“Structural modeling of the impact of bank nonperforming loans on the banking sector: the Ukrainian experience”

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ARTICLE INFO	Eugenia Bondarenko, Olena Zhuravka, John O. Aiyedogbon, Ologunla Emmanuel Sunday and Vita Andrieieva (2020). Structural modeling of the impact of bank nonperforming loans on the banking sector: the Ukrainian experience. *Banks and Bank Systems*, *15*(2), 67-78. doi:10.21511/bbs.15(2).2020.07
DOI	http://dx.doi.org/10.21511/bbs.15(2).2020.07
RELEASED ON	Monday, 04 May 2020
RECEIVED ON	Wednesday, 18 March 2020
ACCEPTED ON	Monday, 27 April 2020

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JOURNAL	"Banks and Bank Systems"
ISSN PRINT	1816-7403
ISSN ONLINE	1991-7074
PUBLISHER	LLC “Consulting Publishing Company “Business Perspectives”
FOUNDER	LLC “Consulting Publishing Company “Business Perspectives”

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
34	2	7

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BUSINESS PERSPECTIVES

LLC "CPC "Business Perspectives"
Hryhorii Skovoroda lane, 10,
Sumy, 40022, Ukraine

www.businessperspectives.org

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STRUCTURAL MODELING OF THE IMPACT OF BANK NONPERFORMING LOANS ON THE BANKING SECTOR: THE UKRAINIAN EXPERIENCE

Received on: 18th of March, 2020
Accepted on: 27th of April, 2020
Published on: 4th of May, 2020

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Conflict of interest statement:
Author(s) reported no conflict of interest

Abstract

The paper aims to develop scientific and methodological approach to assessing the interaction of nonperforming loans of Ukrainian banking institutions, the profitability of the banking sector and its financial stability, which will allow a more detailed assessment of the directions and degree of mutual influence of these elements. To substantiate this interaction economically and mathematically, structural equation modeling was chosen. Particularly, Statistica was chosen as a software tool to assess the adequacy of the resulting model and determine the level of statistical significance of its parameters. Six key indicators were selected as a research information base, two for each subject of research: indicators of nonperforming loans in the banking sector (the volume of nonperforming loans and the ratio of problem loans excluding capital reserves), profitability indicators of the Ukrainian banking sector (assets profit and rate of return on capital), and indicators of financial stability of the Ukrainian banking sector (regulatory capital-to-risk-weighted assets ratio and liquid assets-to-total assets ratio). For calculations, statistic data of selected indicators for 2005–2019 were used.

As a result of calculations, mathematical data were obtained that accurately described the interaction of nonperforming loans of Ukrainian banking institutions, the profitability of the banking sector and its financial stability. The adequacy of the model was verified based on the following criteria: main summary statistics (ICSF criterion, ICS criterion, discrepancy function, maximum residual cosine), noncentrality fit indices (noncentrality parameter, population noncentrality parameter, Steiger-Lind RMSEA index, McDonald noncentrality index, adjusted population Gamma index), other single sample indices (Akaike information criterion, Schwarz criterion), and a normal probability plot.

Keywords nonperforming loans, banking sector, profitability, financial stability, structural modeling

JEL Classification G21, G28

INTRODUCTION

Given the negative impact of 2014–2015 economic crisis on the activity of banks in Ukraine, the tendency to lower quality of their loan portfolios is of particular interest. An increase in the share of nonperforming loans in banks' loan portfolios leads to a loss in financial results and a decrease in capitalization of banking institutions. Significant amounts of overdue loans lead to a loss of depositor confidence, problems with solvency and liquidity, as well as a deterioration in the bank's reputation, which negatively affects the financial results of banks.

The country's banking sector plays an important role in the development and functioning of the economy. It is a major intermediary in the financial resources market and connects all areas of business. The 2014–2015 crisis worsened the financial condition of Ukrainian banks.

http://dx.doi.org/10.21511/bbs.15(2).2020.07

The low resource base and the prevalence of short-term liabilities make the banking sector too vulnerable to the liquidity risk, increased credit and market risks. Low household incomes have a negative impact on banking, and poor financial position of borrowers requires the creation of significant reserves. In the absence of relatively stable sources of income, this complicates the formation of the resource base of commercial banks.

According to international practice, nonperforming loans (NPLs) include doubtful and bad loans. The IMF recommends that loans should be considered inactive if the principal and interest payments are past due: 1) for three months (90 days), or more; 2) less than 90 days; however, according to national banking supervision, it is considered that servicing such a loan is weak or unsatisfactory.

