

Stress-testing as a method of macroprudential policy and information security in banking sector

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Abstract. The article contains an overview of the essence, history, components, scenarios, methodology and results of stress testing of the Ukrainian banking system. The purpose of this paper is to explore and analyze existing approaches to stress testing as a method of macro-prudential policy of the Central Bank, to determine the results of quantitative risk assessment and financial stability of banks and their readiness to have sufficient capital to cover losses in various macroeconomic scenarios, as well as to develop a model of integrated assessment and rating of banks based on the results of stress testing. In order to summarize the results of the study, a model of integrated assessment was developed and a rating of banks was built based on the analysis of their financial stability, capital adequacy and readiness to withstand the crisis. To solve the problem of qualitative analysis of the stress-testing results in terms of a significant number of indicators and calculations a simulation of the integral indicator is proposed which helps information users group the data, obtain a generalized assessment and form a rating of banks according to the financial stability reserve.

1 Introduction

Ensuring the financial stability of the State banking sector every year is becoming increasingly active stipulated by the rapid pace of globalization. As a result, there is a reduction in obstacles to additional cash flows from abroad and an increase in information flows, financial innovation and other technological advances. Such processes contribute to the formation of close links between the financial markets of different countries and regions. Therefore it results in serious risks because financial crises tend to spread beyond national borders and have a strong impact on the world economy.

Central banks of the countries should be prepared for shocks that may occur both outside and within the country and will be transmitted through channels of interconnection to the core of the national economy and are likely to damage financial stability. This raises the question how it is possible to prevent potential banking sector shocks and the country as a whole at an early stage. Macroeconomic stress testing is a key method to ensure an effective financial stability.

2 Related literature

Assessment of financial stability of the banking system by means of stress testing is a relatively new method of macroprudential policy of central banks, the content of which is considered in various regulations of the Basel Committee, the International monetary Fund (2018), the Federal reserve system of the United States (2018, 2019)

of European Central banks and other national regulators. The experience and the mechanism of application of the stress tests were analyzed in writings by M. Čihák, L. L. Ong (2014), C. Schmieder, L. Schumacher (2014), A. Foglia (2009), P. Kapinos, O. Mitnik (2015), M. A. Espinosa-Vega, J. Sole (2014), et al. Thus, in particular, M. Čihák and L. L. Ong (2014) paid attention to the use of stress testing in the IM; the approach to stress testing on the basis of balance was studied by C. Schmieder and L. Schumacher (2014). The actions of the regulator on stress testing of credit risk were investigated by A. Foglia (2009), the stress testing by the top-down method was described by P. Kapinos and O. Mitnik (2015). On the other hand, M. A. Espinosa-Vega and J. Sole (2014) carried out an introduction to the network analysis of the stress testing. Since 2014 the National Bank has made an attempt to introduce this method of quantitative risk assessment for Ukrainian banks. The practice of such use as well as the experience of the regulator was tackled by domestic scientists, in particular Yu. Duba and A. Murina (2015) who defined the conceptual approaches of the National Bank of Ukraine to stress testing, N. Zaderey (2017) analyzed the instruments of macroprudential policy as new liquidity requirements, P. Dadashova (2018) studied the theoretical basis of stress testing and the structure of the model of regular assessment of bank stability. However, as a result of constant adjustment and improvement of the methodology and development of the banking system of Ukraine by the National Bank, the analysis of the results of stress testing remains an important issue. In addition, the obtained findings allow us to pay attention to

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modeling of the generalization of indicators for the banks rating construction based on the results of stress testing.

3 The purpose of the research

The aim of this work is to analyze the existing approaches to stress testing as a method of macroprudential policy of the Central Bank, to determine the results of quantitative risk assessment and financial stability of banks and their readiness to have sufficient capital to cover losses in various macroeconomic scenarios, as well as to develop a model of integrated assessment, to make up the rating of banks according to the stress-testing results.

4 Results

According to the “Strategy of the National Bank of Ukraine Action Program 2019” (2019) it can be concluded that the regulator is focused on the issues of macroprudential regulation necessary to prevent the accumulation and implementation of systemic risks in the financial sector. The ultimate goal of macroprudential policy is to ensure financial stability, i.e. the state of the financial system which can properly perform the main functions such as financial intermediation and payments as well as successfully confront the crisis. The achieved goal will contribute to a sustainable economic growth. Macro-prudential policies cannot completely eliminate systemic risks, but can prevent their excessive accumulation and reduce the likelihood of their implementation. Thus, it increases the stability of the economy, reduces the volatility of GDP confirmed by the results of empirical studies.

