Journal of Applied Finance & Banking, Vol. 13, No. 5, 2023, 97-123
ISSN: 1792-6580 (print version), 1792-6599(online)
https://doi.org/10.47260/jafb/1355
Scientific Press International Limited

Measuring the Cost Efficiency of Lebanese Commercial Banks using the Stochastic Frontier Approach

Nasma A. Berro[1]

Abstract

This paper attempts to measure the cost efficiency of 44 banks operating in Lebanon throughout the period 1992-2016, using the stochastic frontier technique. The additional purpose of this study is to detect the impact of some endogenous and exogenous factors on the cost efficiency scores calculated. The empirical results show a stabilization in the cost efficiency of Lebanese banks over the period studied and that on average those banks could reduce up to 12% of their allocated resources while maintaining the same level of their final outputs. We also found that cost efficiency among Lebanese banks is driven by 1) macroeconomic factors such as economic growth and inflation development and 2) by banks specific factors such as liquidity, capitalization, profitability and the diversification strategy.

JEL classification numbers: C10, C67, D61, G20, G21.
Keywords: Stochastic frontier, Parametric approach, Cost efficiency, Banks, Efficiency determinants.

[1] Department of Finance, School of Business, Lebanese International University, Beirut, Lebanon.

Article Info: *Received:* May 15, 2023. *Revised:* June 7, 2023.
Published online: June 19, 2023.

1. Introduction

The financial sector has a dynamic function in terms of growth and the development of the economic activity, by ensuring the efficient mobilization of financial resources towards adequate productive results (Levine, 2005; Arcand et al, 2012). As for the banking sector, it occupies a preponderant place in the economic process by contributing significantly to the financing of the economy, the setting of prices, the valuation of financial investments and the mitigation of inherent risks. Banks are thus a main component of the economy and their investment decisions are estimated to influence the development of different economic activities in a country. As a result, it turns out that the economic growth and stability of a country are generally stimulated by the proper functioning of its banking sector, which is manifested particularly by an acceptable performance in terms of the optimization of profits or cost minimization (Casu and Girardone ,2005). To achieve their objectives, banks are encouraged to use their resources efficiently in financing the economy. It therefore becomes essential for the regulatory and managerial authorities of banks to ensure the efficiency of the latter. Accordingly, empirical studies covering the efficiency of the banking system are getting additional consideration over the last years. Nonetheless, banks operate in a fluctuating competitive environment: Technological development, rapid-growth information flows, tight regulations and continuous multifold reforms stimulate considerable alterations in banking systems; namely at the level of costs incurred and profits earned.

The interest of this study derives mainly from the specificity of the banking activity in Lebanon and the particularity of the Lebanese banks which operate mostly in a fragile and delicate political and economic climate marked by a high public debt (85 billion dollars in 2018 or almost 152% of GDP), a large deficit (constituting almost 11% of GDP), a remarkable level of corruption (the 138th rank out of 180 countries in the 2018 ranking of the Corruption Perceptions Index, Transparency International) and a severe competitive environment. Fragility within the economic performance in Lebanon may reduce bank credit quality and increase their risks, which could negatively affect their efficiency and overall costs. To eliminate this risk, banks have to make further effort and thus incur additional costs. This situation encourages Lebanese banks to rationalize the use of their production factors in order to reduce their costs and ensure acceptable profitability to meet economic, financial and regulatory requirements. This paper lays on a parametric approach, established on econometrics techniques, in order to explore the productive performance of Lebanese commercial banks. The parametric approach used is the stochastic frontier analysis (SFA) whereby the efficiency score is calculated through a cost function. The use of the stochastic cost frontier permits the calculation of an isolated random error term that indicates the inefficiency of each individual bank in the used sample of 44 banks. The establishment of the cost frontier will allow in a second phase to evaluate the way in which internal and external factors influence the efficiency scores. This phase is essential in shedding light on the determinants and dynamics

of efficiency performance of Lebanese banks.
The remaining part of this paper is structured as follows: Section 2 presents the related banking efficiency literature using the production frontier approaches. Section 3 defines the empirical methodology that will be implemented in this paper. We describe and analyze the data in section 4. The empirical results and findings of the study are presented and discussed in section 5.

2. Review of Banking Efficiency Literature

The evaluation of efficiency within the banking systems has become increasingly popular over the past decade as the number of studies and empirical applications in this area has significantly increased. The literature review reveals a multitude of studies, at the international level, developing the notion of productive efficiency and its determinants within the banking sector. One of the first studies using the production frontiers was that conducted by Sherman and Gold (1985) who used the Data envelopment analysis to measure the efficiency of 14 US bank branches. The Stochastic frontier analysis has been applied also by various authors to assess banking efficiency: Dietsch and Chaffai (1999) examined the efficiency of the European banks; Mendes and Rebelo (1999) measured the level of efficiency in the Portuguese banking sector; Berger and Mester (2001) evaluated the efficiency within the U.S. banking system; and Kumbhakar et al. (2001) studied Spanish banking efficiency levels. Fontani and Vitali (2014) investigated the performance of the Italian banking system from 1993 to 2004 and determined the role of the main factors that portray banks efficiency. On the other hand, few empirical studies have been conducted on the Lebanese banking sector. Ariss (2008) examined the evolution of efficiency in the Lebanese banking sector following the period of deregulation and financial liberalization. The results disclosed that cost efficiency of banks has improved over the examined period and that banks exhibit a minimal level of average cost inefficiency at around 12%. Moussawi and Saad (2009) have evaluated the efficiency of 43 Lebanese commercial banks for the period 1992-2005 using two distinct methods: the Data Envelopment Analysis and the stochastic Frontier Analysis. Their results showed an average improvement in the level of efficiency. In order to assess the efficiency of the sector in producing the conventional outputs over the period 1993-2002, Djoundourian and Raad (2008) evaluated in their study the main performance indicators of the Lebanese banking sector. The stochastic production and cost function estimates indicate that bank level inefficiency declines over the studied period and increases in function of some variables such as number of branches and ratio of staff to operating expenses. Awdeh and Moussawi (2009) measured productive efficiency scores over the period (1996-2005). Using the DEA method and classifying banks in Lebanon according to their nationality but independently of their ownership structure, they detected some inefficiency of banks with an average cost-efficiency score of 86%. Elkanj and Zreika (2011) applied the DEA method to calculate the technical efficiency of Lebanese banks according to their size over two sub-periods (2002-2006) and

(2006-2009). They concluded that the large banks are those with the highest level of technical efficiency and noted that the average technical efficiency of the 40 banks in the sample improved after the financial crisis of 2007.

3. Research Methodology

Bank performance evaluation relies whether on accounting-based techniques or on economics-based techniques. Accounting-based examination of bank performance focus on available information within the common financial statements to detect the drivers of bank performance such as net profit margin or operating cash flow or return on equity/assets. On the other hand, techniques based on economics studies concentrate on the concept of efficiency based on the construction of frontiers. This measure of efficiency is calculated as the distance that separates a given bank from a best-practice frontier relatively to the lowest cost or highest profit bank in the observed sample.

Commonly, frontier techniques fall into two main categories: the parametric approach (such as the stochastic frontier analysis-SFA) and the non-parametric approach (mainly the data envelopment analysis-DEA). In this empirical study, a SFA model, which allows the specification of a composed error, is used to estimate the efficiency.

The pioneer authors of the stochastic formulation of the parametric frontier are Aigner, Lovell and Schmidt (1977), and Meeusen and Van den Broek (1977) who simultaneously and independently introduced the notion of the random effect to take into account the errors of estimation (Timmer, 1971) or exogenous variables beyond management control (Aigner and Chu, 1968). This proposition is introduced to compensate for the shortcomings attributed to the deterministic frontier. The estimation of the stochastic frontier is done only using econometric techniques without any recourse to mathematical programming like the non-parametric approach (DEA). As for the DEA, it does not account for the presence of a random error term, thus, any deviation from the productive frontier is explained as inefficiency. The stochastic frontier method, called compound error model, divides the error term of the statistically estimated production function into two variants, which allows the transition from a deterministic frontier to a stochastic frontier (Worthington, 2001**):**

The first variant, a one-sided error, represents the technical inefficiency specific to each decision-making unit. This term follows a skewed distribution on only one side of the frontier explained as inefficiency increases cost in a production function and reduces output in a cost function. The stochastic frontier requires a prior hypothesis on the distribution of the inefficiency term. It is best to commit to a general and flexible specification and let the data establish the most suitable correct distribution. To be greater than zero, several distributions are accepted in the literature such as the truncated normal law proposed by Stenvenson (1980), the gamma distribution (Greene, 1980), the semi-normal law and the exponential law.

