Russian Banks Credit Risk Stress-Testing Based on the Publicly Available Data

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Abstract. This paper suggests an algorithm for stress testing of the credit risk of a Russian commercial bank, intended for use by investors and bank customers to assess the bank's financial stability under stressful scenarios. Indicator of bank losses in this work is the indicator "loan loss provision". An algorithm is proposed that describes the bank's cash flows in stressful situations, taking into account the demand function for the loans of the analyzed bank, the bank's availability of the necessary capital to increase the loan portfolio, and the availability of a sufficient amount of liquid funds to cover losses.

Keywords: Stress-testing · Loan loss provision · Cash flow
Financial stability · Credit risk · Investors

1 Introduction

There are many definitions of the concept of stress testing. According to the Bank of International Settlement (BIS), stress testing is "a variety of methods that are used by financial institutions to assess their vulnerability to exceptional but plausible events." The Bank of Russia defines stress testing as an assessment of "the potential impact on the financial stability of a credit institution of a number of specified changes in risk factors that correspond to exceptional but plausible events." According to the International Monetary Fund, stress testing is nothing more than "methods for assessing the sensitivity of a portfolio to significant changes in macroeconomic indicators or to exceptional but possible events" [1]. Stress testing tools have been successfully integrated into the risk management systems of individual banks (microprudential stress testing) and the banking system as a whole in Central Banks (macroprudential stress testing). The final distribution of stress testing was after the financial crisis of 2008, during which many large banks collapsed (for example Lehman Brothers among many others). At now, many international organizations, as well as central banks of many countries carry out stress testing on a regular basis. Thus, European Banking Authority (EBA) on an annual basis, starting in 2011, conducts stress testing of risks of the largest European banks, for example 2011 EU-wide stress test results [2], according to the developed methodology [3]. Basel Committee of Banking Supervision (BCBS) developed the principles of stress testing for individual financial institutions and for supervisory authorities. The US Federal Reserve, since 2009, has been implementing

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the Supervisory Capital Assessment Program (SCAR) annually. In addition, at the legislative level, the Dodd-Frank Act of Stress-Testing (DFAST) according to which stress testing of banks with total capital of more than $10 billion conducted, and the Comprehensive Capital Assessment and Review (CCAR) program, which analyzes the financial condition of banks whose total assets exceed $50 billion. Stress testing is one of the key components of the IMF carrying Financial Stability Analysis Program (FSAP) program, which examines the financial systems of countries [4]. The actual issue is the publication of information on the results of stress testing. A number of authors are advocates of disclosure, while other authors actively oppose [5, 6].

As a rule, stress testing is conducted by the supervisory authorities and the banks themselves to identify the bank's ability to absorb losses in stressful situations. However, the results of stress testing can be useful to investors and clients when choosing a bank for investment, as they give an information of the financial statement of the bank in adverse situations. Thus, for conducting independent stress testing, investors may use only published bank reports. The purpose of this study is to develop an integrated approach to stress testing of the credit risk of a Russian commercial bank on the basis of public bank reporting. Within the framework of this work, the process of developing stressful scenarios is omitted.

The rest of the article consists of the following paragraphs: in the second paragraph gives a brief review of the literature on the methodology of stress testing. In the third paragraph, the data source on the basis of which credit risk stress testing of a Russian commercial bank is described, as well as the limitations in which the results of stress testing are consistent. In the fourth paragraph, a method for modeling indicators is provided. In the fifth paragraph we propose an algorithm for calculating the capital adequacy ratio of a bank. In paragraph 6, the areas for future developments are designated, and in conclusion the main conclusions on the work are indicated.

2 Relation to Literature

In the context of stress testing, one of the fundamental issues is the choice of risk factors, which, if worsened, will check the financial state of the bank. In most cases, under stress testing of credit and market risks, macroeconomic variables act as risk factors [4]. However, a more detailed analysis of the structure of assets and liabilities allows you to identify really stressful indicators. It should take into account the sectoral, regional structure of assets, urgency and sources of liabilities.

For the most part, the methodology of scenario stress testing is based on econometric models, with the help of which the predicted values of the analyzed variables are obtained under certain specified scenarios. Regression models of time series, binary choice models, vector autoregressive model and error correction model, simulation modeling, etc. are applied [7, 8].