In the Guidelines on the procedure for stress testing in banks of Ukraine (2009) and Guidelines for the organization and functioning of risk management systems in banks of Ukraine (2004) stress testing is defined as a method of quantitative risk assessment which is to determine the value of the inconsistent position exposing a bank to a risk, and to determine the shock value of changes in the external factor that is the exchange rate, interest rate and the like. The combination of these values gives an idea of possible losses or incomes of a Bank if the events develop under the assumptions. Stress testing is widely used to assess a credit risk, liquidity risk, currency risk, interest rate risk and asset value.

Stress-testing has evolved as a response to the crisis. Since 2010 it has been included in the regulatory practice of many countries. The concept of modern prudential supervision is based on the understanding that banks should always be ready for the crisis. The theoretical basis of the stress-testing is the understanding that in crisis conditions the significant losses are certain to occur. According to the bank, there are requirements to have sufficient capital to cover such losses.

In the stress test scenario, macroeconomic, sectorial and specific financial indicators deteriorate. Therefore, stress-testing allows us to assess how different economic shocks can possibly affect banks, the plausible losses of the banking system. Even if the shock inherent in the scenario never takes place, the NBU receives plethora of

information as a result of testing. It will be the basis for the adoption of special measures or the provision of recommendations to individual financial institutions or the introduction of macroprudential instruments.

Thus, the purpose of stress-testing is to assess risks and determine the aptitude to withstand shocks in the financial market. In other words, stress-testing is aimed at assessing the potential stability of banks during a hypothetical crisis.

The most common objects of stress-testing can include: a sharp change in interest rates on domestic or foreign borrowings, loans, securities etc.; significant exchange rate fluctuations; credit risks in loan portfolios; sharp changes in the volume and structure of capital of a financial institution, the value of collateral for mortgages; reduced liquidity and possible default of the Bank; the possibility of a systemic risk based on a sharp decline in liquidity or capital loss etc.

The innovation of 2018 was the annual assessment of the stability of bank which consists of an assessment of the quality of assets and for the largest banks it was stress-testing which involves the modeling of an adverse low-level but plausible macroeconomic scenario. Asset quality assessment and stress-testing is a well-established practice of the world's leading regulators which makes it possible to prevent excessive accumulation of systemic risks and prepare banks for feasible future crises. As a result, it contributes to the stability of the banking system in Ukraine and financial stability in general.

Every year the NBU tests banks, which account for at least 90% of the assets of the banking sector. Small banks will not be affected because their loss of capital during the crisis is hardly to create systemic risks.

The testing cycle of banks individually and the banking system as a whole includes a calendar year and it covers asset quality assessment, extrapolation and stress-testing of the NBU, preparation and implementation of the capitalization program by the Bank. The regulator conducts stress-testing at the micro and macro levels. As a rule, the NBU assesses the quality of banks' assets before micro-stress testing. The tests themselves simulate in detail the activities of individual financial institutions. Testing is carried out on a top-down principle. According to the results of micro-stress testing the NBU establishes additional requirements for banks to form additional capital buffers or to restructure assets and business processes. Their implementation should ensure the stability of banks in the event of a crisis.

Macro-stress testing is conducted for the sector as a whole, mainly without going into the activities of individual institutions. Macro-stress tests operate on aggregated data. If testing reveals systemic risks concerning many banks, the NBU may resort to the use of macroprudential instruments. The macrostress test can be based on the results of individual evaluation of banks. Then it further models the relationship between financial institutions that can lead to a chain reaction (feedback loop). The macrostress test can be based on the results of individual evaluation of banks. Then it further models the relationship between financial institutions leading to a chain reaction (feedback loop). The stress-testing process determines the estimated indicators of the bank's financial

statements (balance sheet and income statement) for three years after the reporting date.

Stress tests include two macroeconomic scenarios – baseline and adverse scenarios. The most significant risk factors are the basis for modeling of the adverse scenario, according to which the NBU assesses the banks’ resilience to the crisis. The baseline scenario provides a basis for comparison, as well as identifies weaknesses of the current business model of banks. NBU develops scenarios for three years. This period is good for simulating all stages of the crisis that is from its deployment to the beginning of economic recovery.

Banks must meet the minimum requirements for the adequacy of fixed and regulatory capital under the baseline scenario and reduced requirements under the adverse scenario.

