), i.e. avoiding excessive levels of input use (technical efficiency) and non-optimal relative proportions of inputs (allocative efficiency).

In this work, we will try to apply the same approach observed in the literature to Saudi banks. Indeed, we will try to determine the x-efficiency, the economies of scale and the economies of scope for each Saudi bank. To accomplish this task, a period of six years is therefore chosen [2017-2022], i.e. 3 years before the coronavirus crisis and 3 years after. A sample of Saudi banks was selected. We then applied the DFA (Data Frontier Approach) model.

The remainder of this article is organized as follows. Section 2 provides a literature review, more specifically the approaches used to estimate x-efficiency. In Section 3, we present the methodological approach applied in the context of Saudi banks. Section 4 describes the results and the empirical interpretations. Finally, the conclusion will be presented in Section 5.

2. Literature Review

The research interested in the operational efficiency of banks has relied on cost, production or profit function analyses that require the calculation of banking inputs and outputs. Each of these functions presents a limit on the observed data and therefore traces a so-called efficiency frontier. Deviations from this frontier constitute a measure of input efficiency called x-efficiency. The x-efficiency represents the proportion of costs or resources used efficiently (for example, a bank with an x-efficiency of 0.70 is said to be 70% efficient, or in the other words, wastes 30% of its costs).

Academic studies differ mainly in the methods used to measure x-efficiency. We distinguish the non-parametric frontier approaches: the DEA (Data Envelopment Analysis) approach and the FDH (Free Disposable Hull) approach, and the parametric frontier approaches: the SFA approach (Stochastic Frontier Approach), DFA (Distribution-Free Approach) and TFA (Tick Frontier Approach).

First, non-parametric approaches are mathematical methods that do not require strong assumptions on the efficiency frontier. The DEA method was developed by Charnes, Cooper and Rhodes (1978), it is indeed a linear programming technique that builds an (efficient) frontier based on the current data of the sample. Each bank presents a production plan (input/output), and the boundary approximated by the (DEA) method-assumed to be convex-envelops these production plans. The distance between each observed plane and this boundary approximation is thus used as an efficiency measure.

The FDH approach introduced by Tulkens (1993) is also a linear programming technique. It is indeed a special case of the DEA approach, only the convexity condition of the functional form is not necessary, which consequently implies that the efficiency estimates generated by the FDH method are larger than those of DEA.

The advantage of these two non-parametric methods (DEA and FDH) is that they do not require strong assumptions on the efficiency frontier, always requiring only the linearity and/or the convexity of the functional form (the frontier). However, the major problem with both of these approaches is that they assume no random error, so any error in the calculation of the data can be attributed to the efficiency measure.

For parametric approaches, we find econometric techniques that use a specified flexible functional form for the cost function. These techniques assume a compound residual term that includes the x-efficiency measure and random noise. However, these techniques differ in the assumptions used to decompose this residual term.

The SFA model was proposed by Aigner, Lovell and Schmidt (1977), it assumes that the observed cost deviates from the optimal frontier cost due to a residual term composed of random noise (assumed to be normally distributed) and the efficiency term (assumed to be semi-normally distributed). An advantage of using this method is that it allows for deriving efficiency estimates for each bank without assuming that the efficiency frontier is common for all banks. Nevertheless, the criticisms addressed to this method concern the relatively robust assumptions applied to the components of the residual term.

The DFA approach initiated by Berger (1993) overcomes the assumptions required by the SFA method. By using a panel of data, the DFA method assumes that the sum of the random errors will cancel out over time and that the measure of effectiveness remains constant over the period studied. This method is particularly attractive since its statistical assumptions are intuitive and easy to apply. However, this approach describes the average efficiency of each firm over the period studied rather than the efficiency at each point in time.

The TFA technique was developed by Berger and Humphrey (1991), it divides the sample of banks into groups according to their ratio of total cost per total assets, it then estimates a cost function for each group of banks. This method assumes that efficiency measures differ between the lowest average cost and highest average cost groups and that random error exists within these groups. The advantage of this approach is that it does not impose any distribution on the measure of efficiency or on the random error. However, the problems related to this approach relate to the measure of efficiency sensitive to the fact that the banks are divided into 4 or 5 or any other group, moreover that the TFA method does not provide an estimated point of efficiency for the firms. individual but an estimate of a general level of overall effectiveness.

Recently, Li et al. (2022) used the (DEA) model to study the operational efficiency of Chinese Internet banks. The results showed that internet banking in 2019 is higher than in 2018. Additionally, the authors found no significant difference in the average overall efficiency of internet banks.

3. Methodology

This section will present hypotheses to be tested, the model to be estimated, variables and data used.