Particular attention in the stress-testing is given to the development of scenarios. In work [4], current stress testing methodologies used by international organizations and central banks of developed countries that use only 2–3 stress scenarios and do not evaluate the plausibility of the scenarios criticized. A limited number of scenarios can lead to false positive conclusions, since with the same degree of plausibility of different scenarios, the results of stress testing can vary significantly. Authors classify such methodologies as first-generation stress tests, while second-generation stress tests apply many different scenarios and estimate their plausibility, for example, using the Mahalanobis distance or the Kullback-Leibler divergence. However, this approach can lead to computational difficulties. Therefore, the authors of the article propose an approach for selecting scenarios that satisfy the "Worst Plausible Stress Scenario" principle. In [9], in addition to the Mahalanobis distance, the Bregman distance [10] or *f*-divergence is also proposed, introduced by [11].

Also in the academic literature, indicates the need to take into account the discount rates in the sale of assets. In paper [12] the analysis of the impact of discount factors at stress testing of credit and market risks of small and large banks is given. It is alleged that large banks are forced to sell their assets to the trade book at a discount, in view of large volumes, while small banks are not.

A number of papers [13–15] within the framework of stress testing for the purposes of maintaining capital adequacy, in addition to capital management, also consider the management of the RWA structure necessary. In [12], a hypothesis is proposed that in order to reduce the denominator of the formula for calculating the capital adequacy it is first necessary to sell the assets with the highest risk factor.

3 Data

3.1 Banking Reports

Official public financial reporting is the basis for conducting stress testing of the credit risk of a Russian commercial bank. The data are published on the Bank of Russia website[1]. The following reporting forms are used:

- 0409101 "Balance Sheet";
- 0409102 "Profit and Losses Statement";
- 0409123 "Calculation of own funds (capital) (Basel III)"[2];
- 0409135 "Information on mandatory standards".

Table 1 shows the variables needed to carry out stress testing of credit risk, extracted from the above reporting forms.

The characteristics of credit risk are the portfolios *LLP*s (hereafter *LLP* – Loan Loss Provision). There are two types of portfolios: a consumer loans portfolio, which includes all types of loans granted to individuals, and a corporate portfolio, granted to legal entities. As part of stress testing, it is assumed that the *LLP*s at the time of the beginning of stress testing are formed in full[3]. The peculiarity of the formation of reserves is that a large part of the reserves is formed on the account "45818" of balance sheet. However, the structure of the *LLP*s on loan portfolios is unknown. In this paper,

[1] www.cbr.ru/credit/forms.asp.

[2] Before 01.2014 the form 0409134 "Calculation of own funds (capital)" was adopted.

[3] We also impose other assumptions such as shareholders cannot invest their funds to raise a capital. Securities and bonds are not re-evaluated.

Table 1 Data for credit risk stress testing and their sources

Variable	The reporting form	Designation
Retail loans	0409101	loan_ret
Retail loan loss provision	0409101	llp_ret
Retail overdue loans	0409101	odl_ret
Corporate loans	0409101	loan_corp
Corporate loan loss provision	0409101	llp_corp
Corporate overdue loans	0409101	odl_corp
Overdue loan loss provision	0409101	llp_45818
Corporate deposits	0409101	dep_corp
Funds on corporate accounts	0409101	acc_corp
Individual deposits	0409101	dep_ind
Funds on individual accounts	0409101	acc_ind
Total capital	0409123	cap
Liquid assets	0409135	la
Highly liquid assets	0409135	hla
$H_{1.0}$ capital adequacy ratio	0409135	H1.0
$H_{1.1}$ common equity Tier1 ratio	0409135	H1.1
$H_{1.2}$ common equity Tier2 ratio	0409135	H1.2

it is proposed to divide the *LLP*s formed on the account "45818" by loan portfolios, based on the share of overdue debt for each loan portfolio in the total overdue debt.

$$llp_{i,458} = \frac{llp_{458} * odl_i}{odl_{corp} + odl_{ret}} \quad (1)$$

where

$llp_{i,458}$ – loan loss provision at the "45818" balance sheet item; *i: "corp"* – corporate portfolio, *"ret"* – retail;
res_{458} – loan loss provision, reflected in account "45818";
odl_{corp} – overdue loans of the corporate portfolio;
odl_{ret} – overdue loans on the portfolio of retail loans.