The second variant is that of the random error effect, combining both measurement errors and exogenous effects that cannot be controlled by the unit. This term is assumed to be identically and independently distributed on each side of the production frontier according to a normal distribution, with zero expectation and variance σ^2 such that N $(0, \sigma^2)$. The symmetric distribution is explained by the fact that the measurement or specification error term, and depending on its nature, can be added to or subtracted from the frontier.

The justification for such a breakdown comes down to the idea that a production process whose planning has been prepared in an optimal way ex-ante can provide partly random production levels. This is how it is possible for some units, through the use of the stochastic frontier, to lie above the frontier (Daouia et al. 2020). This situation occurs when a unit has not only ensured an optimal planning of its production process but has also taken advantage of more beneficial states of effects or random variables than the average. In the same manner, the efficiency estimates deduced by this approach have statistical properties and therefore the results are easily validated by econometric tests. Compared to the non-parametric approach, the parametric approach is less sensitive to extreme values.

To measure the level of productive efficiency in the Lebanese banking context, we estimate a translogarithmic cost function which is flexible in nature (Christensen et al. 1973). This form makes it possible to take into account both the multi-product nature of banks, which makes it possible to mitigate the problem of heterogeneity of banking output and the complexity linked to production technology. Our designated base specification for the Translog cost function includes three types of banking products (Remunerated Assets, Off-Balance Sheets, and Bank Deposits) and three input prices.

We measure cost efficiency by adopting the stochastic frontier model in unbalanced panel data proposed by Battese and Coelli (1995) which separates, at the level of inefficiency, a deterministic component representing the variables that we aim to test its impact on the efficiency scores. The importance given to the production frontier estimated in the presence of a data panel comes down to the fact that this panel ensures a more precise evaluation of efficiency since the consistency of the estimator becomes more important when the number of periods or observations rises (Schmidt and Sickles, 1984). Thus, our work consists in simultaneously determining in a single step the efficient cost frontier and the explanatory variables of the level of efficiency displayed by the banks in our sample (Kumbhakar and Lovell, 2000; Wang and Schmidt, 2002; Cornwell and Schmidt, 2008). The establishment of a link between the efficiency scores and the structural variables already defined is thus ensured through the direct incorporation into the stochastic specification of these variables, which allows us to carry out this estimation in a single step. The estimated Translog cost function is described as follow:

$$\ln \boldsymbol{CT_{nt}} = \alpha_0 + \sum_{i=1}^{3} \alpha_i \, ln y_{it} + \frac{1}{2} \sum_{i=1}^{3} \sum_{k=1}^{3} \delta_{ik} \, \ln y_{it} \ln y_{kt} + \sum_{j=1}^{3} \beta_j \, \ln P_{jt} + \frac{1}{2} \sum_{j=1}^{3} \sum_{l=1}^{3} \gamma_{jl} \, \ln P_{jt} \ln P_{lt} + \sum_{j=1}^{3} \sum_{i=1}^{3} \rho_{jl} \, \ln y_{it} \ln P_{jt} + \mathcal{V}_{it} + \mathcal{U}_{it} \quad (1)$$

Given the following variables:

- CT_{nt} : the function of total cost of the banks made up of financial and operating costs will be estimated for each bank n in year t
- $Y_{(it)}$: the selected outputs (i=1,2,3) ;
- $P_{(jt)}$: the prices of the selected inputs (j=1,2,3) ;
- $\mathcal{V}_{it}$: representing the random terms assumed to follow a normal law $N\left(0,\sigma_u^2\right)$ and which are identically and independently distributed;
- $\mathcal{U}_{it}$: The asymmetric variable, distributed on one side of the frontier, introduced to intercept the level of inefficiency in the banking production process. In order to take into consideration the impact of the explanatory variables of efficiency, we assume that this term follows a normal distribution law truncated at zero: $N(\mu,\sigma_u^2)$ independent of that of V_{it}; with $\mu = m_{nt}$ such that $m_{nt} = \delta_0 + \delta.z_{nt}$
  In this specification, z_{nt} represents a vector of (p×1) variables capable of explaining the efficiency scores of bank n in year t and δ describes a vector of (p×1) parameters that will be estimated.

By introducing our eight explanatory variables of efficiency, the equation $\{m_{nt} = \delta_0 + \delta.z_{nt}\}$ is rewritten as follows:

$$m_{nt} = \delta_0 + \delta_1\ (V1) + \delta_2\ (V2) + \delta_3\ (V3) + \delta_4\ (V4) + \delta_5\ (V5) + \delta_6\ (V6) + \delta_7\ (V7) + \delta_8\ (V8) \qquad (2)$$

The Translog form makes it possible to take into consideration the crossing between the different explanatory variables without any restriction imposed a priori on the characteristics of the production technology. Similarly, this form satisfies the assumption of price homogeneity through the inclusion of a set of linear restrictions on the parameters. Standard symmetry constraints are also imposed.
The set of parameters of the equation as well as the terms associated with the variances of the random variables ($\mathcal{V}_{it}$ + $\mathcal{U}_{it}$) : $\sigma^2 = {\sigma^2}_{v+}{\sigma^2}_u$ et $\gamma = \frac{{\sigma^2}_u}{\sigma^2}$ are estimated in one step using the maximum likelihood method. The parameter γ is comprised between 0 and 1. A value equal to 1 means that inefficiency explains all the deviation from the frontier, while a value of zero indicates that all the deviation from the frontier comes from random shocks. Thus, a value between 0 and 1 reflects variation that is due to both inefficiency and random shocks.
In a last step, the Hausman specification test was used to determine the presence of fixed effects (the case where there is a correlation between the specific effects and the explanatory variables of the model) or random effects (when the specific effects are orthogonal to the explanatory variables of the model). This test follows a Chi-square law with (k-1) degrees of freedom. We used a significance level of 10% with

the null hypothesis" the random effects model is appropriate" and the alternative one is" The fixed effects model is appropriate". The results of the Hausman test, performed with e-views, are presented in table (1).

Table 1: Hausman Test results

Correlated Random Effects - Hausman Test			
Test cross-section random effects			
Test Summary	Chi-Sq. Statistic	Chi-Sq. D.F.	Prob.
Cross-section random	14.89095	8	0.0613

The probability of the Hausman test is lower than the retained threshold of 10% and thus the null hypothesis is rejected and the adequate model for our study is the fixed effects model. Practically, this model assumes that the regression coefficients are similar for all the units examined except for a fixed effect which is specific to each unit. This is possible by combining the true variables that explain the basic model with indicative variables specific to units and periods. The fixed effects model will thus allow us to take into account the specific aspect of each bank in the study of the existing relationship between the level of efficiency and the factors that are examined (endogenous and/or exogenous factors).

4. Data and Variables Specifications

The objective is to measure, for a given level of output, the degree of similarity between the costs borne by each bank and those generated by the best practice banks. Therefore, the estimation of a cost frontier for commercial banks in Lebanon requires the definition of outputs and inputs that will be retained in the banking production process. For the measurement of bank outputs and inputs, a hybrid approach, which is consistent and similar to that adopted by several authors such as Altunbas et al. 2001; Grigorian and Manole, 2002, is chosen. The inclusion of off-balance sheet activities will allow subsequently incorporating a certain level of risk in our specification and to also taking into account the different variables expressing managerial preferences, banking activity at the macroeconomic level, the degree of risk, agency theory, etc. It remains to be noted once again that theoretical studies relating to the banking field unquestionably find it difficult to accept a unanimous definition of the banking activity. We believe that the approach adopted offers a global vision of banking production in general and of Lebanese banking activity in particular.

