# A STOCHASTIC FRONTIER ANALYSIS OF UKRAINIAN BANKS EFFICIENCY

**Bohdan Kyshakevych**
Professor, Doctor of Economics, Polonia University,
e-mail: b_kyshakevych@ukr.net, http://orcid.org/0000-0001-5721-8543, Poland
**Dmytro Mazharov**
Post-graduate student, Drohobych Ivan Franko State Pedagogical University,
e-mail: d.mazarow@gmail.com, http://orcid.org/0000-0002-9640-491X, Ukraine

**Abstract.** The authors have developed a model for assessing the Ukrainian banks cost efficiency by means of Stochastic Frontier Analysis, in which the banks are considered as financial intermediaries. On the basis of the likelihood ratio test results the trans-logarithmic function steps forward in the role of the bank's cost function. In the role of input variables we used the value of fixed assets, the price of labor and price of loanable fund, in the role of output − total loans, other assets and total cost.

**Keywords:** cost efficiency, trans-logarithmic function, profit efficiency, intermediation approach, production approach, Stochastic Frontier Analysis.

*DOI: http://dx.doi.org/10.23856/3103*

## Introduction

The efficiency of banking has long been the subject of many scientific studies, mostly dealing with the banking systems in leading industrialized countries, such as the United States and European countries (Great Britain, Germany, France, etc.) The study of the efficiency of banking systems in developing countries and countries with transition economies is much less common. Commercial banks, which constitute the main element of the banking system, should function effectively otherwise they will create problems and hinder the development of the economy of any country. Identifying key performance determinants is a major issue in its analysis.

It is also worth noting a rather difficult situation in the banking sector of Ukraine, which lately has been particularly aggravated. Thus, an unpleasant and very expensive for the economy record was set in 2017, namely, the highest proportion of unemployed loans in the history of world observation was recorded in Ukraine − the share of *non-performing loan* (NPL) reached its peak in July and amounted to 58%, and their volume almost equaled to one trillion UAH. In the state banks, the share of problem loans is generally 75%. In fact, there are many reasons for the emergence of such a difficult situation, the Ukrainian banks found themselves in and most of them are systemic. However, some decisions in the field of banking often had political and sometimes populist undertones. Thus, the adoption of interim decisions on a moratorium on debt collection did not solve the problem, but on the contrary led Ukraine to the first place in terms of volume of problem loans. To reduce dramatically the number of toxic bank assets is one of the strategic objectives of the government. One of the conditions for achieving this goal is to increase the efficiency of banking institutions.

## Literature reviews and theoretical framework

The first studies of the efficiency of banking activities based on Stochastic Frontier Analysis (SFA) date back to 1985, when G. Sherman and F. Gold applied this approach to the analysis of banking business, focusing on the efficiency of operational activities of savings banks departments (see Fig. 1). The problems of assessing the efficiency of banks based on

intermediation and production approaches can be found in many research publications, among which we should be single out the works of G. Sherman & F. Golda *(1985)*, Maslak N.G. & Buryaka A.V. *(2009)*, A. Berger & L. Mester *(1997)*, T. Coeli *(1986)*, D. Codd & F. Palma *(1986)*, K. Aikaterini *(2010)*, A. Prykarpatskyi et al *(2009)*, B. Kyshakevych & D. Mazharov *(2016, 2017)* et al.

Dong Yizhe et al *(2014)* used the SFA approach to assess the performance of China's public and shareholding banks in order to identify potential reserves for their development. According to the results, the growth rates of joint-stock banks in China were somewhat higher compared to the state banks, primarily due to a more successful introduction of innovative banking technologies.

It should be noted that the analysis of the efficiency of Ukrainian banks by means of the SFA approach has already been done by a group of authors in the paper *(Pilyavskyy et al, 2012)*, but this study was conducted only throughout a single year of 2008, and a slightly different set of variables was used for this. The authors of this study state that the banks efficiency assessment is very sensitive to the choice of methods of analysis. Thus, the results of their analysis regarding the efficiency of Ukrainian banks using the DEA (Data envelopment analysis) approach can not be compared with the results obtained on the basis of the SFA approach, since the DEA approach has been used to assess technical efficiency, while the SFA approach deals is used for cost efficiency.

In general, the problem of comparing the two most popular methods of evaluating performance − DEA and SFA approaches − is a fairly common theme of scientific discussion. Thus, a group of German analysts: M. Coether, A. Karman, E. Fiorentino *(2006)* from Deutsche Bundesbank investigated the compatibility of these two approaches on the basis of comparing the results of the German banks efficiency assessment for the period from 1993 to 2004. The average value of efficiency estimates obtained with the SFA approach was generally bigger in comparison with the DEA assessment. These two approaches gave comparatively similar results only when exclusively the banks of the same group were included in the sampling. In addition, the parametric nature of the SFA approach was less intrusive to external influences by taking into account the error of estimation.