Having studied the dynamics of nonperforming loans in Ukraine in 2005–2019, it was concluded that it began to grow since 2008. A significant increase in the share of nonperforming loans occurred in two stages: the first stage is from 2014 to 2016 (banking and political crisis in Ukraine); the second is the year 2017 (Ukraine's transition to international standards for determining nonperforming assets). As of December 31, 2019, the share of nonperforming loans in the banking system of Ukraine amounted to 48.36%; that is, there was a certain decrease compared to 2017–2018. However, there is concern about the general deterioration of the economic situation in Ukraine and the world amid the global COVID-19 pandemic, which could lead to an increase in the volume and share of nonperforming loans in the short term. All of the above determines the need to assess the impact of nonperforming loans on the Ukrainian banking sector.

The article is structured as follows: Section 1 provides an overview of the literature, which analyzes studies by domestic and foreign authors on the impact of nonperforming loans on the country's economy and its banking sector. Section 2 provides information on the research methods, the data necessary for the calculation, and the research algorithm. Section 3 presents the results and their economic interpretation. The final section contains the findings of the study.

1. LITERATURE REVIEW

In recent decades, the problem of researching nonperforming loans and their impact on the state of the country's banking system has been relevant to all countries of the world. Therefore, both domestic and foreign scientists pay much attention to its study. In many countries, scientists conducted studies that provided important data on the quality of bank loan portfolios and their impact on the banking system and the country's economy as whole, factors stimulating the growth of nonperforming loans, the impact of regulation of central banks, etc.

The results of most studies show that nonperforming loans in most cases lead to a crisis in the banking sector and the country's economy if they grow uncontrollably (as evidenced by the crises of the 1990s and 2000s). Besides, scholars often see nonperforming loans as financial pollution of the country's banking and financial systems that damages its social and economic development (Gonzales-Hermosillo, 1999; Barseghyan, 2010; Zeng, 2011).

American scientists Sinkey and Greenawlat (1991) conducted a survey among US commercial banks for the period 1984–1987. The study showed a correlation between the size of credit risk of a bank it accepts and the amount of credit losses received: those banks that took higher credit risk were more unprofitable. According to the authors, the financial condition of the bank depends directly on its credit policy and, as a result, on the amount of nonperforming loans (Sinkey & Greenawlat, 1991). Keeton (1999) conducted a similar study, but over a longer period (1982–1996). A study conducted on the basis of banks throughout the United States concluded that low credit standards (requirements for borrowers) led to an increase in nonperforming loans in the bank's loan portfolio. McGoven (1993), another US researcher, obtained the same results. He found that not only low lending standards adversely affected the

http://dx.doi.org/10.21511/bbs.15(2).2020.07

financial position of a bank, but also insufficient loan requirements and the borrowers' attitude to their obligations to the bank (McGoven, 1993).

Meanwhile, similar studies were undertaken in European countries. For example, Fernandez de Lis, Pagés, and Saurina (2000) examined Spanish banks for the period 1985–1997. Calculations for some econometric models yielded the following results: the volume of non-performing loans is inversely proportional to the growth rate of the country's GDP (during periods of recession, accompanied by a drop in GDP, an increase in the volume of nonperforming loans is observed). Louzis, Vouldis, and Metaxas (2010), the Greek scholars, conducted an interesting study in which they explored the dynamics of nonperforming loans over the period 2003Q1–2009Q3 and their relationship with key macroeconomic indicators. They found that growth in real GDP, unemployment and lending rates negatively affected the volume of credit payments and led to an increase in nonperforming loans. In addition, the indicators of Return on Equity and Return on Assets deteriorated (Louzis, Vouldis, & Metaxas, 2010).

Similar studies were conducted by Ukrainian scientists.

Kozmenko and Belova (2015) considered the peculiarities of performance of the systemically important banks in Ukraine, their nonperforming loans and assessment of their impact on the occurrence of economic crisis.

Zhuravka, Makarenko, Osetskyi, Podmarov and Chentsov (2019) investigated three types of politically generated shocks and their impact on the banking sector, on the basis of experience of Argentina, Turkey and Ukraine.

Kozmenko, Shkolnyk and Bukhtiarova (2016) profoundly analyzed bank patterns on the basis of Kohonen self-organizing maps with the aim to determine further directions of bank strategies development under the influence of crisis events in Ukraine's economy.