- The total cost incurred by the banks, according to the hybrid approach, includes:
- Financial expenses including interest paid by the bank and similar charges.
- Operating expenses encompassing expenditure on labor and physical capital.

- The inputs are:

1) Financial capital: We retain the financial charges corresponding to the remuneration of bank liabilities in the form of interest expenses (Grigorian and Manole, 2002; Weill, 2006). This production factor is taken into account because it constitutes on average more than 70% of the total banking charges of commercial banks in Lebanon.
2) Labor factor measured by personnel costs expressed in monetary units and
3) Physical capital measured by fixed assets.

- The outputs are:

1) Bank deposits which include demand deposits, savings accounts, term accounts and deposits with overseas branches;
2) Total interest-bearing assets, which essentially include the portfolio of loans granted to customers (individuals and businesses). The choice of loans as output is adapted to the traditional activity of banks on the one hand, and on the other hand, it constitutes the most important service offered by banks. Interest-bearing assets also include the portfolio of financial securities including bonds and other fixed or variable income marketable securities and
3) Off-balance sheet activities, following the example of Chauveau and Blancard (2002), included as an indicator of sensitivity to market risk.

We have adapted the following input prices:

1) The price of financial resources as the ratio of financial charges to total deposits.
2) The price of the labor factor as the ratio of wage costs to the total number of employees
3) The price of physical capital as the ratio of operating overhead to the number of branches.

Table 2: Summary of all the variables used in the adapted model of the production frontier

Inputs	Price of inputs	Outputs
I_1: Financial capital	P1: $\frac{Interest\ and\ financial\ charges}{Total\ Deposits}$	O_1: Deposits
I_2: Labor factor	$P2$: $\frac{Wage\ costs}{number\ of\ employees}$	O_2: Remunerated assets
I_3: Physical capital	$P3$: $\frac{Operating\ overhead}{number\ of\ branches}$	O_3: Off-Balance activities

The statistical analysis of the variables selected for commercial banks in Lebanon reflects a development of banking activity during the period from 1992 to 2016. In fact, all the variables presented in table (3) have experienced a considerable increase for the period observed. The statistics calculated reveal homogeneity at the level of the sample of commercial banks selected because the dispersion, represented by the coefficient of variation, of the various variables listed in this table remains relatively stable with a slight increase for the period considered. Off-balance sheet activities also increased on average, which explains the use of non-traditional activities and additional risk-taking by banks. Indeed, this variable, as shown in figure (1), displays a large fluctuation in the dispersion over time. Its coefficient of variation varies between [1.38-3.31] for the period studied and thus displays the greatest dispersion among the variables retained. This dispersion reflects the risky nature of off-balance sheet activities.

Table 3: Descriptive statistics of selected variables between the period 1992-2016[1]

Variables	Descriptive statistics	1992	1998	2004	2010	2016	1992-2016
Deposits	Average	238	989	2027	4760	8419	2959
	Standard deviation	305	1405	3150	7818	11418	3816
	Coefficient of Variation	1.28	1.42	1.55	1.64	1.36	1.29
	Minimum	3	4	8	5	8	3
	Maximum	1094	5823	13621	37458	54203	54203
Off-Balance	Average	30	149	440	819	2428	687
	Standard deviation	41	242	1275	2601	5392	1689
	Coefficient of Variation	1.38	1.62	2.9	3.18	2.22	2.46
	Minimum	0.2	0.0	2.4	0.0	0.0	0
	Maximum	206	1055	8321	15950	32450	32450
Remunerated assets	Average	276	1181	2379	5571	9742	3376
	Standard deviation	341	1682	3699	8880	13235	4268
	Coefficient of Variation	1.23	1.42	1.55	1.59	1.36	1.26
	Minimum	9	11	42	48	48	9
	Maximum	1256	6737	16120	41725	62760	62760
Interest and charges paid	Average	14	86	95	192	371	140
	Standard deviation	17	130	146	296	513	141
	Coefficient of Variation	1.2	1.52	1.53	1.54	1.38	1.01
	Minimum	0.09	0.01	0.14	0.04	0.10	0.01
	Maximum	56	540	587	1294	2555	2555
Personnel expenses	Average	3	11	18	43	84	29
	Standard deviation	3	13	26	69	129	39
	Coefficient of Variation	1.04	1.22	1.42	1.59	1.54	1.36
	Minimum	0.2	0.1	0.2	0.5	0.8	0.1
	Maximum	13	51	136	353	734	734
General operating expenses	Average	2	7	13	32	55	20
	Standard deviation	3	9	18	49	85	26
	Coefficient of Variation	1.03	1.22	1.35	1.54	1.54	1.3
	Minimum	0.2	0.1	0.1	0.4	0.3	-0.2
	Maximum	10	32	91	233	491	491
Number of employees	Average	0.2	0.3	0.4	0.7	1.0	0.5
	Standard deviation	0.2	0.3	0.4	1.1	1.3	0.4
	Coefficient of Variation	0.97	0.99	1.15	1.48	1.35	0.82
	Minimum	0.01	0.01	0.01	0.01	0.01	0.01
	Maximum	0.7	1.0	1.9	4.8	6.6	6.6

[1] All the numbers in this table are presented in billions of Lebanese pounds except for the numbers relating to the number of employees which are presented in thousands of personnel

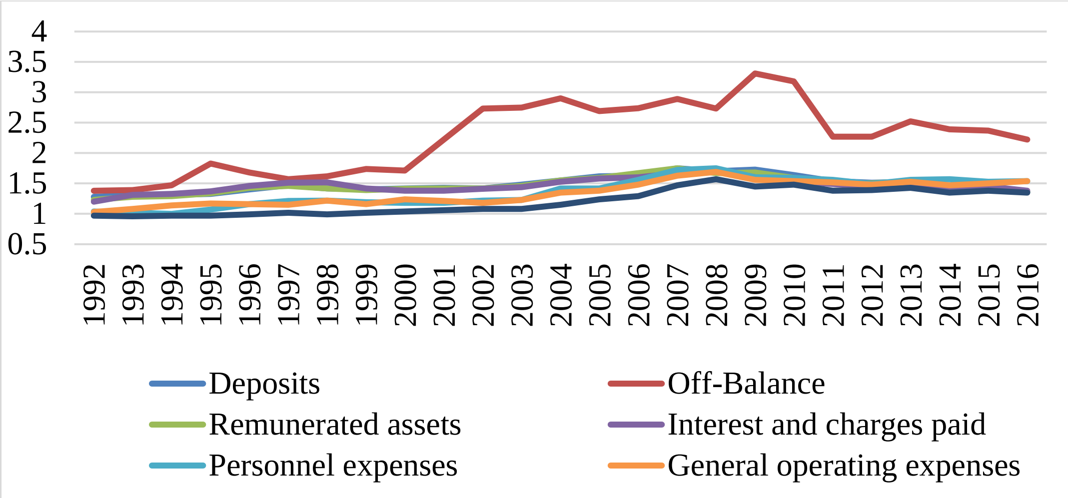

Figure 1: Dispersion of selected variables, measured by the coefficient of variation

Inspired by the work of several authors such as Grigorian and Manole (2002), Andries (2011), Otero et al. (2020), the factors used to explain the efficiency scores of banks in Lebanon are divided into two categories:

Factors Relating to the Macroeconomic Context

1) The economic growth rate (GDP) approximated by the growth rate of the Gross Domestic Product. This variable captures the impact of economic development on banking performance
2) The inflation rate (INFL) measured by the rate of change in the consumer price index. In general, inflation is valued as a factor that increases instability by sometimes changing prices unexpectedly. Bank interest rates then become less informative depending on market conditions and operational and control costs increase. These conditions seem to reflect a negative impact of inflation on banking efficiency.