The analysis of the cost efficiency of 26 commercial banks in Pakistan for the period from 2005 to 2013, implemented by Khalil Sana et al *(2015)* on the basis of the SFA approach, showed that on average Pakistani banks could reduce the inefficiency of using their resources by 33.52%, or in other words, they could only use 66.48% of their resources to achieve the same level of output. The bank may have many local goals, but achieving high profitability is obviously its ultimate goal. Cost efficiency in this context is an important means of achieving long-term profitability. The proper distribution of the bank's financial resources is due to an improvement in the level of its efficiency and growth of investment in the bank. The results obtained Khalil Sana et al *(2015)* interact with the results of the study of Matthews *(2007)*. The features of the SFA approach for analyzing the efficiency of banking systems in different countries have also been reflected by Ferrier G. D. & Lovell A. K. *(1990)*, Resti, A. *(1997)*, Hardy, D. C. & Bonaccorsi di Patti, E. *(2005)*, Hughes, J. P., Mester, L. J. *(2008)*, Altunbas, Y., Liu, M. & Molyneux, P., Rama, S. *(2000)* et al.

However, the problems of analyzing the efficiency of Ukrainian banks on the basis of modeling the stochastic frontier of efficiency are not sufficiently highlighted in the domestic scientific literature, which necessitates the development of appropriate models based on the financial and accounting reporting of Ukrainian banks. Efficiency is often defined as the level of performance that describes the process of achieving the maximum output value at the expense of the minimum inputs. In the economy, efficiency determines the ability to maximize the output of products or services provided at the expense of available resources. It is believed

that one economic system is more efficient than the other if it can produce more products and provide more services without attracting additional resources.

In literature related to banking, you can find different approaches to determining the efficiency. Efficiency is generally viewed from the standpoint of economic theory and organization theory. The classical economic concept of efficiency considers efficiency as the ratio of output to incoming resources. The greater the value of this ratio, the greater the efficiency of the business unit. With regard to banking, Altunbas Y. et al *(2000)* define efficiency as an indicator that demonstrates the ability of banks and their staff to maintain revenue growth at a level that exceeds the increase in operational costs. Many scholars consider activity to be efficient, when its result does not only achieve the goals set, but also provides economic income, which exceeds the costs.

The purpose of the paper is to construct a model for assessing the efficiency of Ukrainian banks as financial intermediaries using the Stochastic Frontier Analysis (SFA).

**A stochastic frontier model of cost efficiency assessment of Ukrainian banks**

The results of the theoretical analysis of existing approaches to the interpretation of the concept of the effectiveness of banking activities indicate that the most used are two criteria of efficiency, namely, profitability indicators and cost indicators, or rather, the coverage of costs. Based on these criteria one can distinguish the following types of bank efficiency:

1. Profit efficiency;
2. Cost-efficiency.

Methodological approaches to the efficiency assessment include the systematization of evaluating tools in the context of each type of performance, taking into account their features, Maslak N. H. & Buriak A. V. *(2009)* schematically presented, as shown in Figure 1.

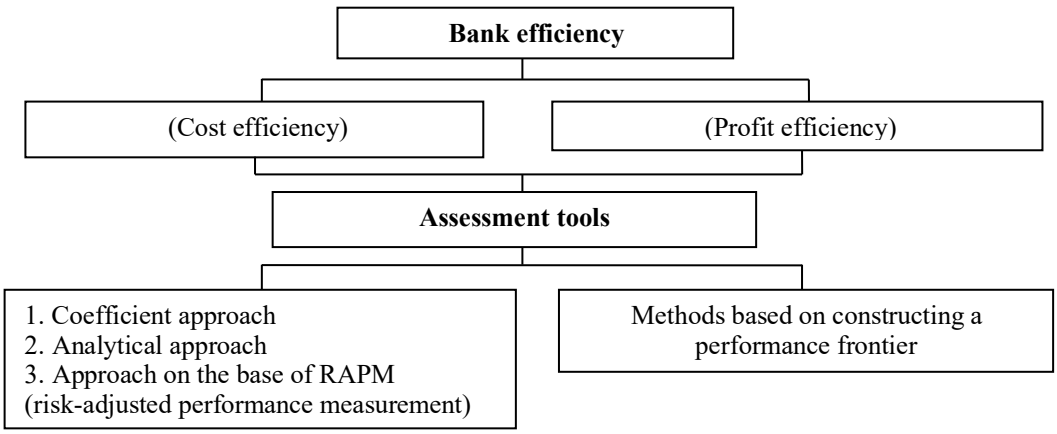


**Fig. 1. Approaches to assessing the performance of banks**
Source: on the base of *(Maslak, Buriak, 2009)*

Different methods for evaluating efficiency can be found in the literature. Most economists usually adhere to the principle of rational behavior and analyze banks using the neo-classical theory of the enterprise. This approach allows you to use traditional economic performance indicators (inputs, outputs, cost limits, etc.).

Until now, the problem of choosing a method that better represents the real costs and

performance of a banking institution is relevant. Two main approaches are used to measure efficiency:

1. Production approach
2. Intermediatory approach.

According to the production approach, the bank's purpose is to maximize the size of financial services with given input resources or minimize the consumption of resources, used to provide a range of services and sales of banking products. Thus, the idea of a production approach is to identify those inputs that are most important in providing financial and other types of the bank's services. In this approach, the results are usually estimated by the number of banking transactions and transactions or open accounts, rather than by income. In the production approach, attracted deposits are considered as the output of the banks. This approach tends to ignore interest costs by focusing on operations, which makes the production approach more suited to study operational efficiency.