3.1. The Model

Given the availability of a panel of data, the approach (DFA) was preferred to measure the efficiency of Saudi banks over the period [2017-2022]. One of the advantages of this method is that it allows the cost function coefficients to vary over time, which is desirable given changes in the operating environment and in bank technology.

Considering a cost function such as:

$$C_{it} = f\left(y_{it}, w_{it}\right)\mu_i \upsilon_{i,t}, \tag{1}$$

where: C is the total cost, f is the cost function, y is an output vector, w is an input price vector, μ_i is the efficiency factor, $\upsilon_{i,t}$ is the random error term .

By raising Equation (1) to the logarithm, the (DFA) method assumes that the efficiency term (μ_i) and the random error term ($\upsilon_{i,t}$) are multiplicatively separated, we then obtain:

$$\log C_{it} = f\left(y_{it}, w_{it}\right) + \log \mu_i + \log \upsilon_{i,t}, \tag{2}$$

According to this approach, we, therefore, notice that the residual term (the difference between the observed costs and the estimated costs), $\varepsilon_{i,t}$, of each bank i in time t can be expressed as:

$$\varepsilon_{i,t} = \log\left(\mu_i\right) + \log\left(\upsilon_{i,t}\right), \tag{3}$$

According to the (DFA) method, two main assumptions are imposed on the components of the residual term. First, the efficiency term ($\log(\mu_i)$) for each bank is assumed to remain constant in period T. Second, the sum of the random error terms $\left(\sum_t \log\left(\upsilon_{i,t}\right)\right)$ is assumed to be equal to zero.

From these assumptions, the average of the residual term $\varepsilon_{i,t}$, ($\sum_t \varepsilon_{i,t}/n$), for each bank i in time T is an estimate of the efficiency term, i.e.:

$$\log\left(\mu_i\right) = 1/T\left(\sum_t \varepsilon_{i,t}\right), \tag{4}$$

After determining the average residual of each bank $\left(1/T\left(\sum_t \varepsilon_{i,t}\right)\right)$, the efficiency measure for each bank is calculated as:

$$EFF_i = \exp\left[\min\left(\log\left(\mu_i\right)\right) - \log\left(\mu_{i,t}\right)\right], \tag{5}$$

where: $\min(\log(\mu_i))$ is the minimum value of $\log(\mu_{i,t})$ of all banks for the estimation period T.

According to Equation (5), the most efficient bank is the one with the lowest average residual $\{\min(\log(\mu_i))\}$. Specifying this equation, therefore, assigns an efficiency value (EFF_i) of 1 for the most efficient bank and values between 0 and 1 for all other banks.

It should be noted, however, that the efficiency measure EFF_i incorporates technical inefficiencies and allocative inefficiencies together.

3.2. The Cost Function

The quantities of outputs and the prices of inputs (calculated from the balance sheets and income statement) are used to estimate a cost function that allows conclusions to be drawn on the technology of banks.

The cost function used in this study is that proposed by Goldberg and Rai (1996) and Allen and Rai (1996). The functional form used for this frontier is of the translog type given its flexibility in estimating scale and scope efficiencies.

The multi-period cost function is given by:

$$\begin{aligned}\log tc = \alpha_0 + \sum_i \alpha_i \log y_i + \sum_j \beta_j \log w_j + 1/2 \sum_i \sum_k \alpha_{ik} \log y_i \log y_k \\ + 1/2 \sum_j \sum_h \beta_{jh} \log w_j \log w_h + \sum_i \sum_j \delta_{ij} \log y_i \log w_j + \varepsilon,\end{aligned} \tag{6}$$

where: tc is the total cost, y_i is the quantity of output $i = (1, 2)$, w_j is the price of input $j = (1, 2, 3)$, two outputs are used (y_1 = loans, y_2 = investments), and three inputs including prices (w_1 = price of labor, w_2 = price of capital, w_3 = price of borrowed funds).

Equation (6) is estimated using maximum likelihood techniques. The usual symmetric restrictions are imposed, ie, $\alpha_{ik} = \alpha_{ki}$ and $\beta_{jh} = \beta_{hj}$.

The cost function is not estimated with proportion equations (share equations), because as already explained by Berger (1993), if the cost function is estimated with proportion equations, then the DFA efficiency measure incorporates only technical inefficiencies.

3.3. The Variables

The data used concerns the period (2017-2022), i.e. 3 years before the coronavirus pandemic and 3 years after for a sample comprising 10 Saudi banks.

The inputs and outputs necessary for the specification of the cost function are estimated according to the intermediation approach proposed by Sealy and Lindelly (1977) who consider the bank as a financial institution that uses labor, physical capital, and deposits to produce investments, this approach is the most adopted in the literature.