Factors Specific to the Banking Activity

These factors are control variables that take into account the impact of banks' strategic choices on their efficiency. In fact, differences in the level and structure of banking activities generally depend on the internal decisions of each bank and might generate differences in efficiency between the banks concerned (Weill, 2006). We retain the following six variables:

1) The level of liquidity (LIQ) measured by the ratio of liquid assets to total assets.
2) The level of capitalization (CAP) measured by the usual ratio of shareholders' equity to total assets
3) Return on assets (ROA) measured by the ratio of net profit to total assets.

4) The size of the balance sheet (TA) measured by the logarithm of total assets Credit risk (RISK) assessed by the ratio of provisions for risks and charges to total assets.
5) The level of diversification of bank income (DIV). The level of diversification will be based on an index that will calculate the share of income from the diversified activity in relation to total banking income inspired by the methodology adopted by Baele et al. (2007) and Laeven and Levine (2007).

According to the table (4), the correlation coefficients do not exceed a maximum of 0.4 for the various independent variables thus there is not a strong correlation between these variables and we can affirm that the multicollinearity between the variables does not constitute a problem within the framework of our work. Subsequently, the regression model including our explanatory factors of efficiency can be retained.

Table 4: Correlation matrix between independent variables

	GDP	**RISK**	**ROA**	**CAP**	**ACT**	**DIV**	**INFL**	**LIQ**
GDP	1							
RISK	0.004	1						
ROA	0.065	0.010	1					
CAP	-0.047	-0.003	0.263	1				
ACT	-0.151	0.005	0.041	-0.245	1			
DIV	0.011	-0.001	0.031	0.061	-0.049	1		
INFL	0.084	-0.002	-0.072	-0.171	-0.280	-0.087	1	
LIQ	0.082	0.018	0.262	0.366	-0.080	0.012	-0.001	1

The data used was collected from the annual statistical series provided for each bank in Lebanon by the banking database “BilanBanques”. In order to avoid any problem related to a lack of homogeneity in the banking production process, the sample includes exclusively of commercial banks operating in Lebanon; thus investment banks are omitted in order to eliminate the risk of including a problem of heterogeneity, which would be likely to alter the basic assumptions of the efficiency frontier estimation method. The choice of banks in our sample thus respects the criterion of homogeneity in terms of their activities, the applied technologies as well as the prevailing environmental factors. We thus have a sample of 44 commercial banks for which we have collected all the annual accounting information useful for our analysis through the balance sheet and the income statement. The “BilanBanques” banking database also enabled us to collect, for each bank, statistics on the number of branches and the number of employees. Therefore, the study will be carried out on an annual basis and therefore an efficiency score will be derived each year for the banks considered. We believe that the statistical data needed to conduct our empirical study on banking efficiency are sufficiently representative of the majority of commercial banks operating in Lebanon. The study period extends over 25 years, from 1992 to 2016. The choice of this period seems interesting to us because the Lebanese banking sector has witnessed, throughout this period, major changes through the industry restructuring, the imposition of prudential regulations and political and economic events. These changes undoubtedly had implications, direct or indirect, on the performance of the Lebanese banking sector.

5. Empirical Results

We evaluate, at this level, the reliability of the parameters of our stochastic cost frontier obtained by the maximum likelihood method. The evaluation of the reliability is ensured using the test of the LR (Likelihood Ratio) statistic which follows a Chi-square with r degree of freedom equal to the number of restrictions imposed in the null hypothesis, i.e., r = 10 in our model. The model obtained is valid if the parameter γ as well as the coefficients (ϑ) of the variables influencing banking efficiency are all different from zero.
Our test hypotheses are as follows:

- null hypothesis (H0): $\gamma=\vartheta_0=\vartheta_1=\vartheta_2=\vartheta_3=\vartheta_4=\vartheta_5=\vartheta_6=\vartheta_7=\vartheta_8=\vartheta_9= 0$ (3)
- Alternative hypothesis (Ha): all the coefficients are different from zero.

The estimated parameters of the Trans logarithmic function are presented in table (5)

The empirical value LR=873 obtained is largely superior to the theoretical value of Chi-square at 10 degrees of freedom. The null hypothesis is then rejected and we can say that $\sigma^2{}_u$ is different from zero. We can conclude that our model is globally explanatory. The Gamma parameter ($\gamma = \frac{\sigma^2{}_u}{\sigma^2}$) is significantly different from 0. This result shows that the error term u_{it} cannot be discarded from the regression since the decomposition of the error term between random noise and inefficiency term is justified.

Table 5: Results of the estimation of the stochastic cost function

Variables	Parameters	Coefficient (t-ratio)
Constant	β0	-0.051517 (-4.250*)
LNY1	α1	0.914088 (7.350*)
LNY2	α2	0.330434 (2.967*)
LNY3	α3	-0.234214 (-6.254*)
LNY1LNY1	δ1	-0.034169 (-2.377**)
LNY1LNY2	δ2	0.002229 (0.111)
LNY1LNY3	δ3	0.006918 (1.214)
LNY2LNY2	δ4	0.019490 (2.365**)
LNY2LNY3	δ5	0.022764 (4.025*)
LNY3LNY3	δ6	-0.009794 (-6.628*)
LNP1	β1	0.769880 (11.278*)
LNP2	β2	0.073602 (0.710)
LNP3	β3	-0.216734 (-3.244*)
LNY1LNP1	ρ1	-0.022381 (-1.874**)
LNY1LNP2	ρ2	-0.020810 (-0.814)
LNY1LNP3	ρ3	0.002598 (0.152)
LNY2LNP1	ρ4	0.073272 (6.844*)
LNY2LNP2	ρ5	0.024500 (1.049)
LNY2LNP3	ρ6	-0.029064 (-2 **)
LNY3LNP1	ρ7	0.022078 (4.535*)
LNY3LNP2	ρ8	-0.013581 (-1.459***)
LNY3LNP3	ρ9	0.027794 (5.112*)

LNP1LNP1	γ1	0.013780 (7.288*)
LNP1LNP2	γ2	-0.023385 (-1.337)
LNP1LNP3	γ3	-0.123657 (-11.455*)
LNP2LNP2	γ4	0.018769 (1.723***)
LNP2LNP3	γ5	-0.021821 (-1.503***)
LNP3LNP3	γ6	0.001263 (3.484*)
Sigma-squared		0.706 t-ratio : (13.123*)
Gamma		0.997 t-ratio : (2160.286*)
Log likelihood function		817.87306
LR test of the one-sided error		873.26716

(*), (**), (***): mean that the coefficients obtained are statistically significant at a threshold of 1%, 5% and 10% respectively.

Table 6: Descriptive statistics of cost efficiency for the period 1992-2016

	Stochastic Frontier
Mean	0.88
SD	0.19
CV	0.22
Min	0.48
Max	0.98

Based on the results, Lebanese banks show average cost efficiency score of 88% over the period studied. In other words, some Lebanese banks only exploit their inputs at 88% while not reaching their optimal production potential. That said, banks can reduce their cost by up to 12% compared to the performance of the most efficient banks according to the stochastic frontier. This reduction in the level of cost depends on several factors which must be examined such as the technology used, the quality of the factors of production, the productive dimension of each bank, the differentiation of the products and services offered and the internal management of the bank.

Figure (2) shows the evolution of the annual cost efficiency scores obtained by stochastic frontier over the period from 1992 to 2016.