An intermediary approach considers banks as intermediaries that attract capital in the form of deposits and invest them in loans and other assets in order to obtain profit. In this approach, the costs associated with raising funds are usually considered as sources or inputs, whereas funds provided to borrowers and the proceeds from investing in available funds are considered as output.

The main inputs and outputs of banks in different approaches to the evaluation of efficiency are presented in Figure 2

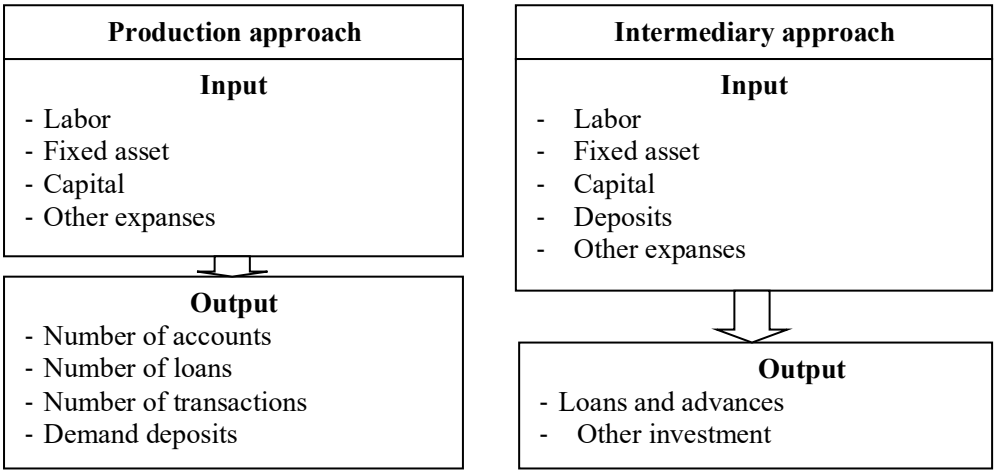


**Fig. 2. Comparison of inputs and outputs in the production and intermediary approaches**

Source: authors' compilation

Efficiency frontier is usually obtained based on the available statistics. As a rule, parametric and non-parametric methods are used for this purpose. Parametric methods include Stochastic Frontier Approach (SFA), Thick Frontier Approach (TFA) and Distribution Free Approach (DFA), while Data Envelopment Analysis (DEA) and Free Disposal Hull (FDH) belong to non-parametric. The advantages and disadvantages of econometric models for assessing the performance of banks are given in Table 1.

When choosing a method for assessing the efficiency of a banking institution, a number of assumptions and limitations should be taken into account which needs to be done in each of the approaches. Thus, when using the SFA we need to consider the following limitations and

typical problems that occur when implementing it:

- It is necessary to make assumptions about the type of production function. An incorrect selection of a production function can significantly affect the result.
- Simple production functions do not allow making a forecast of the companies' technical efficiency with several output parameters.
- The method of maximum likelihood does not allow assessment of the reliability of the results with a small sample.
- The absolute value of the technical efficiency is very sensitive to assumptions regarding the type of distribution and less sensitive to ranking.
- SFA requires the use of a large number of DMU.
- In addition, most of the problems that are typical of the DEA method also arise in the SFA approach.

Table 1

**Advantages and disadvantages of econometric models for assessing the performance of banks**

| Models | Parametric (DFA, TFA, SFA) | Nonparametric (DEA, FDH) |
|---|---|---|
| Advantages | - taking into account such an important characteristic of efficiency as stochasticity, that is, estimating efficiency and not strictly its calculation;<br>- no need to verify the statistical significance of the estimates obtained and the impact of various factors;<br>- the possibility of taking random errors into account. | - no need to define precisely the form of the frontier of efficiency;<br>- the presence of banks with 100% efficiency. |
| Disadvantages | - the need to accurately determine the shape of the frontier, that is, the existence of a previously known function of the frontier of efficiency. | - precise calculation (not estimation) of efficiency values;<br>- necessity of assumption concernig the absence of random errors . |

Source: authors' compilation

In the scientific literature one can come across different types of production functions. Table 2 summarizes the most frequently used types of production functions that are encountered in the analysis of the efficiency of various aspects of entrepreneurial activity.

Table 2

**Types of production functions used in the evaluation of efficiency**

| | |
|---|---|
| Linear | $y = \beta_0 + \sum_{j=1}^{k} \beta_j x_j$ |

| | |
|---|---|
| Cobb-Douglas | $y = \beta_0 \prod_{j=1}^{k} x_j^{\beta^j}$ |
| Quadratic | $y = \beta_0 + \sum_{j=1}^{k} \beta_j x_j + \frac{1}{2} \sum_{j=1}^{k} \sum_{m}^{k} \beta_{jm} x_j x_m$ |
| Normally-quadratic | $y = \beta_0 + \sum_{j=1}^{k-1} \beta_j \frac{x_j}{x_k} + \frac{1}{2} \sum_{j=1}^{k-1} \sum_{m=1}^{k-1} \beta_{jm} \left(\frac{x_j}{x_k}\right)\left(\frac{x_m}{x_k}\right)$ |
| Translogarithmic (translog) | $y = e^{\left(\beta_0 + \sum_{j=1}^{k} \beta_j \ln x_j + \frac{1}{2} \sum_{j=1m}^{k} \sum_{m}^{k} \beta_{jm} \ln x_j \ln x_m\right)}$ |
| Generalized Leontiev | $y = \sum_{j=1}^{k} \sum_{m}^{k} \beta_{jm} \sqrt{x_j x_m}$ |
| Constanst elastisity of substitution (CES) | $y = \beta_0 \left(\sum_{j=1}^{k} \beta_j x_j^{\gamma}\right)^{\frac{1}{\gamma}}$ |

