An investigation into the cost efficiency, scale economies, technological progress and productivity of Algerian banks

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Abstract :

This study investigates the cost efficiency, scale economies, technological progress and total factor productivity growth of Algerian banks. To accomplish this, we us a sample of all the commercial banks operating in Algeria over the period 2003–2016. Results show that banks are wasting 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. Results also show that technological progress reduced the cost of production of banks, and that bank productivity increased over the study period.

Mots clés:
Mot clé.1: Efficience coût
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Résumé : Cette étude examine l'efficience coût, les économies d'échelle, le progrès technologique et la croissance de la productivité totale des facteurs des banques algériennes. Pour ce faire, nous utilisons un échantillon de données comprenant toutes les banques commerciales exerçant en Algérie sur la période 2003–2016. Les résultats montrent que les banques gaspillent 16% de leur coût de production, les banques étrangères de toutes tailles ont montré des économies d'échelle, tandis que les banques publiques de toutes tailles ont montré des déséconomies d'échelle.

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1- The introduction:

Several studies provide empirical evidence that well-functioning financial systems accelerate long-term economic growth (e.g. King and Levine (1993a, 1993b) and Levine and Zervos (1998)). In Algeria, and many other developing countries, the financial system is bank-based, i.e. banks play an important role in the financing of the economy. According to the 2017 annual report of Banque d'Algérie, banks ensure the financing of the totality of private sector and 96.3% of the public sector, which amounts to almost all of the financing of the economy (98.2%).

Given the importance of the banking sector in Algeria, the performance of its banks becomes an issue of great interest for various stakeholders. Thus, in the present study, we plan to examine the cost efficiency, scale economies, technological progress as well as total factor productivity growth of Algerian commercial banks. In this context, several important questions are investigated: **have Algerian banks become more efficient and more productive over the study period? Did the adoption of new banking technologies lead to a lower cost of production? Do Algerian banks exhibit economies of scale? And what is the optimal size of banks in Algeria?**

To investigate the above questions, we use an unbalanced panel data of 20 commercial banks, all the commercial banks in Algeria, over the period 2003–2016. We first estimate cost efficiency scores using a parametric technique, Stochastic Frontier Analysis (SFA), then we use the cost frontier results to obtain estimates of scale economies, technological progress and total factor productivity growth. We start by analyzing the evolution of these performance measures over the study period, then we examine how they are related to bank size and ownership.

Findings of the study can be used by banks to gain insights on how to reduce their cost of production and improve their overall performance. Regulators can also find several insights on how to improve the productivity and efficiency of the Algerian banking sector.

1-1- A brief review of the literature:

The study of banking efficiency has received a lot of attention during recent decades. However, most of the existing studies are carried out in developed countries. The number of studies focusing on developing countries remains small in comparison. Efficiency studies differ in aim, the efficiency concepts used, the definition of input and output of production, the estimation technique of efficiency and in many other aspects. In the following we will focus on studies that use the estimation technique SFA to examine the cost efficiency, scale economies, technological progress and productivity of banks.

Altunbas and al. (2001) find that German banks benefited from scale economies, averaging 9%, and that large banks recorded greater economies than their smaller counterparts. The authors also find that technological progress reduced the average cost of banks by 4.3%, with the largest banks being the main beneficiaries. In another study, Margono and al. (2010) find that Indonesian banks recorded an average cost efficiency score of 66.5%. They also find that foreign banks and domestic private banks are more cost efficient than public banks and that technological progress reduced the average cost of Indonesian banks by 2.9% before the Asian economic crisis of 1997. However, their average cost increased by 6.4% in the post-crisis period.

Altunbaş and al. (2001) find that X-inefficiencies (technical and allocative inefficiencies), ranging between 20% and 25%, are more important than scale economies, ranging between 5% and 7%. The authors also find that scale economies are widespread for the smaller banks and that technological progress reduced the average cost of European banks by 3%. In a similar study, Altunbas and al. (2000) find that the optimal size of Japanese banks is considerably smaller when risk and quality factors, represented by financial capital and loan loss provision, are taken into account in the cost function. However, cost efficiency estimates appear to be less sensitive to the inclusion of these factors. Kasman (2002) finds that Turkish banks recorded an average cost efficiency score of 76.4%. The author also finds no evidence of scale diseconomies; Turkish banks of all sizes showed evidence of scale economies even large banks. In addition, Turkish banks recorded on average a technological recession over the period 2001–1998.