Dudynets (2011) analyzed the causes of distressed assets, considered their impact on the activities of banking institutions in Ukraine and analyzed measures that would help reduce distressed assets. The author found that the reduction of problem assets held by banks led to an improvement in the functioning of the Ukrainian banking system. In addition, the author examined the dynamics of bank reserves for nonperforming loans and determined their impact on the financial results of the banking system (Dudynets, 2011).

Tushnytskyi (2010) also focused on identifying factors for increasing nonperforming loans in Ukrainian banks. The author considered the impact of bank nonperforming loans on the entire banking system of Ukraine, arguing that an increase in nonperforming loans led to deteriorated bank liquidity.

Tsyhanov and Pobocha (2003) and Oliinyk and Volovnik (2016) conducted similar studies, although at different time periods, and obtained identical results: a rapid increase in the share of nonperforming loans in the banks' loan portfolio causes significant deductions to reserves to cover losses on credit operations. The larger the amount of reserves for credit risk, while increasing the cost of banks to manage bad loans, the less effective is the use of bank capital. This situation always leads to a decrease in liquidity and solvency of a banking institution and may have a negative impact on the entire banking system of the country.

Kozmenko and Savchenko (2013) substantiated the importance of developing the money supply explicit monetary rule for the economy of Ukraine, which essentially influences nonperforming loans in banks' loan portfolios.

Despite a large number of studies on nonperforming loans, most authors pay special attention to factors determining the growth of these loans in the banking system (macro and micro factors), and not their impact on the banking sector and the country's economy as a whole. Since in recent years Ukraine has seen a significant increase in nonperforming loans, it is necessary to study how this process can affect its banking system and economy and what risks can be provoked.

2. DATA AND METHODS

It is critical to consider interconnections between indicators of nonperforming loans of banking in-

Table 1. Factors for analysis of the relationship between nonperforming loans, profitability and financial stability indicators in Ukraine's banking sector

Elements under study	Symbol	An indicator corresponding to a symbol
Indicators of nonperforming loans of Ukrainian banking institutions (NPL)	NPL's.V	NPL's volume, UAH mln
	NPL's.E.R	Non-performing loans to equity ratio, %
Profitability indices of the Ukrainian banking sector	ROAR	Return on assets rate, %
	ROCR	Return on capital rate, %
Financial stability indicators of the Ukrainian banking sector	RCRWAR	Regulatory capital to risk-weighted assets ratio, %
	LATAR	Liquid assets to total assets ratio, %

stitutions, profitability and financial stability of the Ukrainian banking sector. To determine these relationships and justify them both economically and mathematically, structural equation modeling was chosen. This method allows formalizing the relationships that exist between the selected elements of the structural equation system. The calculations were performed using the Statistica toolkit, which allowed evaluating the adequacy of the model received and determining the level of statistical significance of its parameters.

Six key indicators have been identified – two for each item under study – as an information base for studying the relationship between indicators of bank nonperforming loans, profitability and financial stability of the Ukrainian banking sector. The indicators of nonperforming loans (*NPLs*), rates of return (*ROR*) of the banking sector and financial stability (*FSIs*) are presented in Table 1.

Table 2 shows the statistics on indices selected for structural equation modeling for 2005–2019.

Structural equation modeling requires the following sequence of actions:

1. Building a path diagram to show the functional and structural relationships between the elements being studied.

2. Calculating and studying the regression dependence between explicit and implicit factors affecting the financial stability and profitability of Ukraine's banking sector, as well as nonperforming loans of banking institutions. This will help to obtain structural equations and interpret them economically.

3. Assessing the compliance of the resulting model residuals with the normal distribution law to verify the adequacy of the obtained model.

Table 2. Statistic data to study the relationship between banking institutions' nonperforming loans, profitability and financial stability of the Ukrainian banking sector for 2005–2019

Source: National Bank of Ukraine (n.d.a, n.d.b).

Year	Indices					
	NPL's.V	NPL's.E.R	ROAR	ROCR	RCRWAR	LATAR
2007	3,145	325.99	1.76	13.9	14.95	18.0271
2006	3,379	352.44	2.1	17.64	14.19	14.28
2007	4,456	313.82	1.92	16.33	13.92	11.6
2008	6,357	9.16	1.46	11.96	14.01	9.35
2009	18,015	31.97	–4.42	–33.71	18.08	11.45
2010	69,935	29.17	–1.46	–10.29	20.83	18.84
2011	84,851	25.76	–0.65	–4.44	18.9	18.65
2012	79,292	36.03	0.48	3.26	18.06	22.15
2013	72,545	30.65	0.26	1.72	18.26	20.63
2014	70,178	61.07	–4.24	–31.95	15.6	26.4
2015	135,858	129.02	–5.54	–65.51	12.31	33
2016	213,311	89.37	–12.47	–122.17	12.69	48.53
2017	307,812	70.18	–1.76	–15.34	16.1	53.94
2018	594,999	60.2	1.6	14.61	16.18	51.14
2019	530,780	25.28	4.7	37.55	19.66	72.28