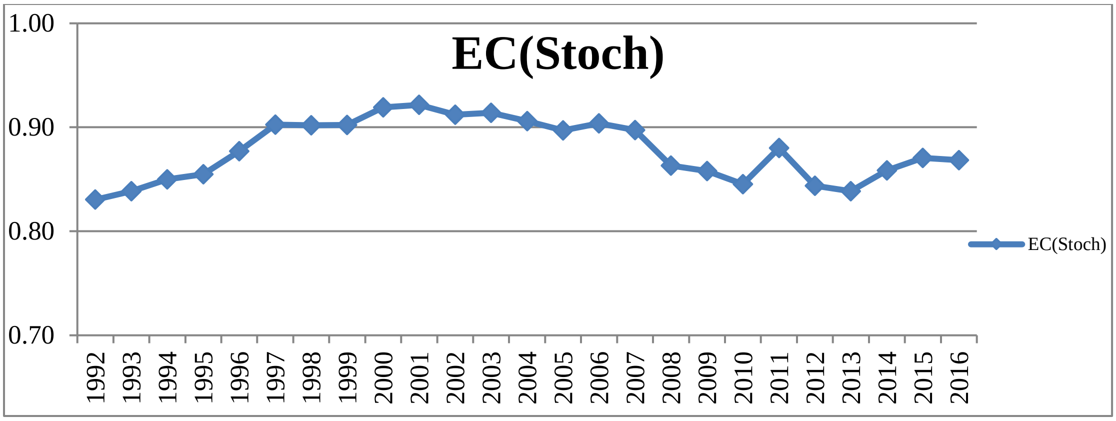

Figure 2: Evolution of Banks cost efficiency (1992-2016)

We can generally observe an improvement in cost efficiency over the years. Indeed, the average annual efficiency score increased from 83% in 1992 to 87% in 2016, i.e. an improvement of 5%. Moreover, we note that the evolution of the efficiency scores is stable throughout the period observed. In order to better interpret these results, we examine the dispersion of the efficiency scores obtained (figure 3).

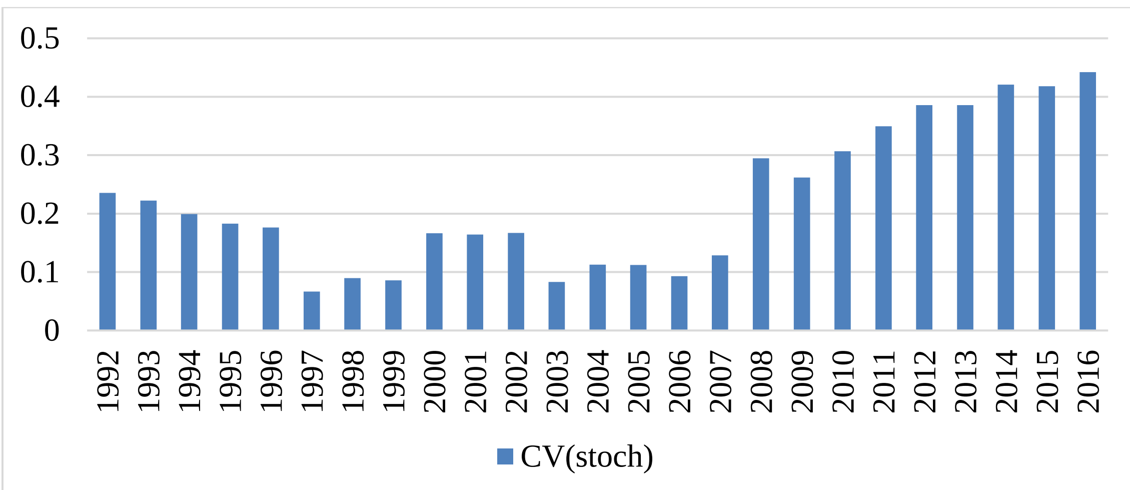

Figure 3: Dispersion of cost efficiency scores (1992-2016)

The figure (3) reflects the level of financial stability of the Lebanese banking sector. A slight reduction in the dispersion of efficiency scores between the years 1992 and 2005 is observed, which is explained by a decrease in the coefficient of variation from 0.23 to 0.09. The attenuation of the dispersion and the improvement of the efficiency for the period 1992-2005 allow us to suggest the existence of a certain phenomenon of convergence at the level of the efficiency between the banks observed, so that the banks which were considered the least efficient in 1992 would have experienced some improvement in their level of cost efficiency. Moreover, the reduction in efficiency volatility can be explained by the introduction of new reforms during this period. In 2007, the coefficient of variation is reduced but does not take long to resume its increase. This increase in dispersion reflects diversity in the efficiency scores, because some banks in the sample are very efficient while others remain far from the frontier.

Following Battese and Coelli (1995), we introduce directly into the stochastic cost function a vector of macroeconomic variables and other bank-specific variables to evaluate their effect on the productive performance of banks. Table (7) shows the results of regression performed using the parametric approach.

Table 7: Results of Cost efficiency Explanatory factors

Variables	Coefficients
Constant	5.36
ACT	0.11*
GDP	-14.86*
INFL	-3.35*
LIQ	0.19*
CAP	-8.88*
ROA	9.23*
RISK	0.02
DIV	-0.37*

(*), (**), (***): mean that the coefficients obtained are statistically significant at a threshold of 1%, 5% and 10% respectively.

There is a negative statistically significant relationship between the “GDP” variable and cost efficiency. The economic growth rate negatively affects cost efficiency in the case of banks operating in Lebanon over the period 1992-2016. However, the majority of studies on banking efficiency report a positive contribution of economic growth to productive performance (Grigorian and Manole, 2002; Maudos et al. 2002, Berger et al. 2009; Garza-garcia, 2011; Moussawi and Salloum, 2010 and Vu and Nahm, 2013). These studies consider that a phase of favorable economic growth improves banking productive efficiency because the probability of default decreases and therefore the quality of credits improves, which reduces the share of non-performing loans in total credits. This situation thus enables banks to better control risks and ensure sound management of production factors involving a reduction in costs. In the Lebanese case, the instability in the level of economic growth which is often accompanied by an increase in failures and a decrease in the demand for financial services as well as the absence of visible productive public expenditure have attenuated the positive contribution of economic growth on the productive performance of banks. Another interpretation of this negative relationship is that during periods of economic growth, banks have greater incentives to innovate and adopt more sophisticated production techniques, which increases the costs incurred and thus explains the reduction in efficiency. Our result coincides with that of Liu and Wilson (2011) who find a negative relationship between the level of GDP and bank efficiency. The authors suggest that a phase of economic growth intensifies competition by reducing barriers to entry and thus increases operational costs and dampens profits.

The results show a negative relationship between the variable “INFL” and bank cost efficiency. This relationship is statistically significant at the 1% level. The inverse relationship between inflation and the cost efficiency obtained is consistent with certain studies analyzing the productive performance of the banking sector. Revell (1979) notes that inflation affects bank performance by increasing operational costs within the banking sector. For Perry (1992), the impact of inflation on bank performance depends on adequate forecasts of price levels. In their empirical study on the determinants of banking efficiency, Barth et al. (2013) find a statistically significant negative relationship between bank efficiency and the level of inflation. They therefore consider that an environment marked by lower inflation rates remains more favorable to efficient banking activities. Indeed, in an inflationary period, interest rates on loans granted by banks increase, which increases income. Nevertheless, the level of inflation may not be adequately anticipated by the banking sector, so that interest rates are not correctly adjusted. This leads to a possibility that the increase in banking costs exceeds that of income, leading to deterioration in the cost efficiency of banks. In other words, the interest paid by banks exceeds the interest received, which reduces the bank interest margin, and subsequently creates pressure on operational costs. On the other hand, if banks manage to adjust costs in accordance with the estimated increase in the general price level, inflation will contribute to an improvement in productive performance.