Source: authors' compilation

Most often, in the study of the efficiency of banking institutions, the trans-logarithmic function is used in the scientific literature, which in the general case has the form:

$$\ln y_{it} = \beta_0 + \sum_{j=1}^{k} \beta_j \ln x_{jt} + \sum_{j=1}^{k} \sum_{m=1}^{k} \beta_{jm} \ln x_{jt} \ln x_{mt} + v_{it} + u_{it}, \quad (1)$$

where i represents the i-bank, t is time, and $x_{it}$ – respectively, the output and input variables of i-bank, $\beta_i, \beta_{ij}$ – unknown parameters. In general terms, model (1) has no restrictions and then $v_{it}$ – a random normally distributed error $v_{it} \sim iid\ N\left(0, \sigma_v^2\right)$, $u_{it} = u_i \exp\left(-\eta\left(t - T\right)\right)$ represents the inefficiency of i-bank, with $u_i$ are also the normally distributed independent random variables: $u_i \sim iid\ N\left(0, \sigma_u^2\right)$.

The article analyzed the efficiency of the cost of Ukrainian banks for 2015 and 2016 on the basis of the intermediary approach. Only these two afore-mentioned years were taken for analysis because previously the National Bank had not published data on the costs of bank personnel which is necessary in determining the cost of labor – an important parameter of almost all banking efficiency assessment methods based on Stochastic Frontier Analysis.

In the case of profit efficiency, as well as in the estimation of cost efficiency, the dependent variable of profit is also expressed as the ratio of profit to total assets in the trans-logarithmic function. As noted by Berger A.N. & Mester L. J. *(1997)*, there are at least three reasons for such normalization:

1) reduction of the probability of the problem of heteroscedasticity;
2) reduction of possible manifestations of the scale effect;
3) the dependent variable used in the estimation of profitability is an indicator of return on assets (ROA), and, consequently, has a clear economic interpretation.

Berger A. N. & Mester L. J. *(1997)* used bank's capital instead of assets for the normalization of variables. In this study, we used the aggregate asset value for this purpose,

since banks of different sizes and different forms of ownership took part in the study. Institutional differences between these banks substantially affect the forms and methods of forming their own capital.

As an input variables we used the value of fixed assets, labor costs, the cost of loan capital, as output variables: issued loans, other assets and aggregate costs. Table 3 shows the input and output variables and methods of their calculation.

The total cost of the bank (TC) are defined as the sum of interest, commission, administrative, operating expenses and deductions to reserves for liabilities. Commission expenses of a commercial bank are fees paid to other banking institutions for cash settlement, cash and credit services, financial intermediaries through the intermediation of securities transactions and the foreign exchange market, as well as commissions paid for off-balance sheet transactions. The interest and commission expenses of the bank depend mainly on the market situation and the competitive position of the bank. Bank's operating costs are significantly influenced by the bank's internal environment − the quality of financial management and the quality of management of the bank's material and labor resources.

Table 3

**Input and Output Variables**

| Variable | Value | Calculation |
|---|---|---|
| TC | Total cost | Sum of the interest, commission, administrative, operating expenses, deductions to reserve for liabilities. |
| P | Profit | Total income of the bank. |
| $y_1$ | Loans | Sum of issued loans. |
| $y_2$ | Other assets | Sum of the investment in other banks, securities, investment property. |
| q | Total assets | Sum of all assets. |
| $w_1$ | Price of physical capital | Sum of the administrative and operating expenses divided into sum of the fixed assets and intangible assets . |
| $w_2$ | Price of Labor | Sum of staff salary, payroll, other staff costs divided into bank assets. |
| $w_3$ | Price of loanable fund | Sum of the administrative and operating expenses divided into loanable capital. |

Source: authors' compilation

All financial and accounting statements required to calculate the values of model variables was used from official site of National Bank of Ukraine. The descriptive statistics of the model variables are presented in Table 4.