It should be noted that the baseline scenario generally corresponds to the macroeconomic forecast of the NBU. The adverse scenario simulates a deep but possible crisis (severe but plausible scenario). It should not necessarily take into account the experience of previous crises and cannot be considered as an alternative macroeconomic forecast of the NBU.

Scenario modeling is based on four key groups of indicators:

1. The volume of GDP and production. It is expected that they will fall significantly and in different sectors in different ways.
2. Exchange rate. A significant devaluation of the hryvnia is expected.
3. Inflation. It is expected that during the crisis, prices will grow at an accelerated pace, including due to devaluation.
4. Interest rate. A sharp increase in the NBU discount rate and commercial rates are being laid, as a result of which the interest spread and the margin of banks are mainly reduced.

As the basic risk factors, the NBU recommends the use of the following:

- 1) macroeconomic indicators: stability of the economic situation (economic recession, radical change in the vector of economic development, defaults of first-class borrowers, etc.); significant fluctuations in the exchange rate of the national currency; openness and availability of the interbank market; the level of political and international stability; stability of financial markets, including the ability to counter speculative attacks; changes in interest rates, for example, LIBOR, interest rates, etc.; the possibility of depreciation of property, which is provided to ensure the credit operations of banks (in particular, due to falling prices in the real estate market, crisis of certain sectors of the economy, etc.); volatility of energy prices;
- 2) microeconomic indicators: the Bank's ability to access external sources of liquidity support; competitive position of the Bank (determined by the SWOT analysis method as a generalized assessment).

The following tests and models are used for stress-testing and regular assessment of resistance: sensitivity tests, scenario tests and extreme value tests; NPL forecasting model to predict the change in the share of non-performing loans (NPL) through multivariate regression models. It can evaluate the migration of

debtors (except large ones) to the default class 10; model of stress-testing of large debtors for forecasting financial statements of large debtors of the Bank on the basis of financial modeling. This model can determine the credit risk of the Bank for large debtors; scenario development model to build an adverse scenario based on macro modeling. As a result of modeling macroeconomic variables for regression models as well as macroeconomic and industry variables for financial models are obtained; the balance sheet model of the Bank to assess the balance sheet and income statement of the Bank for the forecast period, as well as to calculate the capital requirements.

It should be noted that depending on the development of the banking sector and the economy, the NBU will change the list of risk factors in an adverse scenario. It is also possible to use reverse stress-testing (reverse stress-testing). To do this, first determine the amount of losses that banks must absorb, and, despite this, the dynamics of key macroeconomic indicators that form the corresponding losses is modeled. Modeling the performance of individual banks or the sector as a whole is not intended to provide the most accurate forecast of their dynamics. This is impossible due to the assumption of static balance. At the same time, the baseline and adverse scenarios can assess how the existing imbalances can be realized and how this will affect the profitability and capital of banks.

The NBU plans to annually inform banks and the public about macroeconomic scenarios for stress tests, explaining in detail the logic of their construction because carrying out stress-testing and capitalization of banks according to its results is one of the conditions for cooperation with the IMF. The history of stress-testing of Ukrainian banks is shown in table 1.

Table 1. History of stress-testing of Ukrainian banks.

	Stress-testing 2014	Stress-testing 2015-2016	Regular sustainability assessment from 2018
Performers	9 audit companies	NBU	Audit companies, NBU
Bank sample	34 banks (79 % of assets)	60 banks (97% of assets)	24 banks (93% of assets)
Macroeconomic scenarios	- baseline - adverse	- baseline	- baseline - adverse
Stress-testing of large debtors	No	Yes	Yes
Risks	- credit - monetary	- credit - monetary	- credit - monetary - percentage

* systemized by authors based on NBU data (2014, 2015, 2016, 2018)

In 2018 the NBU assessed the stability and stress-testing of the largest banks in Ukraine. According to the schedule for assessing the stability of banks the analysis was carried out in three stages:

1. Asset quality and collateral acceptability assessment (conducted by external auditors for all banks).

2. Extrapolation of the results of the first phase, evaluation of the adequacy and the capital requirements.

The second stage was carried out in case of incorrect display of asset quality by banks during the first stage.

3. Stress-testing (ST), assessment of sufficiency and capital requirements. Stress-testing was conducted by 24 banks, which accounted for more than 94% of the assets of the banking system.