The coefficient associated with the “LIQ” variable shows a positive and statistically significant relationship at the 1% level between efficiency and the level of liquidity According to the results obtained, bank liquidity positively influences bank cost efficiency. This shows that even if the banks grant loans according to the level of deposits available to them, they remain capable of maintaining a level of liquidity that allows them to honor commitments and avoid the risk of cash shortages. This liquidity risk management thus demonstrates good banking performance in Lebanon. As a result, banks are not forced to borrow funds at an excessive cost which will penalize their performance and subsequently their cost efficiency. Some banks also consider that the increase in bank liquidity is manifested by inefficiency in the transformation of their resources. This observation is interpreted by the preference of these banks to direct their resources towards cash uses with limited remuneration but less risky than loans to customers. Athanasoglou et al. (2008) find a negative relationship between liquidity risk (implying reduced liquidity) and bank performance. On the other hand, Molyneux and Thornton (1992) showed that the increase in the share of liquid assets in the bank balance sheet reduces the profitability of assets because of the immobilization of resources and this is how excessive liquidity acts negatively on bank performance. This result is also validated by Ariff and Can (2008) and Repkova (2015) who conclude in their

studies that liquidity risk has a positive impact on banking efficiency.
The results show a statistically significant negative relation at the 1% level between cost efficiency and bank capitalization. A large part of the studies evaluating the relationship between the capitalization of banks and their level of efficiency show that the most capitalized banks are the most efficient ones (Fiordelisi et al. (2011); Barth et al. (2013)). Indeed, banks with a high capital ratio are sheltered from solvency risk since the probability of bankruptcy of such banks is very low. This is how they can access the funds available on the market at lower costs with more advantageous conditions than the less capitalized banks (Bourke, 1989). It normally emerges that a high level of capitalization increases the capacity of banks to absorb losses and reduces their risk and consequently leads to high-cost efficiency. In the same line of ideas, Grigorian and Manole (2002) claim that banks with higher levels of capital have a greater ability to collect deposits than other less capitalized banks. Bank capitalization is thus considered as insurance for the attractiveness of deposits. Chortareas et al. (2012) similarly consider that bank capitalization reduces agency problems between shareholders and management and thus ensures bank efficiency. The negative relationship between capitalization and bank efficiency that was observed in our study coincides with the results obtained by Berger and Bonaccorsi di Patti (2006) for a study on a sample of American banks and by Altunbas et al. (2007) for a study on a sample of European commercial banks. These authors note that the least efficient banks are those with a high level of capitalization. This negative relationship can be explained by the fact that our calculation of the ratio of equity to total assets does not take into account the risk weighting. This finding shows that the most capitalized banks in our case are those that engage in risky activities, which translates into high risk taking, which subsequently leads to an increase in banking costs.
The relationship between efficiency and the measure of bank profitability (ROA) is positive as theoretically, a decision to strengthen profitability taken by the bank leads it to choose its factors of production efficiently while reducing costs.
The coefficient associated with the “ACT” variable shows a statistically positive relationship at the 1% threshold according to the stochastic frontier. In the banking literature, there is no total consensus regarding the effect of size on the productive efficiency of banks. Some authors, such as Molyneux and Thornton (1992), Bikker and Hu (2002), Grigorian and Manole (2002), Goddard et al. (2004), Altunbas et al. (2007) and Moussawi and Salloum (2010), found a positive relationship between the size of banks and their productive performance. This relationship is justified by the ability of large banks to reduce costs, due to the economies of scale they can achieve. Hauner (2005) considers that the positive effect of size also comes from the market power possessed by large banks, which allows them to pay less than other banks for the acquisition of factors of production and therefore to increase their cost efficiency. Other authors have found a negative impact of size on efficiency (Isik and Hassan, 2002, Chen and Dahlman, 2005). This negative link can be explained by the fact that large banks tend to embark on growth strategies of an aggressive nature which affect their cost management and their performance. For

some authors like Stiroh (2004), the increase in the size of the bank makes its internal management difficult and subsequently negatively affects its performance. The coefficient associated with the "RISK" variable is not statistically significant and subsequently it is difficult to decide on the nature of this relationship within banks operating in Lebanon. In the literature, some authors have found a positive correlation between credit risk and cost efficiency, which implies that the most efficient banks are those with the highest level of credit risk (Deelchand and Padgett, 2009). This is how these banks tend to charge high interest on loans, which allows them to generate significant interest margins and therefore cover their production costs. Subsequently, they appear to be cost efficient. On the other hand, Berger and Deyoung (1997) and Podpiera and Weill (2008) found a negative relationship between risk and efficiency, which reflects the importance of a rigorous total risk management policy. Banks, having a high proportion of provisions for credit losses in relation to total credits, thus suffer from high operational costs linked to the low quality of credits and their poor management. This situation pushes banks to deploy their resources towards moral random strategies to mitigate the problem of non-performing loans. As a result, banks incur additional burdens that are associated with loan appraisal, credit function internal control, credit risk transfer tools such as loan securitization and creditor arrangement costs. Thus, the deterioration of the quality of claims increases the risk and the associated costs and thus reduces the cost efficiency of the bank.

There is a statistically significant negative relationship between the “DIV” variable and cost efficiency at the 1% threshold according to the stochastic frontier. Our result is consistent with that of several studies conducted in this context. Boyd et al. (1993) note that banking diversification generates higher risks compared to traditional activities. This is how the cost manifested by the diversification strategy exceeds the benefit that can be generated, so the overall performance of the bank decreases. Deyoung and Roland (2001) show that diversification of banking activities increases profit volatility, reduces stability and subsequently increases banking costs and associated risks. In the same line of ideas, Acharya et al. (2006) indicate that the diversification of activities reduces the performance of banks while increasing the portfolio of risky loans. Additionally, Rossi et al. (2009), conducting a study on the Austrian banking sector, find that diversification negatively affects cost efficiency. Berger et al. (2010) also found a negative effect of diversification on bank performance. By identifying a negative relationship, Goetz et al. (2014) note that diversification affects the behavior of banks with respect to risk taking, which reduces their performance. In the context of our study, the activities carried out by banks in Lebanon in terms of income diversification might be incurring high costs exceeding the potential operational synergies and related to the operation and supervision of these activities. That said the production costs of banks increase and subsequently their cost inefficiency increases. An additional reason that may explain the negative impact of diversification is that the risk associated with diversification activities is greater than the risk associated with traditional activities. This situation may justify the deterioration of bank performance (Boyd et al. 1993) and the effect is also high if the income from different activities is strongly correlated (Chiorazzo et al. 2008).

6. Conclusion

This study examined the productive performance of banks operating in Lebanon using a stochastic cost function. The methodology integrates the risk factor in the banking production function and accordingly, evaluates the efficiency of banks while taking into consideration their risk preferences and some other bank-specific and macro-environmental variables. The results show that 1) there is still a room for further improvement given the average level of inefficiency measured of about 12% for the banks in the sample over the period 1992-2016 and 2) that the causes of this inefficiency are not solely the misallocation of resources, but also several internal and external factors contribute to this inefficiency, such as economic growth, inflation rate, size of banks, return on assets, levels of capitalization and profitability, liquidity and diversification.

This study provides an aid at the managerial level of banks to understand the variables affecting the cost efficiency and thereby to formulate the correct relevant decisions to alter any observed inefficiency.

While evaluating the cost efficiency in the Lebanese banking system, as well as some variables that may influence the level of efficiency, this research exhibits some limitations that will be underlined for future research endeavors. The first limitation is that we didn't expand the list of variables that may influence cost efficiency by introducing additional variables such as corruption index, governance indicator or other country-level variables. The second limitation is that the use of non-parametric approach such as DEA could have been used simultaneously with stochastic frontier in order to test the robustness of the results.

References

[1] Acharya, V; Hassan, I and Saunders, A. (2006). Should banks be diversified? Evidence from individual bank loan portfolio. Journal of Business, vol.32, pp.1355-1412. https://doi.org/10.1086/500679

[2] Aigner, A; Lovell, K. and Schmidt, P. (1977). Formulation and Estimation of Stochastic Frontier Production Function Models, Journal of Econometrics, vol 6, pp. 21-37. https://EconPapers.repec.org/RePEc:eee:econom:v:6:y:1977:i:1:p:21-37

[3] Aigner, D and Chu, F (1968). On Estimating the Industry Production Function, American Economic Review, issue 58, vol. 4, pp. 826-839. https://www.jstor.org/stable/1815535

[4] Altunbas, Y; Carbo, S; Gardener, E. P. M and Molyneux, P. (2007). Examining the Relationships between Capital, Risk and Efficiency in European Banking. European Financial Management, 13, pp. 49-70. https://.doi.org/10.1111/j.1468-036X.2006.00285.x

[5] Altunbas Y; Evans, L and Molyneux, P (2001). Efficiency and technical progress in banking: Empirical results for a panel of German cooperative banks. Journal of Money, Credit and Banking, vol. 33, issue 4, pp. 926-954. https://EconPapers.repec.org/RePEc:eee:jbfina:v:20:y:1996:i:6:p:1003-1023