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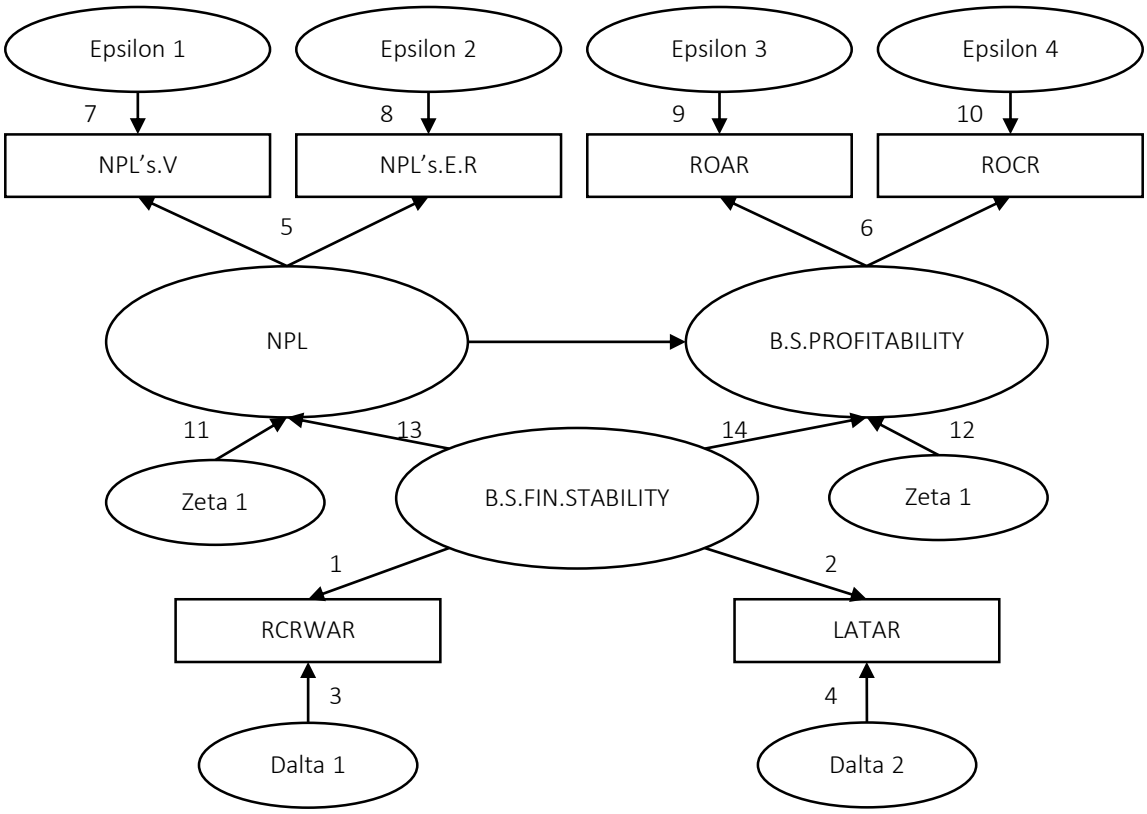

Figure 1. Path diagram to study the relationship between non-performing loans of banking institutions, profitability and financial stability of the Ukrainian banking sector

The factors listed in Table 2 are endogenous explicit variables for the model, which are used to formalize implicit variables, *B.S.FIN.STABILITY*, *NPL*, and *B.S.PROFITABILITY*. The purpose of structural equation modeling was to study the dependence of the financial stability of Ukraine's banking sector (*B.S.FIN.STABILITY*) on the volume of nonperforming loans (*NPL*) and profitability (*B.S.PROFITABILITY*) of the banking sector of Ukraine. Therefore, *B.S.FIN.STABILITY* is an exogenous variable that depends on *NPL* and *B.S.PROFITABILITY*.

Figure 1 shows the path diagram constructed for structural equation modeling.

Before making calculations in Statistica, it is necessary to normalize the selected output data, since the selected indicators have different vectors values, $X=\left(x_1,x_2,\ldots,x_n\right)$, and should be brought to a single scale. Such a transformation will help to ensure that structural modeling is adequately used and that quantitative and qualitative values are consistent.