For this procedure banks were selected according to the largest on average values of two indicators: risk-weighted assets and deposits of individuals. NBU conducted stress-testing of credit and market risks (interest rate and currency). For the baseline scenario, public forecasts of the NBU were used (table 2). The exchange rate value for the baseline scenario is taken from the “Focus Economics” consensus forecast (2018).

Table 2. Macroeconomic indicators of the baseline and adverse stress test scenarios of 2018.

Indicator	Fact	Baseline scenario			Adverse scenario		
	2017	2018F	2019F	2020F	2018F	2019F	2020F
	According to the NBU						
Real GDP, %	2.1	3.4	2.9	2.9	-3.3	-3.8	1.0
Nominal GDP, %	23.0	15.8	11.3	8.9	18.8	12.9	11.6
Consumer price index, % (end of period)	13.7	8.9	5.8	5.0	18.7	15.5	9.3
Consumer price index, % (average for the period)	14.4	11.0	7.3	5.7	20.8	16.5	8.7
Unemployment rate, %	9.5	8.5	8.2	8.3	9.8	10.0	9.5
	According to “Focus Economics”			According to the NBU			
The depreciation of hryvnia to US dollars, %	3.8	5.4	2.7	1.5	23.1	11.1	5.6

* systemized by authors based on NBU data (2018)

The adverse macroeconomic scenario is based on hypothetical assumptions of macroeconomic indicators that lead to the implementation of credit and market risks in significant amounts. According to international practice, the stress test adverse scenario must be tough, but the most likely (severe but plausible scenario). At the same time, it does not show the expectations of economic development in the near future. The adverse scenario is developed by the NBU, it is based on the following assumptions: a decrease in real GDP by one standard deviation (calculated on data from 2000) from the baseline forecast; devaluation of the hryvnia to the US dollar – 23% in 2018 (the average level of devaluation during the previous two crises) and moderately in the future.

In this regard it is advisable to make some international comparisons. Thus, according to the information published by the NBU (2018), an adverse scenario in the US allows for a decline in real GDP at the peak of the crisis by 3.5% and an severely adverse (SA) by 8.9%; in the Euro zone countries, the crisis under the adverse scenario lasts two years and GDP decline is

expected at 2% on average and up to 6% in some countries; in the UK under the adverse scenario, the pound devaluation against the Euro by 24%.

The results of stress-testing should be interpreted only in the context of the key assumptions that formed the basis of the model. Firstly, the regulator assumes that the banks' balance sheet is static, that is, it is influenced only by changes in the quality of assets and changes in the exchange rate. In practice, individual banks are growing quite rapidly and therefore their balances are already significantly different from the balances at the date of stress-testing. Secondly, current profits are expected to capitalize throughout the forecast period. In practice, banks often decide on the distribution of profits between shareholders. According to reports of the NBU (2018), the average capital adequacy under the baseline scenario is growing in the forecast period by almost 13 BP to 24.7%.

According to the results of stress-testing, the need for capital for 8 banks in two scenarios and for 5 banks only in an adverse scenario was established), table 3. The amount of capital requirements under the baseline scenario in the 1st year is 224.13 million USD and grows to 1546.89 million USD for all years in adverse scenario.

Table 3. The results of the stress test.

Scenario	Number of banks*	Capital requirement		
		1st year	2nd year	3rd year
Baseline	8	224.13 million USD	290.27 million USD	349.06 million USD
		892.86 million USD	1451.36 million USD	1546.89 million USD
Adverse	13	892.86 million USD	1451.36 million USD	1546.89 million USD

* number of banks for which capital requirement is established

The main problem of qualitative analysis of stress test results is the presence of a significant number of calculation results and the lack of a generalized rating of banks on their results. Thus, according to the regulator, information on regulatory capital, fixed capital, regulatory capital adequacy ratio, capital adequacy ratio, the amount of capital need (shortage) based on the results of the sustainability assessment, measures taken after 01.01.2018 and before the publication of the results of the sustainability assessment and the amount of capital need (shortage), taking into account measures in the context of the Bank's data for 01.01.18, the results of forecast calculations for 2018, 2019 and 2020 according to the baseline and adverse macroeconomic scenarios are provided for 24 banks. As a result, more than 25 numerical values for each Bank can be radically different from each other and exclude the understanding of the place of a financial institution among others. That is why we consider it expedient to aggregate all the features of the set of indicators into one integral estimate and identify banks according to stress resistance in the form of a top list. Let us call it “integral stress-testing index (I_{ST})”.