Table 1 describes the variables used. The choice of these variables is consistent with the study of Goldberg and Rai (1996) and Allen and Rai (1996). Two outputs are included: y_1 = loans, and y_2 = investments (or placements); and three inputs with their prices which are defined by: w_1 = the price of labor, w_2 = the price of physical capital, and w_3 = the price of deposits (or borrowed funds). Total costs tc include operating costs and interest charges.

3.4. Economies of Scales and Economies of Scope

1) Economies of scales

Efficiency indicates whether banks with similar production technologies and management techniques operate on optimal economies of scale.

Table 1. Description of variables.

Variable	Name	Description
Y_1	Loans	All forms of customer loans (discount portfolio, leasing transactions, accounts receivable, credits from special resources, and other customer loans)
Y_2	Investments	Securities portfolio
X_1	Labor	Total number of employees
X_2	Capital	Net fixed assets
X_3	Deposits	All customer deposits (demand deposit, savings, term account, certificate of deposit, and other sums due to customers)
W_1	Price of labor	Staff costs/total number of employees
W_2	Price of Capital	Capital goods and expenses for rent and maintenance/fixed assets
W_3	Price of borrowed funds	(interest on customer deposits + charges on leasing transactions + charges on borrowings + charges on miscellaneous transactions)/volume of deposits
Tc	Total Costs	Operating costs + interest charges

The measure of economies of scale used here is that adopted by most of the literature:

$$\begin{aligned}\text{SCALE} &\equiv \sum_{i=1} \partial \log c / \partial \log y_i \\ &= \sum_{i=1}^{2}\left[\alpha_i + \sum_{k=1}^{2} \alpha_{ik} \log y_k + \sum_{j=1}^{3} \delta_{ij} \log w_j\right]\end{aligned} \tag{7}$$

- SCALE < 1 indicates that the banks are operating below the optimal levels of scale, and that they have the ability to reduce costs by increasing their outputs more (increasing returns to scale),
- SCALE > 1 implies that banks need to reduce their size in order to achieve optimal combinations of inputs (decreasing returns to scale),
- SCALE = 1 indicates constant returns to scale.

2) Economies of scope

Scope efficiency indicates whether banks enjoy a cost advantage by producing all outputs compared to firms specializing in the production of a single output.

The measure of economies of scope used here is that provided by Mester (1993, 1996) defined by:

$$\text{WSCOPE} \equiv \left\{\left[c\left(y_1 - y_1^m, y_2^m\right) + c\left(y_1^m, y_2 - y_2^m\right) - c\left(y_1, y_2\right)\right]\right\} / c\left(y_1, y_2\right), \tag{8}$$

where y_i^m is the minimum value of y_i produced by a sample bank, and $C(.)$ is the estimated (forecast) cost function to produce a basket of outputs for the average input price.

- WSCOPE > 0 implies economies of scope,
- WSCOPE < 0 implies diseconomies of scope.

This measure is called economies of scope within the sample since it avoids the problem of making data extrapolations outside the sample.

4. Results

The results of regression models are provided in Table 2. In our methodology, the x-efficiency measure is obtained using the (DFA) model which assumes that the average of the residual term (the sum of the residual terms divided by the

Table 2. Results of regression model.

Variable	Coefficient	Estimated	Standard Deviation	Student Test	Prob > |t|
intercepte	α_0	3.1379*	8.3674	3.602	0.0005
$\log y_1$	α_1	−2.4017*	0.6398	−3.754	0.0003
$\log y_2$	α_2	1.2494***	0.7509	1.664	0.0993
$\log w_1$	β_1	−3.2091*	1.1425	−2.809	0.0060
$\log w_2$	β_2	−1.73105***	1.02853	−1.683	0.0956
$\log w_3$	β_3	−2.8428**	1.1872	−2.394	0.0185
$1/2(\log y_1)^2$	α_{11}	0.09026*	0.01453	6.209	0.0001
$1/2(\log y_2)^2$	α_{22}	0.102036*	0.0238	4.286	0.0001
$\log y_1 \log y_2$	α_{12}	−0.03798***	0.0228	−1.666	0.0990
$1/2(\log w_1)^2$	β_{11}	0.32864*	0.09846	3.338	0.0012
$1/2(\log w_2)^2$	β_{22}	−0.06691	0.09939	−0.673	0.5024
$1/2(\log w_3)^2$	β_{33}	−0.221	0.18432	−1.199	0.2334
$\log w_1 \log w_2$	β_{12}	−0.0276	0.1246	−0.221	0.8252
$\log w_1 \log w_3$	β_{13}	0.1362	0.12297	1.108	0.2705
$\log w_2 \log w_3$	β_{23}	0.004318	0.1163	0.037	0.9705
$\log y_1 \log w_1$	δ_{11}	0.255696*	0.08057	3.174	0.0020
$\log y_2 \log w_1$	δ_{21}	−0.2383*	0.08512	−2.600	0.0062
$\log y_1 \log w_2$	δ_{12}	0.07095***	0.042177	1.682	0.0957
$\log y_2 \log w_2$	δ_{22}	0.03141	0.03429	0.916	0.3619
$\log y_1 \log w_3$	δ_{13}	0.10578**	0.04951	2.136	0.0351
$\log y_2 \log w_3$	δ_{23}	−0.04664	0.04335	−1.076	0.2847
R-square 0.983					
Adj R-square 0.9796					
Durbin-watson 2.215					