Data were normalized by formula (1).

$$x_i^{'}=\frac{x_i-x_{min}}{x_{max}-x_{min}}, \quad (1)$$

Transformation of data by normalization makes them dimensionless and placed at [0; 1]. As a result of data normalization, the following output data for calculations were generated (Table 3).

The principle of structural equation modeling is that simpler models allow you to build a complex integrated correlation model between the elements under study. Also, inside the model, causal links between variables are formalized.

In Statistica, in the Sepath Wizard – Select Wizard window, the Structural Modeling option should be chosen. First you need to define exogenous variables in the Exogenous Variables field. According to the path diagram, they include *B.S.FIN.STABILITY*, which is made up of *RCRWAR* and *LATAR*. In the Base Name for Residual Variables field, specify the name for the residual variables – Delta (this name was used in Figure 1).

Table 3. Normalized output data for structural equation modeling

Year	Indices					
	NPL's.V	NPL's.E.R	ROAR	ROCR	RCRWAR	LATAR
2007	0.0000	0.9229	0.8288	0.8519	0.3099	0.1379
2006	0.0004	1.0000	0.8486	0.8753	0.2207	0.0783
2007	0.0022	0.8875	0.8381	0.8671	0.1890	0.0358
2008	0.0054	0.0000	0.8113	0.8398	0.1995	0.0000
2009	0.0251	0.0664	0.4688	0.5538	0.6772	0.0334
2010	0.1128	0.0583	0.6412	0.7005	1.0000	0.1508
2011	0.1381	0.0484	0.6884	0.7371	0.7735	0.1478
2012	0.1287	0.0783	0.7542	0.7853	0.6749	0.2034
2013	0.1173	0.0626	0.7414	0.7757	0.6984	0.1792
2014	0.1133	0.1512	0.4793	0.5649	0.3862	0.2709
2015	0.2242	0.3492	0.4036	0.3547	0.0000	0.3758
2016	0.3551	0.2337	0.0000	0.0000	0.0446	0.6226
2017	0.5148	0.1778	0.6238	0.6689	0.4448	0.7086
2018	1.0000	0.1487	0.8195	0.8564	0.4542	0.6641
2019	0.8915	0.0470	1.0000	1.0000	0.8627	1.0000

The next step is to determine the endogenous variables. In the first field, the *B.S.PROFITABILITY* variable, which includes *ROAR* and *ROCR*, is entered; in the second field, NPL with the endogenous factors of *NPL's.V* and *NPL's.E.R* is introduced. In the Base Name for Residual Variables field, *EPSILON* is automatically prescribed, and in the Base Name for Disturbances field, Zeta (these names were also used in the path diagram).

Using the Define Structural Equation Paths window, set a regression model that connects *B.S.FIN.STABILITY*, *B.S.PROFITABILITY*, and *NPL*. Next, translate the model into Path1 and run an iterative procedure to estimate unknown parameters.

3. RESULTS

After the program calculations, some results of estimating the correlation between indicators of nonperforming loans of banking institutions, profitability and financial stability of the Ukrainian banking sector are presented (see Table 4).

Table rows correspond to a path entry in Path1; columns give estimates of a free parameter, standard errors, t-statistics, and p-levels of statistical significance. Significant t-statistics ($p < 0.05$) are highlighted in red. If t-statistic is significant, then the hypothesis of zero inequality of the corresponding free parameter estimate is true. Table 4 presents the estimates of the regression model parameters that connect the factors of *B.S.FIN.STABILITY*, *B.S.PROFITABILITY*, and *NPL*, that is, using only explicit variables, the program built a regression model that linked hidden common factors.

A system of structural equations, which reflects the relationship between the financial stability of the Ukrainian banking sector, its profitability and nonperforming loans, is given in formula (2).

$$\begin{cases} RCRWAR = 0.026 \cdot B.S.FIN.STABILITY + 0.093 \\ LATAR = 0.285 \cdot B.S.FIN.STABILITY \\ ROAR = B.S.PROFITABILITY \\ ROCR = 1.028 \cdot B.S.PROFITABILITY + 0.109 \\ NPL's.V = NPL \cdot 0.001 \\ NPL's.E.R = NPL \\ NPL = 0.307 \cdot B.S.FIN.STABILITY + 0.008 \\ B.S.PROFITABILITY = -0.667 \cdot B.S.FIN.STABILITY + 2.070 \cdot NPL + 0.024 \end{cases} \quad (2)$$

http://dx.doi.org/10.21511/bbs.15(2).2020.07

Table 4. The results of structural modeling of the relationship between nonperforming loans of banking institutions, profitability and financial stability of the Ukrainian banking sector