It should be noted that such ratings innoway affect the macro-prudential policy of the regulator because they do not deprive banks with a high result of the need to respond to the need for additional capitalization in different scenarios. However, they help information users to group data and obtain a generalized assessment of financial

stability (and hence security) of each of the banks on the basis of baseline and adverse macroeconomic scenarios. Construction of the I_{ST} contains the following steps:

1. Formation of a set of indicators.
2. Normalization and standardization of identifiers.
3. Calculation of the integral index.

To the set of indicators that will form the feature space, we propose to include:

- regulatory capital (x_1) – one of the most important indicators of banks’ activity, the main purpose of which is to cover the negative consequences of the various risks taken by banks in the course of their activities, and to ensure the protection of deposits, financial stability and stability of banking activities,
- fixed capital (x_2) is the regulatory component and it contains: the registered authorized capital (ordinary shares) share premium on common shares, unregistered paid shareholders’ contributions, financial assistance from the bank’s shareholders, quarterly/annual retained earnings revaluation surplus of fixed assets as of 31.12.2010 (with gradual exclusion from the calculation in full), funds/reserves, created at the expense of profits,
- regulatory capital adequacy ratio (x_3) shows the bank’s ability to timely and fully pay its obligations arising from trading, creditor other transactions of monetary nature,

– capital adequacy ratio (x_4) is defined as the ratio of fixed capital to total assets and off-balance sheet liabilities weighted by appropriate credit risk ratios. Since all indicators are stimulants, their standardization will be done according to the formula:

$$z_{ij} = \frac{x_{ij} - x_{min_i}}{x_{max_i} - x_{min_i}}, \tag{1}$$

where x_{ij} is the value of the i indicator ($i=1, \dots, 4$) of the result of stress-testing of the bank for j ($j=1, \dots, 24$), x_{max_i} , x_{min_i} respectively, the maximum and minimum values of the i indicator for the group of banks; z_{ij} – standardized values of indicators.

We will calculate the integral index of stress-testing according to formula (2), because we believe that all indicators are equilibrium in assessing the stability of banks.

$$I_{ST_j} = \frac{1}{m} \sum_{i=1}^m z_{ij}, \tag{2}$$

The value of the integral indicator I_{ST} for 24 banks, that were subject of stress-testing, summarized in table 4.

Table 4. Integrated indicators of stress-testing by banks.

Bank	According to banks data	Baseline scenario			Adverse scenario		
		1st forecast year	2nd forecast year	3rd forecast year	1st forecast year	2nd forecast year	3rd forecast year
A-Bank	0.184	0.536	0.532	0.526	0.669	0.670	0.642
Alfa-Bank	0.134	0.431	0.400	0.386	0.523	0.538	0.538
Investment and Savings Bank	0.443	0.255	0.249	0.251	0.403	0.454	0.451
Vostok	0.119	0.390	0.348	0.323	0.582	0.574	0.539
VTB	0.047	0.000	0.000	0.000	0.044	0.050	0.004
Idea Bank	0.149	0.572	0.572	0.570	0.713	0.707	0.670
Credit Dnipro	0.199	0.259	0.218	0.195	0.431	0.441	0.417
Credit Agricole Bank	0.342	0.535	0.495	0.469	0.761	0.738	0.700
Credobank	0.224	0.494	0.451	0.426	0.681	0.668	0.632
Megabank	0.015	0.268	0.232	0.231	0.455	0.449	0.444
OTP Bank	0.316	0.551	0.499	0.468	0.730	0.708	0.675
Oschadbank	0.683	0.744	0.628	0.582	0.623	0.472	0.464
Pivdennyi Bank	0.126	0.414	0.366	0.346	0.528	0.527	0.512
PrivatBank	0.900	0.952	0.929	0.919	0.833	0.735	0.829
ProCredit.	0.247	0.519	0.479	0.453	0.709	0.696	0.661
Prominvestbank	0.353	0.406	0.346	0.317	0.599	0.567	0.537
PUMB	0.203	0.424	0.431	0.438	0.498	0.545	0.572
Raiffeisen Bank Aval	0.484	0.663	0.655	0.642	0.953	0.961	0.963
Sberbank	0.369	0.540	0.444	0.424	0.646	0.574	0.566
Taskombank	0.077	0.444	0.416	0.397	0.632	0.628	0.598
UkrGasbank	0.393	0.537	0.482	0.450	0.697	0.662	0.633
Ukreximbank	0.367	0.577	0.514	0.475	0.347	0.366	0.387
UkrSibbank	0.548	0.548	0.482	0.450	0.801	0.752	0.715
Universal	0.288	0.216	0.238	0.243	0.414	0.463	0.461