Table 4

**Model variables descriptive statistics**

| Variables | Mean | Minimum | Maximum | Standard deviation |
|---|---|---|---|---|
| TC | 1465992,88 | 2837,91 | 40906509,00 | 4623339,21 |
| P | -1331943,56 | -165004437,70 | 3804018,47 | 11929519,36 |

| | | | | |
|---|---|---|---|---|
| $y_1$ | 6212917,00 | 0,00 | 177810480,90 | 17009620,00 |
| $y_2$ | 2674197,61 | 0,00 | 67901431,00 | 10179501,35 |
| q | 12300867,03 | 64998,75 | 264886279,00 | 35096206,61 |
| $w_1$ | 5,29 | 0,26 | 189,87 | 15,82 |
| $w_2$ | 0,03 | 0,00 | 0,34 | 0,03 |
| $w_3$ | 0,10 | 0,00 | 34,67 | 3,70 |
| Observations | 199 | | | |

Source: authors' compilation

As a result, the efficiency frontier model will look like:

$$\ln\left(\frac{TC}{w_3 q}\right)_{it} = \beta_0 + \beta_1 \ln\left(\frac{y_1}{q}\right)_{it} + \beta_2 \ln\left(\frac{y_2}{q}\right)_{it} + \beta_3 \ln\left(\frac{w_1}{w_3}\right)_{it} + \beta_4 \ln\left(\frac{w_2}{w_3}\right)_{it} +$$
$$+ \beta_5 \ln\left(\frac{y_1}{q}\right)^2_{it} + \beta_6 \ln\left(\frac{y_1}{q}\right)_{it} \ln\left(\frac{y_2}{q}\right)_{it} + \beta_7 \ln\left(\frac{y_2}{q}\right)^2_{it} + \beta_8 \ln\left(\frac{w_1}{w_3}\right)^2_{it} + \beta_9 \ln\left(\frac{w_1}{w_3}\right)_{it} \ln\left(\frac{w_2}{w_3}\right)_{it} +$$
$$+ \beta_{10} \ln\left(\frac{w_2}{w_3}\right)^2_{it} + \beta_{11} \ln\left(\frac{y_1}{q}\right)_{it} \ln\left(\frac{w_1}{w_3}\right)_{it} + \beta_{12} \ln\left(\frac{y_1}{q}\right)_{it} \ln\left(\frac{w_2}{w_3}\right)_{it} \quad (2)$$
$$+ \beta_{13} \ln\left(\frac{y_2}{q}\right)_{it} \ln\left(\frac{w_1}{w_3}\right)_{it} + \beta_{14} \ln\left(\frac{y_2}{q}\right)_{it} \ln\left(\frac{w_2}{w_3}\right)_{it it} + u_{it} + v_{it}$$

To check the existence of costs inefficiency in the Ukrainian banking system and to determine the type of frontier function of the efficiency, tests were carried out to confirm two hypotheses. The first null hypothesis $H_0 : \left(\gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2} = 0\right)$ is intended to verify the existence of technical inefficiency in the constructed model (2). The parameter $H_0$ varies from 0 to 1. Execution of the condition would mean the absolute cost efficiency of the banking system according to the proposed model. An alternative hypothesis indicates the existence of technical inefficiency.

The second null hypothesis is intended to select the type of frontier function and indicates that the Koba-Douglas function has advantages over the trans-logarithmic function.

Typically, tests of Lagrange multipliers, the Wald test, and likelihood ratio test (LR) are usually used to test the constraints on the statistical model parameters. We will use the latter to test hypotheses about the existence of the technical inefficiency effect and for the choice of the most suitable frontier function. Relation of the likelihood LR is given by the following ratio:

$$LR = -2\left[\ln(H_0) - \ln(H_1)\right] \quad (3)$$

where $\ln(H_0)$, $\ln(H_1)$ – is the values of the likelihood functions in the case of null and alternative hypotheses. It is believed that LR statistics has approximately a xi-square or a mixed xi-squared distribution with degrees of freedom, which equal the difference between the parameters in the null and alternative hypotheses.

To obtain estimates of stochastic frontier parameters using the maximum likelihood method, a three-step procedure was implemented:

1) By means of least squares method the estimation of regression parameters (2) were obtained (see Table 5).

Table 5

**Estimation of regression parameters by the least squares method**

| | Coefficient | Standard deviation | t-ratio |
|---|---|---|---|
| beta 0 | 1,8562* | 0,3668 | 5,0607 |
| beta 1 | 0,3621** | 0,1055 | 3,4318 |
| beta 2 | 0,0928* | 0,0419 | 2,2133 |
| beta 3 | -0,2995* | 0,1261 | -2,3745 |
| beta 4 | 0,7543** | 0,1650 | 4,5718 |
| beta 5 | 0,0156** | 0,0055 | 2,8603 |
| beta 6 | 0,0134* | 0,0048 | 2,7876 |
| beta 7 | 0,0025*** | 0,0023 | 1,0778 |
| beta 8 | 0,0423* | 0,0111 | 3,8261 |
| beta 9 | -0,0675* | 0,0313 | -2,1561 |
| beta10 | 0,0009 | 0,0243 | 0,0359 |
| beta11 | -0,0258** | 0,0144 | -1,7916 |
| beta12 | 0,0078 | 0,0177 | 0,4399 |
| beta13 | -0,0061*** | 0,0045 | -1,3429 |
| beta14 | -0,0005 | 0,0068 | -0,0775 |
| sigma-squared | 0.1418** | | |
| log likelihood | -80,2 | | |

*, **, *** parameters estimates are statistically significant at 1%, 5%, 10%, respectively

Source: authors' compilation

2) Using a two-stage grid search, parameter $\gamma$ is found with β parameters obtained in the first stage of the OLS method. Parameters $\beta_0$ та $\sigma^2$ are obtained using the Adjusted Least Squares Method. Other parameters are assumed to be null;

3) Obtained in the result of grid search parameter estimates $\gamma$, β та $\sigma^2$ are used, according to Coelli T.J. (1986) as initial values in the Davidon-Fletcher-Powell Quasi-Newton method for determining the final values of these parameters by the maximum likelihood method.