In another study, Sensarma (2006) finds that foreign banks are less cost efficient and less productive than their domestic private and public counterparts, and that the deregulation of the Indian banking system led to improved cost efficiency and productivity. In addition, the author finds that large banks are less cost efficient than their smaller counterparts. Olson and Zoubi (2011) find that banks in the MENA region recorded an average cost efficiency score of 70.3%. In addition, they found that Islamic banks are less cost efficient than conventional banks and that almost all banks in the MENA region are operating below the optimal size.

The empirical literature on the efficiency of financial institutions is rather limited in Algeria, our country of interest, and the Maghreb region in general. Benzai (2016) finds that Algerian banks recorded an average cost efficiency score of 45.7%. In addition, the author also finds that public banks are more cost efficient than foreign banks, and that large banks are more efficient than medium and small banks. The obtained results also show that the cost efficiency and total factor productivity of Algerian banks deteriorated

over the period 2003–2012. In another study, Bakhouche (2004) finds that inefficiency is substantial in the banking systems of Algeria, Morocco and Tunisia, with an average cost inefficiency of 29%. In addition, the author finds that domestic private banks and foreign banks in these three countries are more cost efficient than public banks. However, in Algeria this conclusion is reversed, public banks are more cost efficient than their foreign counterparts. The author also finds evidence of substantial scale economies in the 8.5% to 66.5% range, particularly for medium and large banks, suggesting the benefits of mergers and acquisitions operations.

2- Research Methods, tools and measures:

The first performance measure to be estimated is cost efficiency as described in Berger and Mester (1997). Cost efficiency gives a measure of how close the cost incurred by a given bank relative to the minimum cost incurred by the industry best-practice bank producing the same level of output and subject to the same input prices.

As mentioned, we use SFA to obtain cost efficiency estimates. This technique consists of first constructing a frontier that include all banks that incurred minimum costs, after that we measure the distance that separate the cost of other banks relative to this frontier. The frontier is stochastic in a sense that it allows for random fluctuations that can increase or decrease the cost inefficiency of a given bank. For example, if a bank is faced with unfavourable conditions, then its inefficiency level is less than the distance between its cost and the relative frontier. It follows that the stochastic cost frontier is expressed by:

$$C_i = f(y_i, w_i, \beta, \varepsilon_i) \quad (1)$$

Where C_i is the total cost of bank i; y_i is a vector of outputs; w_i is a vector of input prices; β is a vector of parameters to be estimated; and ε_i is the composed error term.

The composed error term, as proposed in Aigner and al. (1977), consists of two components: a symmetrical two-sided noise v_i that is supposed to capture errors of observation, measurement and deviations due to random chocs outside the control of managers such as climate in agriculture or the performance of machinery in a plant. The other is an asymmetric non-negative component that represents cost inefficiency (u_i), which corresponds to poor managerial performance. The inefficiency term is separated from random error using the conditional distribution of u given ε as proposed by Jondrow and al. (1982) and Battese and Coelli (1988). As a result, a point estimate of inefficiency is obtained using the mean $\mathbb{E}(u|\hat{\varepsilon})$ or the mode $\mathbb{M}(u|\hat{\varepsilon})$, and cost efficiency can be defined as $exp(-u)$.

SFA requires the specification of the inputs and outputs of production and the functional form of the cost function. For the former we adopt the

intermediation approach proposed by Sealey and Lindley (1977), in which banks are assumed to use physical capital, labour and deposits to produce earning assets: loans and other earning assets. Whereas for the latter, we use the translog specification, which is a second order approximation of any unknown function, given its widespread usage in the literature and its relative flexibility. The cost frontier, which we add to it a time trend to capture the effects of technological progress, is expressed then by:

$$\ln\frac{C_{it}}{w_{2it}} = \beta_0 + \sum_m \alpha_m \ln y_{mit} + \beta_1 \ln\left(\frac{w_{1it}}{w_{2it}}\right) + \delta_1 Trend + \frac{1}{2}\sum_m\sum_j \alpha_{mj} \ln y_{mit} \ln y_{jit} + \frac{1}{2}\beta_{11} \ln\left(\frac{w_{1it}}{w_{2it}}\right)^2 + \frac{1}{2}\delta_{11}(Trend)^2 + \sum_m \gamma_m \ln\left(\frac{w_{1it}}{w_{2it}}\right) \ln y_{mit} + \sum_m \varphi_m ln y_{mit}(Trend) + \rho_1 \ln\left(\frac{w_{1it}}{w_{2it}}\right)(Trend) + v_{it} + u_{it} \quad (2)$$

Where C_{it} is the total cost of bank i during year t, and it is equal to the sum of interest and non-interest expenses; $y_m, m = 1,2$ is a vector of two outputs: total loans and other earning assets (securities such as government bonds and loans to other banks); $w_k, k = 1,2$ is a vector of input prices: labor and physical capital price and the price of funds; β_0, α_m, β_1, δ_1, α_{mj}, β_{11}, δ_{11}, γ_m, φ_m, ρ_1 are coefficients to be estimated; v_{it} is is the random error and u_{it} is the cost inefficiency of bank i during year t. In addition, and to satisfy the condition of linear homogeneity in input prices, i.e. $c(y_i, \lambda w_i, \beta) = \lambda c(y_i, w_i, \beta),\ \forall\ \lambda > 0$, we normalized total cost and prices by w_2 (price of funds).