Indicators	Model estimates			
	Parameter estimate	Standard error	T statistics	Probabilistic level
(*B.S. FIN. STABILITY*) – 1 → [*RCRWAR*]	0.026	0.083	0.311	0.756
(*B.S.FIN.STABILITY*) – 2 → [*LATAR*]	0.285	0.060	4.741	0.000
(*DELTA1*) → [*RCRWAR*]	–	–	–	–
(*DELTA2*) → [*LATAR*]	–	–	–	–
(*DELTA1*) – 3 – (*DELTA1*)	0.093	0.035	2.645	0.008
(*DELTA2*) – 4 – (*DELTA2*)	0.010	0.005	1.991	0.047
(*NPL*) → [*NPL's.V.*]	–	–	–	–
(*NPL*) – 5 → [*NPL's.E.*]	–0.369	0.276	–1.337	0.181
(*B.S.PROFITABILITY*) → [*ROAR*]	–	–	–	–
(*B.S.PROFITABILITY*) – 6 → [*ROCR*]	1.028	0.037	27.902	0.000
(*EPSIL0N1*) → [*NPL's.V*]	–	–	–	–
(*EPSIL0N2*) → [*NPL's.E*]	–	–	–	–
(*EPSIL0N3*) → [*ROAR*]	–	–	–	–
(*EPSIL0N4*) → [*ROCR*]	–	–	–	–
(*EPSIL0N1*) – 7 – (*EPSIL0N1*)	0.000	0.000	–	–
(*EPSILON2*) – 8 – (*EPSILON2*)	0.109	0.041	2.646	0.008
(*EPSILON3*) – 9 – (*EPSILON3*)	0.001	0.000	2.646	0.008
(*EPSILON4*) – 10 – (*EPSILON4*)	0.000	0.000	–	–
(*ZETA1*) → (*NPL*)	–	–	–	–
(*ZETA2*) → (*B.S.PROFITABILITY*)	–	–	–	–
(*ZETA1*) – 11 – (*ZETA1*)	0.008	0.005	1.681	0.093
(*ZETA2*) – 12 – (*ZETA2*)	0.024	0.020	1.235	0.217
(*B.S.FIN.STABILITY*) – 13 → (*NPL*)	0.307	0.063	4.872	0.000
(*B.S.FIN.STABILITY*) – 14 → (*B.S.PROFITABILITY*)	–0.666	0.133	–4.999	0.000
(*NPL*) – 15 → (*B.S.PROFITABILITY*)	2.070	0.000	–	–

It is advisable to economically interpret all the structural equations of the system.

Let's consider the relationship between the hidden variable *B.S.FIN.STABILITY* and the endogenous variables *RCRWAR* and *LATAR* (the first two equations of the resulting structural equation system). If the banking sector's financial stability changes by 1%, the ratio of regulatory capital to risk-weighted assets will change by 0.026%, and the ratio of liquid assets to total assets will change by 0.285%.

That is, a direct relationship is observed between the hidden *B.S.FIN.STABILITY* variable and the endogenous *RCRWAR* and *LATAR* variables. If the financial stability indicator of the banking sector is zero, *RCRWAR* will be 0.093 and *LATAR* will be zero.

The obtained dependencies for assessing the profitability indicators of the banking sector of Ukraine (*B.S.PROFITABILITY*) are expressed by the third and fourth equations in the system of structural equations (formula (2)). Given the third equation of the system, one can conclude that the profitability of the Ukrainian banking sector and the rate of return on capital and assets are directly proportional. That is, a 1% increase in profitability of Ukraine's banking sector is accompanied by a proportional increase in the rate of return on assets and an increase in the rate of return on capital by 1.028%. With a zero profitability of the banking sector, the rate of return on assets will be 0, and the rate of return on capital will be 0.109.

The dependence of *NPL* (a hidden variable) on the explicit variables *NPL's.V* and *NPL's.E.R* is shown in the fifth and sixth equations of the system. Nonperforming loans of Ukrainian banking institutions are directly dependent on the volume of bad loans. That is, if the volume of bad loans increases by 1%, we will receive a 1% increase in nonperforming loans of Ukrainian banking institutions.

In the sixth equation of the system, there is a direct correlation between nonperforming loans of Ukrainian banking institutions and the ratio of non-performing loans, excluding capital reserves. With a 1% increase in *NPL's.E.R*, we get a deterioration in nonperforming loans of Ukrainian banking institutions by 1%.