[6] Andries, AM (2011), The Determinants of Bank Efficiency and Productivity Growth in the Central and Eastern European Banking Systems, eastern European Economics, 49, (6), pp.38-59. https://.doi.org/OI 10.2753/EEE0012-8775490603

[7] Arcand, J-L, Berkes, E and Panizza, U(2012). Too much Finance? IMF working paper. Volume 2012: Issue 161. https://doi.org/10.5089/9781475504668.001

[8] Ariff, M and Can, L (2008). Cost and profit efficiency of Chinese banks: A non-parametric analysis. China Economic Review, 2008, vol. 19, issue 2, pp.260-273. https://doi.org/10.1016/j.chieco.2007.04.001

[9] Ariss, R(2008). Financial liberalization and bank efficiency: evidence from post-war Lebanon, Applied Financial Economics, vol.18:11, pp.931-946. https://doi.org/10.1080/09603100701335408

[10] Athanasoglou, P; Brissimis,S and Delis,M (2008). Bank-specific, industry-specific and macroeconomic determinants of bank profitability. Journal of International Financial Markets, Institutions and Money, Elsevier, vol. 18(2), pp. 121-136. https://EconPapers.repec.org/RePEc:eee:intfin:v:18:y:2008:i:2:p:121-136

[11] Awdeh, A and El Moussawi, C (2009). Bank Efficiency and Foreign Ownership in the Lebanese Banking Sector. Review of Middle East Economics and Finance, De Gruyter, vol 5, issue 2, pp. 66-87. https://doi.org/10.2202/1475-3693.1161

[12] Baele, L, De Jonghe, O and Vander Vennet, R, (2007). Does the stock market value bank diversification? Journal of Banking & Finance, Elsevier, vol. 31,

issue 7, pp. 1999-2023. https://EconPapers.repec.org/RePEc:eee:jbfina:v:31:y:2007:i:7:p:1999-2023
[13] Barth, J; Caprio, G and Levine, R (2013). Bank regulation and supervision in 180 countries from 1999 to 2011. Journal of Financail Economics policy, Emarld Group publishing, vol.5, issue.2, pp.111-219. https://doi.org/10.3386/w18733
[14] Battese, G.E and Coelli J, (1995). A Model for Technical Inefficiency Effects in a Stochastic Frontier Production for Panel Data. Empirical Economics, vol.20, issue 2, pp. 325-332. http://dx.doi.org/10.1007/BF01205442
[15] Berger, A.N and Bonaccorsi di Patti, E (2006). Capital structure and firm performance: A new approach to testing agency theory and an application to banking industry. Journal of Banking and Finance, vol.30, issue.4, pp.1065-1102. https://doi.org/10.1016/j.jbankfin.2005.05.015
[16] Berger, A.N and DeYoung, R (1997). Problem loans and cost efficiency in commercial banks. Finance and Economics Discussion series n.1997/8. https://doi.org/10.1016/S0378-4266(97)00003-4
[17] Berger, A.N, Hasan, I and Zhou,M (2009). Bank ownership and efficiency in China: What will happen in the world's largest nation? Journal of Banking and Finance, vol.33, issue.1, pp.113-130. https://doi.org/10.1016/j.jbankfin.2007.05.016
[18] Berger, A.N; Hasan,I and Zhou,M (2010). The Effects of Focus versus Diversification on Bank Performance: Evidence from Chinese Banks. BOFIT Discussion Paper No. 4/2010. Journal of Banking & Finance, vol. 34, issue 7, 1417-1435. https://urn.fi/URN:NBN:fi:bof-201408072010
[19] Berger, A.N and Mester, L (2001). Explaining the dramatic changes in performance of U.S Banks: Technological change, Deregulation, and dynamic changes in competition. FRB Philadephia Working paper No.01-6. https://doi.org/10.2139/ssrn.283013
[20] Bikker, J.A and Hu, H (2002). Cyclical Patterns in Profits, Provisioning and Lending of Banks and Procyclicality of the New Basle Capital Requirements. BNL Quarterly Review, vol. 221, pp. 143-175.
[21] Bourke,P (1989). Concentration and other determinants of bank profitability in Europe, North America and Australia. Journal of Banking& Finance, vol.13, issue 1, pp.65-79. https://doi.org/10.1016/0378-4266(89)90020-4
[22] Boyd, J; Graham, G and Hewitt, R (1993). Bank holding company mergers with nonblank financial firms, Journal of Banking and Finance, vol.17, pp.43-63. https://EconPapers.repec.org/RePEc:eee:jbfina:v:17:y:1993:i:1:p:43-63
[23] Casu, B and Girardone, C (2005). Bank competition concentration and Efficiency in the Single European Market .Essex Finance Centre Discussion Paper No.05/02. https://doi.org/10.2139/ssrn.796667
[24] Chauveau, T and Capelle Blancard, G (2002). L'apport de modèles quantitatifs à la supervision bancaire en Europe. Revue Française d'Économie, Programme National Persée, vol. 19(1), pages 77-120. https://doi.org/10.3406/rfeco.2004.1542

[25] Chen, D and Dahlman, C (2005). The Knowledge Economy, the Kam Methodology and World Bank Operations. World Bank Institute Working Paper No. 37256. http://documents.worldbank.org/curated/en/695211468153873436/The-knowledge-economy-the-KAM-methodology-and-World-Bank-operations

[26] Chiorazzo, V; Milani, C and Salvini,F (2008), Income Diversification and Bank Performance: Evidence from Italian Banks, Journal of Financial Services Research, 33, (3), 181-203. https://doi.org/10.1007/s10693-008-0029-4

[27] Chortareas, G; Girardone,C and Ventouri, A (2012). Bank supervision, regulation and efficiency: Evidence from the European Union. Journal of financial stability. https://doi.org/10.1016/j.jfs.2011.12.001

[28] Christensen, L; Jorgenson, D and Lau, L.J (1973). Transcendental Logarithmic Production Frontiers. The Review of Economics and Statistics, vol. 55, issue 1, pp.28-45. https://doi.org/10.2307/1927992

[29] Cornwell, C and Schmidt, P (2008). Stochastic Frontier Analysis and Efficiency Estimation. In: Mátyás, L., Sevestre, P. (eds) The Econometrics of Panel Data. Advanced Studies in Theoretical and Applied Econometrics, vol 46. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-540-75892-1_21

[30] Daouia, A; Florens, L-P and Simar. L (2020). Robust frontier estimation from noisy data: a Tikhonov regularization approach. Econometrics and Statistics, vol.14, pp.1-23. https://doi.org/10.1016/j.ecosta.2018.07.003

[31] Deelchand , T and Padgett, C (2009). The relationship between risk, capital and efficiency: Evidence from Japanese Cooperative banks. International Capital Market Association Centre Discussion papers in Finance, p.5. https://doi.org/10.17261/Pressacademia.2022.1550

[32] DeYoung, R and Roland, K (2001). Product Mix and Earnings Volatility at Commercial Banks: Evidence from a Degree of Total Leverage Model. Journal of Financial Intermediation, vol. 10, issue 1, pp. 54-84. https://doi.org/10.1006/jfin.2000.0305

[33] Dietsch, M and Chaffai, M (1999). Mesures de l'efficience technique et de l'efficience allocative par les fonctions de distance et application aux banques européennes. Revue économique, vol.50, issue 3, pp. 633-644. https://doi.org/10.3406/reco.1999.410109

[34] Djoundourian, S and Raad, E. (2008). Efficiency of Commercial Banks in Lebanon. International Journal of Financial Services management, 3(2), 105-123. https://doi.org/10.1504/ijfsm.2008.019665

[35] Elkanj, N and Zreika, M (2011). Banking efficiency in Lebanon: An empirical investigation. Journal of Social Sciences, vol.7, pp. 199-208. https://doi.org/10.3844/jssp.2011.199.208

[36] El Moussawi, C and Saad, W (2009). Evaluating the Productive Efficiency of Lebanese Commercial Banks: Parametric and Non-Parametric Approaches, International Management Review; Marietta Vol. 5, Iss. 1.