Normally, we would have three input prices: the price of labour, physical capital and funds, but given that the number of employees per bank is not available, we follow Hasan and Marton (2003) and use the ratio of non-interest expenses over total assets as a proxy for labour and physical capital prices. The price of funds is equal to the ratio of interest expenses over total deposits.

Instead of using cross-sectional data and thus estimating efficiency scores separately for each year, we use panel data. This is because, as Schmidt and Sickles (1984) argues, having panel data can help relax some of the strong assumptions made in SFA. Our preferred model is the Battese and Coelli (1992) time varying model, called time decay model, in which the inefficiency term is given by $u_{it} = u_i exp\{-\eta(t - T_i)\}$, where η is an unknown scalar to be estimated which represents the evolution of efficiency

over time, t is the tth time period, and T_i is the number of time periods for each producer. In addition, we use the half normal distribution to characterize the distribution of the inefficiency term.

The estimation technique of the cost frontier is the maximum likelihood method, which was carried out using the R package *"Frontier"* developed by Coelli and Henningsen (2013).

Next, scale economies (SE), defined as the decrease in the average cost of production resulting from an increase in output, are estimated using the sum of the partial derivative of total cost with respect to each output:

$$SE = \sum_m \frac{\partial \ln C_{it}}{\partial \ln y_m}$$

$$= \sum_m \alpha_m + \frac{1}{2}\sum_m \sum_j \alpha_{mj} \ln y_{mit} + \sum_m \gamma_m \ln\left(\frac{w_{1it}}{w_{2it}}\right) + \sum_m \varphi_m(Trend) \quad (3)$$

If SE < 1 then a given bank presents increasing returns to scale, which implies economies of scale, i.e. the proportional change in costs is smaller than the proportional change in outputs;

If SE = 1 it presents constant returns to scale, i.e. the proportional change in costs is equal to the proportional change in outputs;

If SE > 1 it presents decreasing returns to scale, which implies diseconomies of scale, i.e. the proportional change in costs is greater than the proportional change in outputs.

Technological progress (TP), defined as the decrease in the average cost of production resulting from the adoption of new production technologies, can be estimated using the partial derivative of total cost with respect to time:

$$TP = \frac{\partial \ln C_{it}}{\partial\, Trend} = \delta_1 + \delta_{11} Trend + \sum_m \varphi_m ln y_{mit} + \rho_1 \ln\left(\frac{w_{1it}}{w_{2it}}\right) \quad (4)$$

According to Baltagi and Griffin (1988), technological progress exists if TP is negative, whereas a positive TP implies a technological recession.

Total factor productivity (TFP) corresponds to the ratio of all of the products and services produced over all of the resources employed to produce them (Färe and al., 2008). The increase in productivity is attributed to three essential factors, namely: technological progress, economies of scale and efficiency. Therefore, Esho and Sharpe (1995) propose to decompose TFP growth, from the cost side, using the following expression:

$$TFP = -TP + (1 - SE)\dot{y} + \dot{CE} \quad (5)$$

Where TP is technological progress; SE is scale economies; $\dot{CE}$ corresponds to the change in cost efficiency $(CE_{it} - CE_{it-1})$; and $\dot{y}$ is the weighted output growth, defined as follows:

$$\dot{y}_{it} = \sum_{m=1}^{2} \left[\frac{SE_m}{\sum_{m=1}^{2} SE_m} (\ln y_{imt} - \ln y_{imt-1}) \right] \quad (6)$$

SE_m is scale economy evaluated at mean values. This decomposition of TFP growth allows us to identify the sources of productivity growth.

2-1- Data:

The dataset consists of balance sheets and income statements of all the commercial banks operating in Algeria, 20 banks in total, over the period 2003–2016. Six of the banks are public, and the remaining 14 are all private foreign banks composed of 10 subsidiaries, three branches of international banks and one joint venture (foreign-public). This dataset is obtained from two main sources: from Bankscope database, which contains financial information about numerous banks across the globe; and from the National Centre of The Trade Register (CNRC), which has a database that contains the financial statements of all the commercial firms operating in Algeria. We also use banks annual reports, as obtained from their websites, in the case of missing values.