The following conclusions can be made about equations describing the correlation between latent implicit variables (the seventh and eighth equations in the system). There is a direct correlation between the financial stability of the banking sector and nonperforming loans of Ukrainian banking institutions. That is, with the improvement in the financial stability of the Ukrainian banking sector by 1%, nonperforming loans of Ukrainian banking institutions also increase, but only by 0.307%.

When determining the relationship between the financial stability of the banking sector of Ukraine, its profitability and nonperforming loans of banking institutions, one can conclude that the inverse relationship exists between the financial stability of Ukraine's banking sector and its profitability, and a direct relationship between nonperforming loans of banking institutions and profitability of the Ukrainian banking sector. If the banking sector's profitability increases by 1%, the financial stability will decrease by 0.667%. With an increase in profitability of the Ukrainian banking sector by 1%, a 2.070% increase in nonperforming loans of banking institutions is observed.

After the economic interpretation of the model, it is necessary to verify the adequacy of the resulting system of equations and its parameters. The model adequacy can be checked by analyzing the following criteria: Main Summary Statistics, Noncentrality Fit Indices, and Normal Probability Plot.

The study of the relationship between the development of the stock market, the activities of depository institutions and individual investors has the basic statistics presented in Table 5.

Having analyzed the value of summary statistics, one can conclude that the model is adequate. Firstly, the iterative process was successful; secondly, ICSF Criterion and ICS Criterion equal zero; thirdly, the Discrepancy Function value is small; and fourth, the value of the Maximum Residual Cosine is zero. Thus, one can conclude that the resulting system of structural equations is adequate.

Now let's analyze the model's noncentrality indices (Table 6). They reflect the degree of the model adequacy by estimating the Noncentrality Parameter χ^2. The following confidence intervals are used to assess the model adequacy by model noncentrality indices: the lower limit of 90% of the confidence interval, the point estimate, and the upper 90% limit of the confidence interval. Using Statistica, the following indices were analyzed: Population Noncentrality Parameter, Steiger-Lind *RMSEA* Index, McDonald Noncentrality Index, Population Gamma Index, and Adjusted Population Gamma Index. The Population Noncentrality Parameter characterizes the reliability of the null hypothesis, and, therefore, the model's adequacy. If it is less than 0.05, then the null hypothesis is true. In this case, only the value for the lower 90% confidence limit corresponds to the specified value. As for the Steiger-Lind *RMSEA* Index, its value should

Table 5. Main summary statistics to study the relationship between banking institutions' nonperforming loans, profitability and financial stability of the Ukrainian banking sector

Indicators	Main summary statistics
Discrepancy Function	1.386
Maximum Residual Cosine	0.000
Maximum Absolute Gradient	14.248
ICSF Criterion	0.000
ICS Criterion	0.000
Chi-square Statistic	19,409
Degrees of Freedom	7.000
Chi-square p-level	0.007
RMS Stand. Residual	0.180