* authors’ calculations according to the NBU data

As can be seen from the results obtained in different years and for different scenarios for each bank, the value I_{ST_j} can be radically different. For example, according to the baseline scenario and data of the bank, PAK CB “PrivatBank” had the highest value of the indicator, and in the worst case scenario the result deteriorated,

Raiffeisen Bank Aval took the first place in the rating of banks.

Thus, to form a generalized rating for a group of 24 banks, find the average I_{ST} . The results are summarized in table 5 and showed that according to the results of the stability assessment of 2018, PrivatBank, Raiffeisen Bank Aval and UkrSibbank are among the top three banks that

are “ready for shock conditions” and do not need additional capitalization. Other banks (except Sberbank), which are in the top ten of the rating also have no shortage of capital. Oschadbank is in need of 230 million USD in the adverse scenario and according to the restructuring plan should cover until 31.12.2009.

Table 5. Average integral index of stress-testing ($\overline{I_{ST}}$).

Bank	Group	$\overline{I_{ST}}$	Rating
PrivatBank	Banks with a state share	0.871	1
Raiffeisen Bank Aval	Banks of foreign banking groups	0.76	2
UkrSibbank	Banks of foreign banking groups	0.614	3
Oschadbank	Banks with a state share	0.599	4
Credit Agricole Bank	Banks of foreign banking groups	0.577	5
Idea Bank	Banks of foreign banking groups	0.565	6
OTP Bank	Banks of foreign banking groups	0.564	7
Ukrgasbank	Banks with a state share	0.551	8
ProCredit.	Banks of foreign banking groups	0.538	9
A-Bank	Banks with private capital	0.537	10
Credobank	Banks of foreign banking groups	0.511	11
Sberbank	Banks with Russian state capital	0.509	12
Taskombank	Banks with private capital	0.456	13
Prominvestbank	Banks with Russian state capital	0.447	14
PUMB	Banks with private capital	0.445	15
Ukreximbank	Banks with a state share	0.433	16
Alfa-Bank	Banks of foreign banking groups	0.421	17
Vostok	Banks with private capital	0.41	18
Pivdennyi Bank	Banks with private capital	0.403	19
Investment and Savings Bank	Banks with private capital	0.358	20
Universal	Banks with private capital	0.332	21
Credit Dnipro	Banks with private capital	0.309	22
Megabank	Banks with private capital	0.299	23
VTB	Banks with Russian state capital	0.021	24

* authors' own calculations according to the NBU data

According to the NBU, VTB Bank in November 2018 was recognized as insolvent, which is also confirmed by the 24th place in the ranking of financial institutions with almost zero value I_{STj} . The results of stress-testing vary by group of banks. When assessing the quality of assets (asset quality review, AQR), the capital adequacy ratio

decreased only for private banks and banks under the control of the Russian Federation.

Under the baseline scenario, there is an increase in the capital adequacy of almost all groups of banks, but at different rates. Most notably, the capital adequacy of foreign banks is growing. Only for banks with state-owned Russian capital the capital adequacy falls below the limit of 7%. In the adverse scenario for almost half of the banks' capital would be reduced below the limit level.

The total cumulative impact of the hypothetical crisis on fixed capital is almost 9 G.P. of capital adequacy; it is reduced to 3.1% in the three-year forecast period. Under the adverse scenario for banks of all groups, except foreign, there was a decrease in fixed capital.

The most significant reduction was expected in the first year of the forecast period of stress-testing. A slight recovery of capital occurred only in the third year of stress. The depth of capital subsidence due to the hypothetical crisis is almost the same for public and private banks. Due to the high entry-level state-owned banks store an average of positive capital.

At the same time, for private banks, the average level of sufficiency becomes negative (equivalent to 6% of capital adequacy). Also, according to table 5, it can be seen that the top ten of the rating includes 3 banks with a state share, 6 banks of foreign banking groups and one Bank with private capital. At the same time, 3 banks with state Russian capital occupy 12, 14 and 24 places in the rating with a lack of capital for the adverse scenario for a total of about 367.43 million USD.