The panel data is unbalanced since four foreign banks were established after 2003, and two banks at the end of 2003. Overall, it consists of 257 bank-year observations, 84 observations for six public banks and 173 observations for 14 foreign banks. However, due to data unavailability for some years, and, to a lesser extent, the exclusion of the first year of operation for banks that were established during or after 2003, the sample size was reduced to 210 bank-year observations.

3- Results and Discussion:

Table 1 gives the estimation results of the cost frontier described in (2). From the Table we read that $\gamma = \sigma_u^2/\sigma^2$ is equal to 85.1%, indicating that the percentage of inefficiency in the composite error term is relatively large, in other words, almost all of the variation in the composite error term is attributed to inefficiency. In addition, we note that the parameter η, representing the evolution of efficiency over time, is equal to -9.2% and it is significantly different from zero at the 1% level, suggesting that the cost efficiency of Algerian commercial banks did actually decrease over the period 2003–2016. Since the estimation results of the remaining parameters are not of particular interest per se, we do not comment on them to save space.

The yearly average cost efficiencies, scale economies, technological progress and TFP growth are presented in Table 2. The results show that mean cost efficiency is equal to 84%, indicating that the average bank wastes 16% of its cost relative to the best-practice bank in the sample, or similarly, the

average bank can reduce its cost by 16% while producing the same level of output. In addition, we notice a significant decline in cost efficiency over the study period. Mean cost efficiency went down from 91.9% in 2003 to 76% in 2016, that is a deterioration of 15.9 percentage points, although for some years it recorded a slight improvement (2007 and 2012).

For comparison, the average level of cost efficiency found for Algerian commercial banks is equal to that found for the case of German banks (83.8%) (Altunbas and al., 2001); lower than that indicated by Mendes and Rebelo (1999) for the case of Portuguese banks (94.3%); and higher than those indicated by Margono and al. (2010) for the case of Indonesian banks (66.5%) and Kasman (2002) for the case of Turkish banks (76.4%).

Table 1 Parameters estimates of the cost frontier using the Battese and Coelli (1992) time varying model

Dependent variable	**Total cost**		**Total cost**
Intercept	9,466	**(trend^2)/2**	-0,004
	(6,751)		(0,004)
y1	0,932	**w1*y1**	-0,037
	(0,695)		(0,036)
y2	-0,559**	**w1*y2**	-0,008
	(0,222)		(0,014)
w1	1,725***	**trend*y1**	0,019*
	(0,628)		(0,010)
trend	-0,100	**trend*y2**	-0,016***
	(0,175)		(0,005)
(y1^2)/2	0,001	**trend*w1**	0,013
	(0,038)		(0,010)
(y2^2)/2	0,056***	σ^2	0,208**
	(0,008)		(0,089)
(y1*y2)/2	-0,032	γ	0,851***
	(0,028)		(0,066)
(w1^2)/2	0,076*	η	-0,092***
	(0,041)		(0,029)
N	210	**log likelihood**	46,187

Notes : standard errors are in parentheses. ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively. **Source** : realized by the authors.

With respects to scale economies, we note that for each year in the period 2003–2016, the economies of scale factor, SE, is less than one, which suggests the existence of economies of scale in the Algerian banking sector,

ranging between 4.5% and 10.1%. We also note that the average scale economy is around 91.9%, suggesting that a 1% increase in output would increase the expected average cost of banks by 0.92%. In addition, because X-inefficiencies (16%) are more important than scale economies, Algerian banks can obtain greater cost savings if they focus more on reducing managerial inefficiency, compared with increasing size. This conclusion is similar to that found for the case of European banks (Altunbaş and al., 2001), and it is also similar to that found in the literature, see for example Berger and al. (1993).

The average scale economy factor recorded for Algerian banks is higher than those recorded for the case of Indonesian banks (87%) (Margono and al., 2010) and Turkish banks (74.3%) (Kasman, 2002). However, it is lower than those recorded for the case of European banks (94.6%) (Altunbaş and al., 2001) and European savings banks (92.5%) (Carbó and al., 2002).