*, **, *** indicate a level of significance of 1%, 5% and 10%, respectively.

number of years $\sum_t \varepsilon_{i,t}/T$) serves to estimate the x-efficiency of each bank. Table 3 provides the average residual for each bank in the period [2017-2022].

According to the assumptions of the method (DFA), the most efficient bank in the sample is the one with the lowest average residual.

In our sample, the most efficient bank is the NCB with an average residual of −0.192263. The model therefore assigns an efficiency value of 1 for the NCB, and efficiency values between 0 and 1 for the other banks calculated according to Equation (5). Table 4 provides a classification of Saudi banks based on their x-efficiency.

Table 4 shows that the average x-inefficiency for Saudi banks is in the order of 7% to 19%. Thus, if an average bank will use its inputs efficiently, it can reduce its cost by 7% to 19%. The results suggest that NCB presents the best efficiency practices in our sample during the period studied. Furthermore, the results do not indicate a significant difference in the efficiency of Saudi banks before and after the corona pandemic.

Table 5 reports the measures of economies of scale attributed for average quantities of outputs and average levels of input prices for each bank in the sample over the period [2017-2022].

The measures are defined on the evaluated cost frontier and therefore indicate whether a bank that minimizes the cost of producing a basket of outputs, can minimize its costs proportionally by removing another level of output. The results indicated that output inefficiency is around 5%.

Table 3. Residual term for each bank.

Bank	Residual	Stand deviation
NCB	Min −0.356413 Ave −0.192263 Max −0.040860	0.095442
Al Rajhi Bank	Min −0.073564 Ave 0.041510 Max 0.142590	0.063901
Riyad Bank	Min −0.104926 Ave −0.013085 Max 0.170426	0.076952
SAAB	Min −0.168860 Ave −0.063015 Max 0.041077	0.063383
ANB	Min −0.071918 Ave 0.104742 Max 0.225165	0.097087
Alinma	Min −0.062879 Ave 0.037115 Max 0.146728	0.056536

The measures of economies of scope for each bank are described in Table 6. These measures are also evaluated for average quantities of outputs and average prices of inputs; they are based on the estimated cost function and show whether a bank minimizing its production cost can lower its costs proportionally by changing the composition of its output set.

From the measurement of economies of scope within the sample (WSCOPE), all Tunisian deposit banks seem to benefit from economies of scope (WSCOPE > 0 for all banks).

Table 4. X-efficiency for each bank.

Rank	Bank	Efficiency % [2017-2019]	Efficiency % [2020-2022]
1	NCB	100	100
2	Al Rajhi Bank	92.773	91.62
3	Riyad Bank	87.876	86.74
4	SAAB	87.115	85.65
5	ANB	83.596	82.87
6	Alinma	81.763	81.11

Table 5. Economies of scale.

Rank	Bank	Economies of scale [2017-2019]	Economies of scale [2020-2022]
1	NCB	0.9987	0.9985
2	Al Rajhi Bank	0.977	0.974
3	Riyad Bank	0.96337	0.962
4	SAAB	0.961	0.96
5	ANB	0.954	0.9523
6	Alinma	0.952	0.951

Table 6. Economies of scope.

Rank	Bank	Economies of scale [2017-2019]	Economies of scale [2020-2022]
1	NCB	0.91041	0.9
2	Al Rajhi Bank	0.87567	0.865
3	Riyad Bank	0.8624	0.842
4	SAAB	0.86134	0.853
5	ANB	0.83699	0.825
6	Alinma	0.81887	0.811

5. Conclusion

In this research, we adopted the (DFA) approach to determine the operational efficiency of Saudi banks using data from the period [2017-2022]. We proceeded by measuring the x-efficiency, the economies of scale and the economies of scope for each bank.

The x-inefficiency measure for Saudi banks is in the range of 7% - 19%, indicating that NCB is the most efficient bank in the Saudi banking industry.

We note that most of the Saudi banks benefit from increasing returns to scale. Similarly, Saudi banks all seem to benefit from economies of scope across output.

Finally, there is no significant difference in efficiency before and after the Coronavirus pandemic.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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