In our case, for the first hypothesis, using the FRONTIER 41 program, the following value of the likelihood ratio

$$LR = -2\left[-80{,}2 + 66{,}9\right] = 26{,}6, \tag{4}$$

which is much larger than the critical value of 3.38, taken from Kodde D. A. & Palm F.C. *(1986)*.

The results confirm the existence of the effect of technical inefficiency in the banking system of Ukraine according to the proposed model (2). The estimation of the parameter $\gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$ over the analyzed period was 0.74 and indicates that 74% of the variation of the overall error can be explained by the technical inefficiency of costs.

The results of the likelihood ratio test for the second null hypothesis, which are presented in Table 6, indicate the necessity to reject this hypothesis, and thus, that the trans-logarithmic function is statistically more attractive for estimating the efficiency at the expense of Ukrainian

banks in 2015 and 2016.

All critical values for comparing them with the LR and deciding whether to accept or reject the corresponding hypotheses are obtained using the mixed xi-square distribution of Kodde D.A. & Palm F.C.

Table 6

**A generalized likelihood ratio test**

| Null hypotheses | likelihood function | LR | Critical value* | Decision |
|---|---|---|---|---|
| $H_0 : \gamma = 0$ | -66,9 | 26,6 | 3,38 | Reject $H_0$ |
| $H_1 : \beta_{ij} = 0$ | -175,6 | 98,1 | 19,35 | Reject $H_1$ |

* All critical values for 5% significance level

Source: authors' compilation

The main indicator that defines inefficiency is the parameter $\gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$. The statistical significance obtained on the basis of the maximum likelihood method indicates the existence of a stochastic frontier. If not equal to zero, this means that the difference between the real and the marginal cost value is explained mainly by technical inefficiency. If it is not statistically significant, then any difference is due solely to a random error. In other words, banks operating on the frontier are considered to be technically efficient and, with a few exceptions, receive the maximum output for the selected combination of input data.

Technical efficiency can be measured by means of a coefficient that determines the level of deviation of the output from the marginal level and which is explained by technical efficiency. In fact, it corresponds, as noted Aikaterini K. *(2010)*, to the ratio of unexplained and aggregate errors and covers the aggregate output effect of technical efficiency by defining the percentage of deviation that arose due to technical inefficiency. It is obvious that $\gamma \in [0,1]$. If $\gamma$ is close to one and is a statistically significant parameter, this indicates that the majority of the total deviation of the output is due to technical inefficiency.

After performing the step 3 we obtained final estimates of regression parameters (see Table 7).

As a result, we obtained cost efficiency evaluation of the Ukrainian banks for the period from 2015 to 2016, the values ten the best and worst of which are given in Table 8. The average cost efficiency of Ukrainian banks for the analyzed period amounted to 0.63.

Table 7

**Estimation of regression parameters by the method of maximum likelihood**

| | Coefficient | Standard deviation | t-ratio |
|---|---|---|---|
| beta 0 | 1,4678 | 0,3421 | 4,2909 |
| beta 1 | 0,3792 | 0,0939 | 4,0387 |
| beta 2 | 0,0709 | 0,0375 | 1,8883 |
| beta 3 | -0,2661 | 0,1166 | -2,2816 |
| beta 4 | 0,8238 | 0,1481 | 5,5621 |
| beta 5 | 0,0165 | 0,0048 | 3,4547 |
| beta 6 | 0,0146 | 0,0043 | 3,4221 |
| beta 7 | 0,0025 | 0,0021 | 1,2012 |

| | | | |
|---|---|---|---|
| beta 8 | 0,0352 | 0,0106 | 3,3327 |
| beta 9 | -0,0811 | 0,0273 | -2,9713 |
| beta10 | 0,0114 | 0,0202 | 0,5628 |
| beta11 | -0,0221 | 0,0126 | -1,7482 |
| beta12 | 0,0226 | 0,0151 | 1,5026 |
| beta13 | -0,0043 | 0,0038 | -1,1362 |
| beta14 | -0,0115 | 0,0061 | -1,8836 |
| sigma-squared | 0,3055 | 0,0584 | 5,2316 |
| gamma | 0,8081 | 0,0568 | 1,4236 |
| log likelihood | -66,9 | | |

Source: authors' compilation

Table 8

**Ukrainian banks cost efficiency**

| N | Bank | Cost efficiency |
|---|---|---|
| 1 | ING Bank Ukraine | 0,93 |
| 2 | Bank Alliance | 0,93 |
| 3 | Alpari Bank | 0,93 |
| 4 | Hephaestus | 0,93 |
| 5 | Investment-Trust Bank | 0,93 |
| 6 | Credit Europe Bank | 0,92 |
| 7 | SEB Corporate Bank | 0,89 |
| 8 | Credit Optima Bank | 0,89 |
| 9 | Classic Bank | 0,89 |
| 10 | Ukrainian Bank of Reconstruction and Development | 0,88 |
| ---------- | | |
| 102 | Privatbank | 0,49 |
| 103 | Ukreximbank | 0,47 |
| 104 | Neos Bank | 0,47 |
| 105 | Ukrsotsbank | 0,46 |
| 106 | Finbank | 0,43 |
| 107 | Idea Bank | 0,38 |
| 108 | Divi Bank | 0,35 |
| 109 | Europrombank | 0,30 |
| 110 | Fortuna Bank | 0,26 |
| 111 | RVS Bank | 0,15 |
| | ***Mean*** | ***0,63*** |