Table 2 Estimation results of cost efficiency, scale economies, technological progress and TFP growth

Year	Cost efficiency	Scale economies	Technical progress	TFP growth
2003	0.919	0.942	-0.024	-
2004	0.909	0.919	-0.017	0.070
2005	0.893	0.899	-0.008	0.118
2006	0.871	0.922	-0.016	0.062
2007	0.879	0.912	-0.014	0.050
2008	0.873	0.916	-0.013	0.047
2009	0.840	0.918	-0.020	0.052
2010	0.826	0.906	-0.014	0.029
2011	0.826	0.901	-0.011	0.025
2012	0.827	0.913	-0.018	0.056
2013	0.813	0.901	-0.011	0.023
2014	0.801	0.936	-0.021	0.043
2015	0.786	0.955	-0.028	0.053
2016	0.760	0.947	-0.027	0.057
Average	0.840	0.919	-0.017	0.049

Note : TFP: total factor productivity. **Source** : realized by the authors.

The results regarding technological progress (TP) show that Algerian commercial banks recorded technological progress during the period 2003–2016, as indicated by the TP coefficients which are negative. Therefore, it can be concluded that the adoption of new production technologies led to a decrease in the average cost of banks. Indeed, during the study period

technological progress lowered the average cost of banks by 1.7%. In addition, the yearly TP estimates suggest that the contribution of technological progress to reducing the average cost of banks reached its maximum during the last two years, 2015 and 2016, that is 2.8% and 2.7%, respectively.

The average level of technological progress recorded for Algerian banks is lower than that recoded for the case of European banks (3.5%) (Altunbaş and al., 2001). However, it is higher than those recorded by Turkish banks (-1.3%) (Kasman, 2002); Indonesian banks (-1.7%) (Margono and al., 2010) and Portuguese banks (-6%) (Mendes and Rebelo, 1999), which all recorded a technological recession.

The reduction in the average cost of banks associated with technological progress might be due to the adoption of new technologies such as the computerization of bank operations and the installation of more automated teller machines (ATMs). Indeed, the number of ATMs per 100,000 adults increased from 1.3 in 2004 to reach 9.1 in 2018 (World bank data 2018). The entry of foreign banks following the financial liberalization, equipped with advanced banking technologies, might have pushed existing banks to invest in new technologies in order to be able to compete, which had the effect of reducing the average cost of production.

With regard to total factor productivity growth, the results show that TFP growth of Algerian commercial banks averaged 4.9%. Interestingly, throughout all the study period, banks experienced positive TFP growth, with the year 2005 recording the highest growth rate (11%). This is due, in part, to the scale economies and technological progress recorded over the same period. As discussed earlier, TFP growth is attributed to three essential factors: technological progress, economies of scale and efficiency. Therefore, we can conclude that the reduction in costs resulting from technological progress and the operation of banks at increasing returns to scale led to the observed increase in productivity.

3-1- Cost efficiency, scale economies, technological progress and TFP growth according to ownership type:

Estimates of cost efficiency, scale economies, technological progress and TFP growth of Algerian commercial banks according to ownership type are presented in Table 3. As mentioned earlier, the Algerian banking sector consists of only two ownership types, public and private foreign. Results show that for each year in the period 2003–2016, except the last year, the average cost efficiency of public banks is higher than that of foreign banks. In addition, the average cost efficiency of public banks is equal to 85.8%, higher than that of foreign banks (83.2%). Therefore, and to our surprise, we find that foreign banks are less cost efficient than public banks. This result is in contrast to most studies that compare the cost efficiency of foreign and public banks in developing countries, which find that private foreign banks

tend to be more cost efficient than their public counterparts. However, it is consistent with those obtained by Sensarma (2006) for the case of India; Staub and al. (2010) for the case of Brazil; Benzai (2016) and Bakhouche (2004) for the case of Algeria.

Table 3 Estimation results of cost efficiency, scale economies, technological progress and TFP growth according to ownership type

Year	Cost efficiency		SE		TP		TFP growth	
	Public	Foreign	Public	Foreign	Public	Foreign	Public	Foreign
2003	0.933	0.910	1.055	0.867	-0.036	-0.016	-	-
2004	0.912	0.907	1.048	0.839	-0.031	-0.008	0.028	0.099
2005	0.905	0.886	1.022	0.828	-0.029	0.004	0.034	0.174
2006	0.897	0.859	1.034	0.872	-0.035	-0.007	0.039	0.075
2007	0.885	0.875	1.045	0.837	-0.039	-0.001	0.041	0.055
2008	0.875	0.872	1.062	0.842	-0.045	0.003	0.037	0.052
2009	0.864	0.830	1.044	0.869	-0.039	-0.013	0.045	0.056
2010	0.867	0.809	1.080	0.833	-0.053	0.003	0.060	0.019
2011	0.857	0.812	1.071	0.828	-0.049	0.005	0.049	0.015
2012	0.845	0.820	1.056	0.847	-0.042	-0.007	0.039	0.064
2013	0.831	0.805	1.062	0.827	-0.042	0.003	0.049	0.010
2014	0.819	0.791	1.083	0.854	-0.047	-0.007	0.045	0.042
2015	0.802	0.775	1.074	0.876	-0.047	-0.016	0.057	0.052
2016	0.751	0.764	1.072	0.884	-0.048	-0.016	0.064	0.054
Average	0.858	0.832	1.059	0.849	-0.042	-0.004	0.045	0.052

Note : SE: scale economies; TP: technological progress; TFP: total factor productivity. **Source** : realized by the authors.