http://dx.doi.org/10.21511/bbs.15(2).2020.07

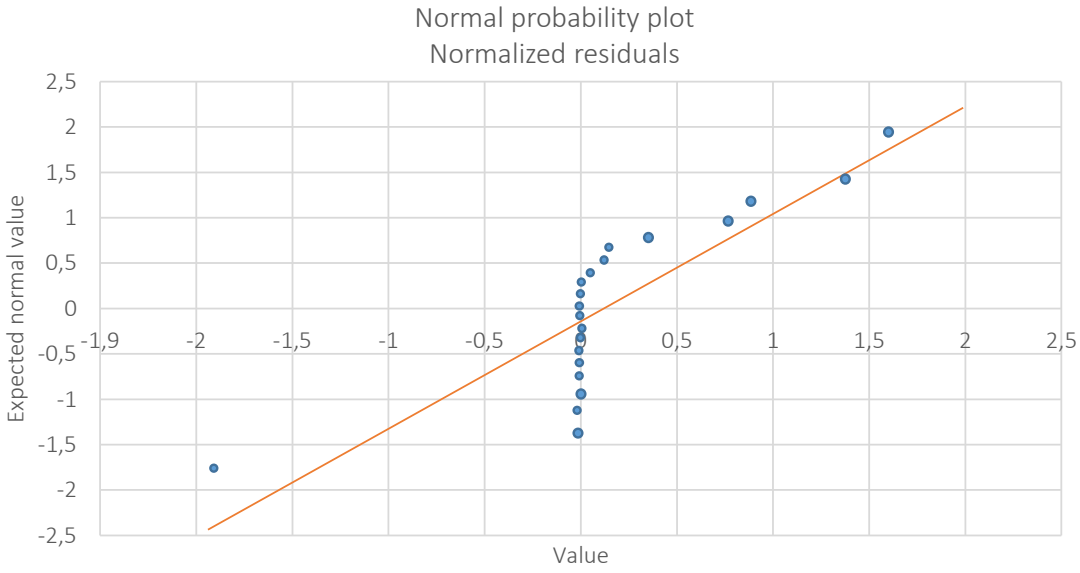

Figure 2. Checking the adequacy of the model of relationships between NPLs of banking institutions, profitability and financial stability of the Ukrainian banking sector

be less than 0.05, which is true only for the lower 90% confidence limit in the model. The McDonald Noncentrality Index, the Population Gamma Index and the Adjusted Population Gamma Index should be greater than 0.95, which corresponds to only the upper 90% confidence limit in the current system of structural equations. It can be concluded that the values of these indices indicate normal model fitting.

Table 6. Model noncentrality indices of the relationship between NPLs of banking institutions, profitability and financial stability of the Ukrainian banking sector

Indicators	Noncentrality fit indices		
	Lower 90% conf. bound	Point estimate	Upper 90% conf. bound
Population Noncentrality Parameter	0.000	0.478	1.519
Steiser-Lind RMSEA Index	0.000	0.261	0.466
McDonald Noncentrality Index	0.468	0.788	1.000
Population Gamma Index	0.664	0.863	1.000
Adjusted Population Gamma Index	–0.009	0.588	1.000

It is also advisable to consider other Single Sample Indices (Table 7), among which the most important are the Akaike Information Criterion and the Schwarz Criterion. According to these indices, the model with the least value of these indices is the best. The resulting model (one of the five analyzed by authors) is characterized by the lowest values of these indices, which indicates its adequacy.

Table 7. Single Sample Indices of the relationship between NPLs of banking institutions, profitability and financial stability of the Ukrainian banking sector

Indicators	Other Single Sample Indices
Jorescog Index (GFI)	0.754
Adjusted Jorescog Index (AGFI)	0.263
Akaike Information Criterion	3.386
Schwarz Criterion	4.094
Brown Kudek Cross-Validation Index	5.386
Chi-square for an independent model	105.965
Degrees of freedom for an independent model	15.000
Bentler-Bonet Normalized Consent Index	0.817
Bentler-Bonet Non-Normalized Consent Index	0.700
Bentler-Bonet Comparative Consent Index	0.864
James-Mulaik-Brett Consent Index	0.381

An important feature of a model's adequacy is its compliance with the normal residual distribution law, which can be analyzed in the Normal Probability Plot (Figure 2). The denser the points on the line, the more the residual distribution law corresponds to the normal law. In Figure 2, the points are rather densely located on the line, which indicates the adequacy of the obtained model.

CONCLUSION

Having analyzed all of the above criteria for the adequacy of the obtained economic and mathematical model, one can conclude that almost all factors indicate the adequacy of the structural equation system and the normal distribution of the normalized model residuals.

As a result of the economic and mathematical calculations using the structural modeling method, the conclusion can be made that there is an interdependence between indicators of nonperforming loans of banking institutions, profitability and financial stability of the Ukrainian banking sector. In determining the relationship between the financial stability of the banking sector of Ukraine, its profitability and nonperforming loans of banking institutions, it is concluded that there is an inverse relationship between financial stability of the Ukrainian banking sector and its profitability, and a direct relationship between nonperforming loans of banking institutions and profitability of the Ukrainian banking sector.

An interesting trend indicates a deterioration in the financial stability of the Ukrainian banking sector by 0.667%, while increasing its profitability by 1%. In addition, a 1% increase in Ukraine's banking sector profitability leads to an increase in nonperforming loans of banking institutions by 2.070%. This confirms that in Ukraine there is a problem with an adequate definition of borrowers' creditworthiness by credit organizations.

Thus, bank nonperforming loans do exist in Ukraine, and an increase in the share of problem loans in the banking sector negatively affects its financial stability. Meanwhile, an increase in the profitability of banking institutions, which is usually a positive phenomenon, exacerbates the situation with nonperforming loans. This is because banks are ready to take on more credit risks to obtain additional profit, which is a key risk factor in terms of rising nonperforming loans in Ukraine and their negative impact on the financial stability of the banking sector.

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