Source: authors' compilation

The analysis of the cost efficiency for the period from 2015 to 2016 indicates that subsidiary banks of foreign banking groups used their own and attracted capital more efficiently to provide banking services. The average value of banks cost efficiency of 'foreign banking groups' in Ukraine was 70.9%, while for banks with a public share this figure was only 62.1% (Figure 3).

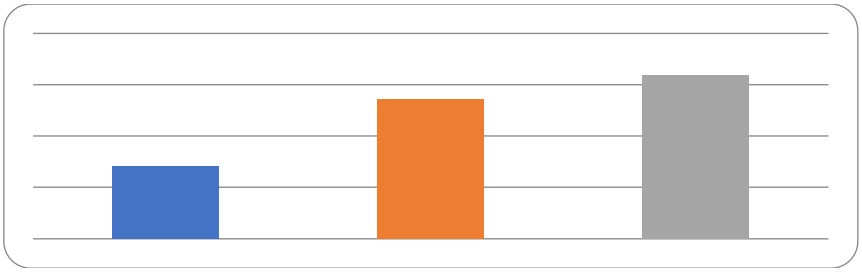

**Fig. 3. The average value of the Ukrainian banks cost efficiency for 2015-2016**
Source: authors' compilation

Anxiety is caused by extremely low cost efficiency of the two banks, which are actually systemic for the banking system of Ukraine: PrivatBank and Ukreksimbank, namely 49% and 47% (see Table 8).

The analysis showed somewhat higher values of the cost efficiency of small banks (Table 9), but their market share is insignificant, and besides, their future depends, to a large extent, on whether all small banks will be able to meet the NBU's requirements for increasing the authorized capital.

It should be noted that optimism is added by the fact that the requirement for a minimum capital of 300 million UAH was postponed for another two years, namely July 11, 2020, and at UAH 400 million. − for three years. At the same time, the deadline for the capitalization of 500 million UAH remained unchanged − July 11, 2024. However, according to many experts, for Ukraine, the real capital of a minimum capital is UAH 200 million.

Table 9

**Ukrainian banks cost efficiency depending on the size of their assets**

| Banks | Mean cost efficiency |
|---|---|
| 50 bn. UAH < assets | 0,56 |
| 25 bn. UAH < assets < bn. UAH | 0,66 |
| 10 bn. UAH < assets <25 bn. UAH | 0,70 |
| 5 bn. UAH < assets <10 bn. UAH | 0,69 |
| 1 bn. UAH < assets <5 bn. UAH | 0,69 |
| 0,5 bn. UAH < assets <1 bn. UAH | 0,68 |
| Assets <0,5 bn. UAH | 0,74 |

Source: authors' compilation

The problem can be considered as delayed, but unresolved, since about 40 out of 82 banks are not significantly up to date with the capital adequacy ratio. The majority of these 40 banks will be able to attract additional capital through mergers with other banks or by attracting new shareholders and investors. The problem of increasing the authorized capital for small banks is delayed, which, on the one hand, gives them a break, but at the same time reduces the motivation of this group of small banks to structural changes within these banks, especially in the field of improving the efficiency of corporate governance.

## Conclusions and suggestions

The article analyzes the Ukrainian banks cost efficiency for the period from 2015 to 2016 on the basis of Stochastic Frontier Analysis. To this end, an intermediary approach was used, where the value of loan capital, personnel costs, the value of fixed assets, and the role of initial variables: issued loans and other assets were taken as input variables. The test of the likelihood ratio used in the article showed that the trans-logarithmic function most closely approximates the costs of Ukrainian banks for the analyzed period.

The average value of the Ukrainian banks cost efficiency during this period was 0.63. A negative signal for regulators is the fact that such systemic financial institutions as PrivatBank, Ukreksimbank and Ukrsotsbank hit the top ten worst performing banks. Confirmation of such a negative assessment of the spending management policy in these banks was bankruptcy and further nationalization of PrivatBank in December 2016. Small Ukrainian banks showed somewhat higher value for cost efficiency, but their share in the domestic banking market is very small.

The reason for the low efficiency of public banks should be sought in the absence of their motivation to conduct business effectively, as opposed to banks with private capital. First of all, state-owned banks have the opportunity to almost constantly attract cheap capital, and, secondly, no one sets strategic goals for profitability before them. As a result, the active operations of such banks are not often rational, which is reflected in the quality of the bank's assets portfolio and the financial institution's level of profitability.