In the context of the Algerian banking sector, the observed low-cost efficiency of foreign banks relative to public banks can be explained in large part by the higher cost incurred by foreign banks due to expanding their branch networks. Indeed, according to the 2017 annual report of Banque d'Algérie, the number of branches of foreign banks went up from 152 branches in 2006 to 364 in 2017, that is 212 new branches were established in a period of 12 years. On the contrary, public banks established a mere 19 branches over the same period. This is because public banks have already a large network of branches (1145 in 2017) that covers all the national territory. Therefore, foreign banks are incurring higher costs because they are focused on reinforcing their presence in the Algerian banking sector. Another possible reason is the fact that employees of foreign banks tend to be better

remunerated than their public counterparts, which results in a higher cost of production.

The results regarding scale economies reveal that economies of scale only exist for the case of foreign banks, public banks on the other hand showed evidence of diseconomies of scale, as indicated by the coefficients of SE which are greater than 1, and this is throughout the study period. On average, the scale economies recorded by foreign banks were 84.9%, whereas they were 106% for public banks. Therefore, it can be inferred that a 1% increase in output would increase the average cost of foreign banks by 0.85%, and that of public banks by 1.06%.

For the case of technological progress, the negative coefficients recorded by public and foreign banks suggest that both ownership types benefited from technology to reduce their average cost of production. However, foreign banks recoded positive TP coefficients in the years 2005, 2008, 2010, 2011 and 2013, suggesting that in these years foreign banks experienced a technological recession, that is to say the adoption of new technologies increased their average cost of production. Furthermore, on average, technological progress has enabled the cost of production of public banks to be reduced by 4.2%, compared with only 0.4% for foreign banks. As a result, public banks seem to have benefited more from the adoption of new banking technologies than did foreign banks.

The results of TFP growth indicate that over the period 2003–2016, both public and foreign banks recorded a positive TFP growth, an average score of 4.5% for public banks lower than the average score recorded by foreign banks which is equal to 5.2%. In addition, TFP growth of foreign banks is higher than that of public banks for the period from 2004 to 2009, then it becomes lower for the remaining years, except for the year 2012. It is interesting to note that despite the superior performance of public banks in terms of cost efficiency and the fact that they have benefited more from technological progress, they recorded a lower average TFP growth score than that of foreign banks. This can be explained in part by the fact that public banks exhibited diseconomies of scale, unlike foreign banks which showed evidence of economies of scale.

3-2- Cost efficiency, scale economies, technological progress and TFP growth according to bank size:

Estimates of cost efficiency, scale economies, technological progress and TFP growth of Algerian commercial banks according to bank size are presented in Table 4. Banks are divided into 5 categories based on yearly total assets. The Table shows that small banks with total assets below 27.5 billion Algerian dinars (DA) and between 27.5 and 53.9 billion DA are the most cost-efficient banks, with an average cost efficiency score of 90.1% and 88.3%, respectively. Next, we find large banks whose total assets are between 167

and 802.9 billion DA and greater than 802.9 billion DA, with an average cost efficiency score of 83%. It seems that medium-sized banks whose total assets are between 54 and 166.9 billion DA are the least cost-efficient banks in our sample (75.2%). Therefore, the obtained results suggest that there is no clear relationship between the level of cost efficiency and bank size.

With regard to scale economies, we notice that the magnitude of the scale economies factor increases with size. Indeed, this factor is the smallest for small banks with total assets below 27.5 billion DA (80.3%), and exceeds 1 for large banks with total assets greater than 802.9 billion DA. This result suggests that very large banks exhibit diseconomies of scale, whereas small and medium-sized banks exhibit economies of scale. Therefore, for small and medium-sized banks the cost of producing one more unit decreases as output increases, unlike large banks, for which the cost of producing of one more unit increases as output increases. In other words, a 1% increase in output

Table 4 Estimation results of cost efficiency, scale economies, technological progress and TFP growth according to bank size