It should be noted that the need (lack) of capital arises when the estimated values of the banks' standards at least in one of the years of the forecast horizon fell below the established limit levels (7% for the baseline and 3.5% for adverse scenarios).

The capital requirement established by the results of the assessment in the first year of the baseline scenario should be covered by the implementation of the capitalization program until the end of March 2019. The need identified in the adverse scenario is covered by the implementation of the restructuring plans until the end of 2019. The total capital requirement of the banks is 1546.89 million USD, for solvent banks (excluding VTB Bank) – 1274.99 million USD (of which 102.88 million USD should be covered by the capitalization program). So far, the NBU has verified and confirmed the measures of banks in the amount of 551.15 million USD. Some of the activities carried out by the banks at the end of 2018 will be taken into account later, after checking their impact on capital. According to the NBU at the end of 2018, the need decreased to 723.84 million USD. Of the 13 banks completely shut down the capital requirement in the adverse scenario four banks: the PUMB, Universal Bank, Bank “Vostok” and the Sberbank.

Three more banks have more than half completed restructuring plans: Pivdennyi, Alfa-Bank and Oschadbank. Other banks have time until the end of 2019 to fully implement the restructuring plans, which are developed in accordance with the Resolution of the Board of the National Bank of Ukraine dated August 14, 2018 No. 94 “About the features of the assessment of the stability of banks and the banking system of Ukraine in

2018". In case of revealing the lack of capital following the results of the annual assessment of banks' stability taking into account the results of stress-testing under the baseline scenario, banks need to develop a program of additional capitalization.

Thus, banks' compliance with the requirements of the National Bank of Ukraine allows for the results of stress-testing: to create a "safety margin" of the banking system to overcome possible crisis phenomena; to form an understanding of banks' own risks of activity and to stimulate adequate risk management; to discipline all participants of the sustainability assessment process and develop a common understanding of the threats and prospects of the banking system; to increase the level of financial stability; to provide the information security in banking sector.

5 Conclusions and suggestions

According to the results of the study, one of the key methods of macro-prudential policy, which contributes to the effective provision of financial stability and will prevent potential shocks to the banking sector and the country as a whole is macroeconomic stress-testing.

The analysis of the regulatory framework and scientific publications made it possible to clearly identify the approaches, stages, scenarios and the procedure for stress-testing of banks by the National Bank of Ukraine.

By means of modeling of the integrated indicator "stress-testing" (I_{ST}) the data was grouped and generalized assessment of the financial stability of each of the banks was obtained, which in 2018 were subject to the appropriate procedure by the regulator for baseline and adverse macroeconomic scenarios. The analysis of the formed rating showed that according to the results of the 2018 stability assessment, PrivatBank, Raiffeisen Bank Aval and UkrSibbank are among the top three banks "ready for shock conditions" and don't need additional capitalization. Other banks (except Sberbank), which are in the top ten of the rating, have no shortage of capital. Oschadbank is in need of 230 million USD, in the adverse scenario and according to the restructuring plan should cover until 31.12.2009. At the same time, according to the NBU, VTB Bank was declared insolvent in November 2018, which is also confirmed by the 24th place in the ranking of financial institutions with almost zero I_{ST} .

To sum up, the results of the assessment of the stability of 24 banks in Ukraine indicate that the banking sector is sufficiently capitalized, but should increase the margin of safety to strengthen resistance to possible crises. To do this, the NBU is to:

- improve the tools of macroeconomic forecasting, including by expanding the range and modernization of existing models;
- bring prudential requirements for banks in line with EU legislation and recommendations of the Basel Committee on banking supervision;
- deepen the application of risk-based approach in the process of banking supervision, in the licensing procedures of banks;

- regularly conduct stress tests to assess banks in the framework of the SREP;
- limit the concentration of risks by determining capital requirements based on the results of stress-testing and the buffer of systemic risk.

The proposed measures will ensure a stable, transparent and efficient banking system, make it resistant to macroeconomic shocks and systemic risks, bring the liquidity standards of the banking system in line with Basel III and EU Directive/ Regulation (CRD IV/CRR); increase the share of highly liquid assets in the banking system to meet the liquidity standard LCR to 100%, get more transparent prudential requirements for banks, improved Supervisory processes and tools, harmonized with the best approaches of the European Central Bank and the European banking Supervisory authority, improve approaches to the construction of the system risk management in banks, contributing to the improvement of the quality of credit portfolios of banks and increase the profitability of the banking system.

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