## References

*Aikaterini, K. (2010). Estimating technical inefficiency: an empirical approach to EU industries. Regional Science Inquiry Journal, Vol. II (2), 95-104. [in English].*

*Altunbas, Y., Liu, M., Molyneux, P., Rama, S. (2000). Efficiency and risk in Japanese banking. Journal of Banking and Finance, No. 24, 1605–1628. [in English].*

*Berger, A. N., & Mester, L. J. (1997). Inside the Black Box: What Explains Differences in the Efficiencies of Financial Institutions? Journal of Banking and Finance, No. 21, 895-947. [in English].*

*Coelli, T. J. (1986). A Guide to FRONTIER Version 4.1: A Computer Program for Stochastic Frontier Production and Cost Function Estimation, CEPA Working Paper. Department of Econometrics, University of New England, Armidale, 7/96.*

*[Electronic resource]. Retrieved from http://www.uq.edu.au/economics/cepa/frontier.php. [in English].*

*Dong,Y., Hamilton, R., & Tippett, M. J. (2014). Cost Efficiency of the Chinese Banking Sector: A Comparison of Stochastic Frontier Analysis and Data Envelopment Analysis. Economic Modelling, 36, 298–308. [Electronic resource]. Retrieved from https://www.sciencedirect.com/science/article/pii/S0264999313004021?via%3Dihub. DOI: 10.1016/j.econmod.2013.09.042. [in English].*

*Ferrier, G. D., & Lovell, A. K. (1990). Measuring Cost Efficiency in Banking: Econometric and Linear Programming Evidence. Journal of Econometrics, No. 46, 229–245. [in English].*

*Fiorentino, E., Karmann, A., Koetter, M. (2006).The cost efficiency of German banks: a comparison of SFA and DEA. Discussion Paper Series 2: Banking and Financial Studies. Deutsche Bundesbank, No. 10. [in English].*

*Hardy, D. C., & Bonaccorsi, di Patti E. (2005). Financial sector liberalization, bank privatization, and efficiency: Evidence from Pakistan. Journal of Banking & Finance, 29 (8), 2381-2406. [in English].*

*Hughes, J. P., Mester, L. J. (2008). Efficiency in banking: theory, practice, and evidence. Federal Reserve Bank of Philadelphia, Working Paper, No. 08-1. [Electronic resource]. Retrieved from http://ideas.repec.org/p/fip/fedpwp/08-1.html. [in English].*

*Iza, M. T., Mazlin,a A. B., Haron, S. (2009). Evaluating efficiency of Malaysian banks using Data Envelopment Analysis. Int. J. Bus. Manage, 4(8), 96-106. [in English].*

*Khailuk, S. O. (2014). An assessment of the bank efficiency. Financial and credit activity: problems of theory and practice, Vol. 1, No. 8, 112-118. Retrieved from: http://fkd.org.ua/article/view/29510/26466. [in Ukrainian].*

*Kodde, D. A., & Palm, F. C. (1986). Wald Criteria for Jointly Testing Equality and Inequality Restrictions. Econometrica, No. 54,1243-1248. [in English].*

*Kyshakevych, B. Y., & Mazharov, D. V. (2017). Application of SFA simulation to assess the effectiveness of banking. Eastern Europe: economy, business and management, 6 (11), 386-390. [in Ukrainian].*

*Kyshakevych, B. Y., Kubai, R. Y., & Mazharov, D. V. (2016). Effectiveness of banks: the economic essence and methods of evaluation. Scientific Herald of the International Humanitarian University, Series: Economics and Management. Collection of scientific works, 22, 200-204. [in Ukrainian].*

*Maslak, N. H., & Buriak, A. V. (2009). Methodical approaches to assessing the effectiveness of the bank. Businessinform, No. 12(2), 187-190. [in Russian].*

*Matthews, K. (2007). Banking efficiency in emerging market economies. Cardiff Economics Working Papers, No. E2010/12, 19. [in English].*

*NBU Official Site (n.d.). Bank System Indicators. [Data file]. [Electronic resource]. Retrieved from https://bank.gov.ua/control/uk/publish/category?cat_id=74208. [in Ukrainian].*

*Pilyavskyy, A., Matsiv, Y., & Vovchak, O. (2012). Cost efficiency of ukrainian banks. Does it make difference? Zeszyty Naukowe Wydziału Informatycznych Technik Zarządzania Wyższej Szkoły Informatyki Stosowanej i Zarządzania „Współczesne Problemy Zarządzania", 1, 53-61. [in English].*

*Prykarpatskyi, A. K., Kyshakevych, B. Y., & Tverdokhlib, I. P. (2009). The analysis of optimal strategies of the portfolio competitive model of the stock market. Reports of the National Academy of Sciences of Ukraine, 1, 40-47. [in Ukrainian].*

*Resti, A. (1997). Evaluating the Cost Efficiency of the Italian Banking System: What can be learned from the Joint Application of Parametric and NonparametricTechniques. Journal of Banking & Finance, 21, 221–250. [in English].*

*Sana, K., Bilal, M., & Nisar, A. (2015). Cost Efficiency of Pakistani Banking Sector: A Stochastic Frontier Analysis. Journal of Commerce (22206043), Vol. 7, Issue 3, 110-126. [in English].*

*Sherman, H. D., & Gold, F. (1985). Bank branch operating efficiency: Evaluation with Data Envelopment Analysis. J Bank. Finan, 9(2), 297-315. [in English].*