Year	Total assets (Billion DA)				
	< 27.5	**27.5 – 53.9**	**54 – 166.9**	**167 – 802.9**	**> 802.9**
			Cost efficiency		
2003	0.938	0.769	0.926	0.935	NA
2004	0.929	0.750	NA	0.926	0.852
2005	0.918	0.862	NA	0.927	0.839
2006	0.913	0.821	0.813	0.921	0.825
2007	0.902	0.921	0.807	0.892	0.876
2008	0.903	0.914	0.791	0.882	0.865
2009	0.831	0.909	0.731	0.881	0.853
2010	0.873	0.842	0.760	0.863	0.868
2011	0.913	0.891	0.688	0.828	0.858
2012	0.883	0.895	0.703	0.813	0.846
2013	0.833	0.890	0.681	0.797	0.833
2014	0.819	0.951	0.700	0.766	0.819
2015	NA	0.899	0.791	0.673	0.802
2016	NA	0.871	0.886	0.650	0.751
Average	0.901	0.883	0.752	0.831	0.832
			Scale economies		
2003	0.857	0.916	1.019	1.067	NA
2004	0.826	0.928	NA	1.032	1.112
2005	0.740	0.894	NA	1.005	1.075
2006	0.807	0.915	0.930	1.009	1.111
2007	0.764	0.901	0.893	1.026	1.074
2008	0.776	0.870	0.934	1.038	1.100
2009	0.854	0.853	0.905	1.022	1.058
2010	0.807	0.878	0.824	1.047	1.089
2011	0.711	0.900	0.809	0.949	1.078
2012	0.825	0.836	0.831	0.951	1.069
2013	0.787	0.789	0.845	0.947	1.074
2014	0.880	0.784	0.875	0.871	1.083
2015	NA	0.816	0.858	0.931	1.074
2016	NA	0.833	0.838	0.932	1.072
Average	0.803	0.854	0.866	0.982	1.078

			Technological progress		
2003	-0.018	-0.003	-0.042	-0.035	NA
2004	-0.008	-0.009	NA	-0.027	-0.050
2005	0.024	-0.012	NA	-0.023	-0.045
2006	0.012	-0.020	-0.023	-0.027	-0.061
2007	0.012	-0.021	-0.004	-0.036	-0.043
2008	0.017	-0.007	-0.014	-0.041	-0.050
2009	-0.024	-0.006	-0.011	-0.039	-0.038
2010	-0.001	-0.023	0.017	-0.049	-0.054
2011	0.040	-0.033	0.021	-0.023	-0.050
2012	-0.018	-0.011	0.013	-0.025	-0.045
2013	0.007	0.008	0.007	-0.023	-0.045
2014	-0.031	0.015	-0.019	-0.001	-0.047
2015	NA	-0.003	-0.020	-0.023	-0.047
2016	NA	-0.008	-0.006	-0.025	-0.048
Average	0.002	-0.009	-0.001	-0.027	-0.047
			Total factor productivity growth		
2003	-	-	-	-	-
2004	0.112	0.030	NA	0.028	NA
2005	0.366	0.079	NA	0.026	0.056
2006	0.097	0.044	0.073	0.031	0.063
2007	0.036	0.077	0.060	0.046	0.036
2008	0.082	-0.006	0.050	0.041	0.031
2009	0.047	0.102	0.004	0.045	0.046
2010	0.087	0.099	-0.055	0.057	0.062
2011	-0.100	0.047	0.035	0.039	0.049
2012	0.149	0.041	0.058	0.046	0.039
2013	-0.014	-0.026	0.053	0.046	0.051
2014	0.095	-0.018	0.051	0.056	0.045
2015	NA	0.022	0.045	0.077	0.057
2016	NA	0.033	0.071	0.055	0.064
Average	0.090	0.040	0.031	0.046	0.050

Source : realized by the authors.

increases the average cost of very small and medium-sized banks by 0.80% and 0.87%, respectively, whereas the same 1% increase in output increases the average cost of very large banks by 1.08%. In addition, the optimal size of banks seems to be between 167 and 802.9 billion DA (scale economies factor close to 1).

Because small and medium-sized banks exhibit scale economies, more growth-related activities, either increasing output levels, establishing new branches or merging with other banks, are recommended for these banks so as to reduce their costs and reach constant returns to scale. It should be noted that the number of commercial bank branches per 100 000 adults in Algeria (5.2) is significantly lower than that of the neighboring countries, Tunisia (22) and Morocco (24.9) (World Bank data 2018), suggesting the need to increase the number of banks in Algeria.