[37] Hauner, D (2005). Explaining efficiency differences among large German and Austrian banks. Applied Economics. Taylor and Francis Journals, vol. 37(9), pp. 969-980. https://doi.org/10.1080/00036840500081820
[38] Moussawi, C and Salloum, A (2010). Evaluation de la performance productive des banques libanaises par la méthode d'enveloppement des données (DEA). National Defense magazine, issue 73.
[39] Fiordelisi, F; Marques-Ibanez, D and Molyneux, P (2011). Efficiency and risk in European banking. Journal of Banking and Finance, Elsevier, vol.35, n.5, pp.1315-1326. https://doi.org/10.1016/j.jbankfin.2010.10.005
[40] Fontani ,A and Vitali, L (2014). Cost Efficiency of Italian Commercial Banks: A Stochastic Frontier Analysis. Universal Journal of Industrial and Business Management, 2(3), pp. 80 - 91. https://doi.org/10.13189/ujibm.2014.020304
[41] Garza-Garcia, J.G (2011). Determinants of Bank Performance in Mexico: Efficiency or Market Power. Centre For Global Finance, Working Paper Series n.3. https://doi.org/10.1080/13504851.2012.665589
[42] Goddard, J; Molyneux, P and Wilson, J (2004). The profitability of European banks: a cross-sectional and dynamic panel analysis. The Manchester School, Vol.72, issue 3, pp. 363-381. https://doi.org/10.1111/j.1467-9957.2004.00397.x
[43] Goetz, M.R, Laeven, L and Levine, R (2014). Identifying the valuation effects and agency costs of corporate diversification: Evidence from the geographic diversification of US banks. Review of financial studies, vol.26, n.7, pp. 1787-1823. https://doi.org/10.5089/9781463937119.001
[44] Greene, William, (1980). Maximum likelihood estimation of econometric frontier functions, Journal of Econometrics, vol. 13, issue 1, p. 27-56. https://EconPapers.repec.org/RePEc:eee:econom:v:13:y:1980:i:1:p:27-56.
[45] Grigorian, D and Manole, V (2002). Determinants of Commercial Bank Performance in Transition: An Application of Data Envelopment Analysis. Policy Research Working Paper n.2850, World Bank. https://ssrn.com/abstract=636214
[46] Huang, T.H and Wang, MH (2002). Comparison of Economic Efficiency Estimation Methods: Parametric and Nonparametric Techniques. The Manchester School, vol. 70, pp. 682-709. https://doi.org/10.1111/1467-9957.00320
[47] Isik, I and Hassan, M.K (2002). Cost and Profit Efficiency of the Turkish Banking Industry: an Empirical Investigation, The Financial Review, vol. 37, issue 2, pp. 257-279. https://doi.org/10.1111/1540-6288.00014
[48] Kumbhakar, S and Lovell, C.A.K. (2000) Stochastic Frontier Analysis. University Press, Cambridge. https://doi.org/10.1017/cbo9781139174411
[49] Kumbhakar, S; Lozano-Vivas,A; Lovell, C.A and Hasan, I (2001). The Effects of Deregulation on the Performance of Financial Institutions: The Case of Spanish Savings Banks,Journal of Money, Credit and Banking Vol. 33, No. 1 , pp. 101-120. https://doi.org/10.2307/2673874

[50] Laeven, L and Levine, R (2007). Is there a diversification discount in financial conglomerates? Journal of Financial Economics, vol.85, issue 2, pp.331-367. https://doi.org/10.1016/j.jfineco.2005.06.001

[51] Levine, R (2005). Finance and Growth: Theory and Evidence. Handbook of Economic Growth, Volume 1A. Edited by Philippe Aghion and Steven N. Durlauf, pp.866-934.

[52] Liu, H., and Wilson, J. O. S. (2010). The profitability of banks in Japan. Applied Financial Economics, 20(24), pp.1851 - 1866. https://doi.org/10.1080/09603107.2010.526577

[53] Maudos, J; Pastor, J and Perez, F (2002). Competition and efficiency in the Spanish banking sector: the importance of specialization. Applied Financial Economics, vol.12, issue 7, pp.505-516. https://doi.org/10.1080/09603100010007977

[54] Meeusen, W., & van Den Broeck, J. (1977). Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error. International Economic Review, 18(2), 435–444. https://doi.org/10.2307/2525757

[55] Mendes, V and Rebelo, J (1999). Productive efficiency, technological change and productivity in Portuguese banking, Applied financial economics, Taylor & Francis Journals, vol 9(5), pages 513-521. https://doi.org/10.1080/096031099332177

[56] Molyneux,P and Thornton,J (1992). Determinants of European bank profitability: A note. Journal of Banking and Finance, 1992, vol. 16, issue 6, pp.1173-1178. https://doi.org/10.1016/0378-4266(92)90065-8

[57] Otero, L; Razia,A; Cunill,O and Mulet-Forteza,C (2020). What determines efficiency in MENA banks?,Journal of Business Research, Volume 112,2020,Pages 331-341. https://doi.org/10.1016/j.jbusres.2019.11.002

[58] Perry, P (1992). Do Banks Gain or Lose from Inflation. Journal of Retail Banking, vol. 14, n.2, 1992, pp. 25-30.

[59] Podpiera, J and Weill, L (2008). Bad Luck or Bad Management? Emerging Banking Market Experience", Journal of Financial Stability, vol.4, issue 2, pp. 135-148. https://doi.org/10.1016/jijfs.2008.01.005

[60] Repkova, I (2015). Banking efficiency determinants in the Czech Banking sector. Procedia Economics and Finance, Elsevier, vol.23, pp.191-196. https://doi.org/10.1016/S2212-5671(15)00367-6

[61] Revell, J. (1979). Inflation and Financial institutions. Financial Times, London.

[62] Rossi, S, Schwaiger, M and Winkler, G (2009). How loan portfolio diversification affects risk, efficiency and capitalization: A managerial behavior model for Austrian banks, Journal of Banking & Finance, vol 33, issue 12, pp. 2218-2226. https://doi.org/10.1016/j.jbankfin.2009.05.022.

[63] Schmidt, P and Sickles, R (1984). Production Frontier and Panel Data, Journal of Business and Economics Statistics, vol 2, pp. 367-374. https://doi.org/10.2307/1391278

[64] Sherman, H.D. and Gold, F. (1985). Bank Branch Operating Efficiency. Evaluation with Data Envelopment Analysis. Journal of Banking and Finance, 9, 297-315. https://doi.org/10.1016/0378-4266(85)90025-1
[65] Stevenson, R. (1980). Likelihood functions for generalized stochastic frontier estimation. Journal of Econometrics, Vol 13, Issue 1, pp/ 57-66. https://doi.org/10.1016/0304-4076(80)90042-1.
[66] Stiroh, K (2004). Diversification in banking: Is non-interest income the answer? Journal of Money, Credit and Banking, vol.36, issue 5, pp.853-882. https://doi.org/10.1353/mcb.2004.0076
[67] Timmer, C.P. (1971). Using a Probabilistic: Frontier Production Function to Measure Technical Efficiency. Journal of Political Economy, vol.79, pp.776-794. https://doi.org/10.1086/259787
[68] Vu, H and Nahm, D (2013). The determinants of profit efficiency of banks in Vietnam. Journal of the Asia Pacific Economy, vol.18, issue 4, pp. 615-631. https://doi.org/10.1080/13547860.2013.803847
[69] Wang H-J, Schmidt P (2002). One-step and two-step estimation of the effects of exogenous variables on technical efficiency levels. J Prod Anal, vol.18, pp.129–144. https://doi.org/10.1023/a:1016565719882
[70] Weill, L (2006). Cost efficiency of Belgian banks during the 90s. Brussels Economic Review, ULB, vol. 49, issue 1, pp.21-36.
[71] Worthington, A (2001). An Empirical Survey of Frontier Efficiency Measurement Techniques in Education, Education Economics, vol.9:3, pp.245 268. https://doi.org/10.1080/09645290110086126