Technological progress according to asset size reveals that small banks with total assets less than 27.5 billion DA recorded, on average, a technological recession over the study period, that is their cost of production actually increased by 0.2% following the adoption of new technologies. However, it should be noted that for certain years these banks recorded a

technological progress, for example the years 2009 and 2014. Medium-sized banks whose total assets are between 54 and 166.9 billion DA as well as small banks whose total assets are between 27.5 and 53.9 billion DA recorded technological progress but this progress was small; the adoption of new banking technologies only reduced the average cost of these banks by 0.1% and 0.9%, respectively. Large banks also recorded technological progress with their cost decreasing by 2.7% (asset size between 167 and 802.9 billion DA) and 4.7% (asset size greater than 802.9 billion DA). As a result, it seems that large banks benefited more than small and medium-sized banks from technological progress.

The results of TFP growth show that Algerian commercial banks of all sizes recorded positive TFP growth. Small banks with total assets of less than 27.5 billion DA appear to have the highest average growth rate, at 9%. In second place, large banks whose total assets exceed 802.9 billion DA (5%). Medium-sized banks with total assets between 54 and 166.9 billion DA appear to have the lowest growth rate (3.1%). It is interesting to note that despite the fact that they experienced a technological recession over the period 2003–2016, small banks recorded the highest TFP growth rate.

3-3- Cost efficiency, scale economies, technological progress and TFP growth according to ownership type and bank size:

Because public banks tend to be of large size and foreign banks tend to be of small and medium size, we decided to examine in this section the average cost efficiency, scale economies, technological progress and TFP growth scores according to ownership type and size. Table 5 presents the results. The table shows several interesting findings. First, we notice that there are not any small public banks, Algerian commercial public banks are either of medium-size or large. In addition, we also notice that there are not any very large foreign banks with total assets exceeding 802.9 billion DA. With regard to public banks, it appears that medium-sized banks are more cost efficient than large banks, 92.6% versus 83.2%, and as the size of public banks increases, they become less cost efficient. This conclusion also holds for foreign banks. Indeed, small foreign banks are more cost efficient than medium and large banks, 90.1% versus 74.7% and 72.9%, respectively. As a result, we conclude that there exists a negative relationship between size and cost efficiency, that is as the size of public and foreign banks increases, they become less cost efficient.

With regard to scale economies, results show that public banks of all sizes exhibited diseconomies of scale, whereas foreign banks of all sizes showed evidence of economies of scale. This result suggests that the finding that small and medium-sized banks exhibited economies of scale is actually

attributed to foreign banks and not public banks. Technological progress and TFP growth results do not show any new interesting finding.

Table 5 Estimation results of the average cost efficiency, scale economies, technological progress and TFP growth according to ownership type and bank size

	Cost efficiency		SE		TP		TFP growth	
Total assets (Billion DA)	**Public**	**Foreign**	**Public**	**Foreign**	**Public**	**Foreign**	**Public**	**Foreign**
< 27.5	NA	0.901	NA	0.803	NA	0.002	NA	0.090
27.5 – 53.9	NA	0.883	NA	0.854	NA	-0.009	NA	0.040
54 – 166.9	0.926	0.747	1.019	0.862	-0.042	0.000	NA	0.031
167 – 802.9	0.901	0.729	1.027	0.916	-0.033	-0.018	0.037	0.056
> 802.9	0.832	NA	1.078	NA	-0.047	NA	0.050	NA

Note : SE: scale economies; TP: technological progress; TFP: total factor productivity. **Source** : realized by the authors.

4- Conclusion:

The present study investigated the cost efficiency, scale economies, technological progress and total factor productivity growth of Algerian banks. Results show that the average bank wastes 16% of its cost of production, and that bank efficiency decreased over the period 2003–2016. In addition, we found evidence of economies of scale in the Algerian banking sector, ranging between 4.5% and 10.1%. However, further analysis revealed that economies of scale only exist for foreign banks of all sizes, whereas public banks of all sizes exhibited diseconomies of scale. Moreover, the optimal size of banks seems to be between 167 and 802.9 billion DA of total assets.

Results also show that technological progress reduced the average cost of banks by 1.7%, with large banks and public banks being the main beneficiaries from the adoption of new banking technologies. Algerian banks' total factor productivity increased by an average of 4.9% over the study period. In addition, and to our surprise, we found that foreign banks are less cost efficient than public banks, and that as the size of banks increases, they become less cost efficient.

The above findings give rise to the following recommendations: foreign banks of all sizes are encouraged to increase their size so as to reach constant returns to scale. Greater investments in new banking technologies are also encouraged, especially for public banks and large banks. Regulatory bodies should introduce more competition in the banking sector so as to reduce managerial inefficiency, one possible way is the removal of the 51-49 rule. Public banks are "too big" and exhibit diseconomies of scale, therefore reducing their size through breaking them up is also recommended.

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