The total volume of *LLP*s for each portfolio is the sum of the *LLP*s reflected in the accounts of each portfolio type and the *LLP* for each portfolio type, calculated by formula (1). The formula for calculating the total amount of provisions for portfolio *i* is presented on the formula (2):

$$llp_{i,all} = llp_i + llp_{i,458} \quad (2)$$

where

$llp_{i,all}$ – total loan loss provision; *i: "corp"* – corporate portfolio, *"ret"* – retail;
$llp_{i,458}$ – loan loss provision, reflected in account "45818" for *i* portfolio;

llp_i – loan loss provision for i portfolio, reflected in correspondent accounts.

3.2 Macroeconomic Variables

Within a proposed framework of credit risk stress-testing macroeconomic variables are chosen as a risk factors. We impose macroeconomic shocks to banks financial stability. To carry out stress testing, the following variables used as variables describing the macroeconomic environment:

- GDP growth;
- consumer price index;
- unemployment rate;
- household income growth;
- mean, standard deviation of RTS index;
- mean, standard deviation of MICEX index;
- mean, standard deviation of USD/RUB currency rate;
- mean, standard deviation of MIACR[4] rate.

The source of macroeconomic data are www.gks.ru, www.finam.ru.

Selected variables well describe a macroeconomic environment from our point of view.

4 Modelling Banking Variables

Modeling of bank indicators within the framework of stress testing is conducted depending on macroeconomic variables. The general specification of the model is as follows (3):

$$y_{j,t} = \beta_0 + \sum_{p=1}^{m} \beta_p x_{p,t} + \varepsilon_{j,t} \tag{3}$$

where $y_{j,t}$ – j banking variable at time t;

β_0 – constant;
$x_{p,t}$ – p macroeconomic variable at time t;
β_p – coefficient for p macroeconomic variable, $p = \overline{1 \ldots m}$, m – total number of macroeconomic variables;
$\varepsilon_{j,t}$ – error term of j banking variable at time t.

Models are estimates using Least Square Estimator (4):

$$\hat{\beta} = \left(x^T x\right)^{-1} x^T y \tag{4}$$

[4] MIACR – Moscow Interbank Actual Credit Rate.

In the case of heteroscedasticity and/or autocorrelation, robust standard errors are used in the residuals (5):

$$\widehat{Var}(\beta|x) = (x'x)^{-1}x'\hat{\Omega}x(x'x)^{-1}$$
$$\hat{\Omega} = diag\left(\hat{\varepsilon}_1^2 \ldots \hat{\varepsilon}_t^2\right) \tag{5}$$

Based on the forecast values of bank variables, stress testing is carried out.

It should be noted that at the stage of modeling indicators, methods of machine learning, neural networks can also be applied. However, the lack of the possibility of interpreting the results of the model, and also, in most cases, the dependence of the final result of the model on the initially chosen point does not allow to fully apply this tool for modeling the indicators. In view of this, the choice of linear regression models is justified.

5 Calculating Capital Adequacy Ratio

In each quarter, the capital adequacy ratio is calculated in the horizon. This procedure is carried out in 3 steps.

At the first step, the capital adequacy ratio is calculated taking into account the necessary addition of *LLP*, the volume of which is calculated on the basis of regression models. The calculation formula is as follows (6):

$$H_{1,k} = \frac{C_k - \Delta llp_{corp} - \Delta llp_{cons}}{RWA_k - cr_{corp} \cdot \Delta llp_{corp} - cr_{ret} \cdot \Delta llp_{ret}} \tag{6}$$

where $H_{1,k}$ – k capital adequacy ratio; k = 0 – total capital, k = 1 – Core Tier 1; k = 2 – Core Tier 2.

RWA_k – risk weighted assets for k capital;
C_k – k capital;
cr_{corp} – risk coefficient for corporate loans portfolio;
cr_{ret} – risk coefficient for retail loans portfolio;
Δllp_{corp} – additional charge of corporate loan loss provisions;
Δllp_{ret} – additional charge of retail loan loss provisions.

In the second step, based on the projected values of the variable resource base, as well as the demand function for the loans of the analyzed bank, the volume of the loan portfolio is calculated. Figure 1 shows the cash flow diagram of the bank that takes into account the inflow (outflow) of the resource base, the demand function for loans, the availability of the necessary capital to meet the capital adequacy requirements and allowances, and the bank's ability to cover the outflows with liquid funds.

The procedure for determining the forecast value of the volume of the loan portfolio is carried out in three stages.

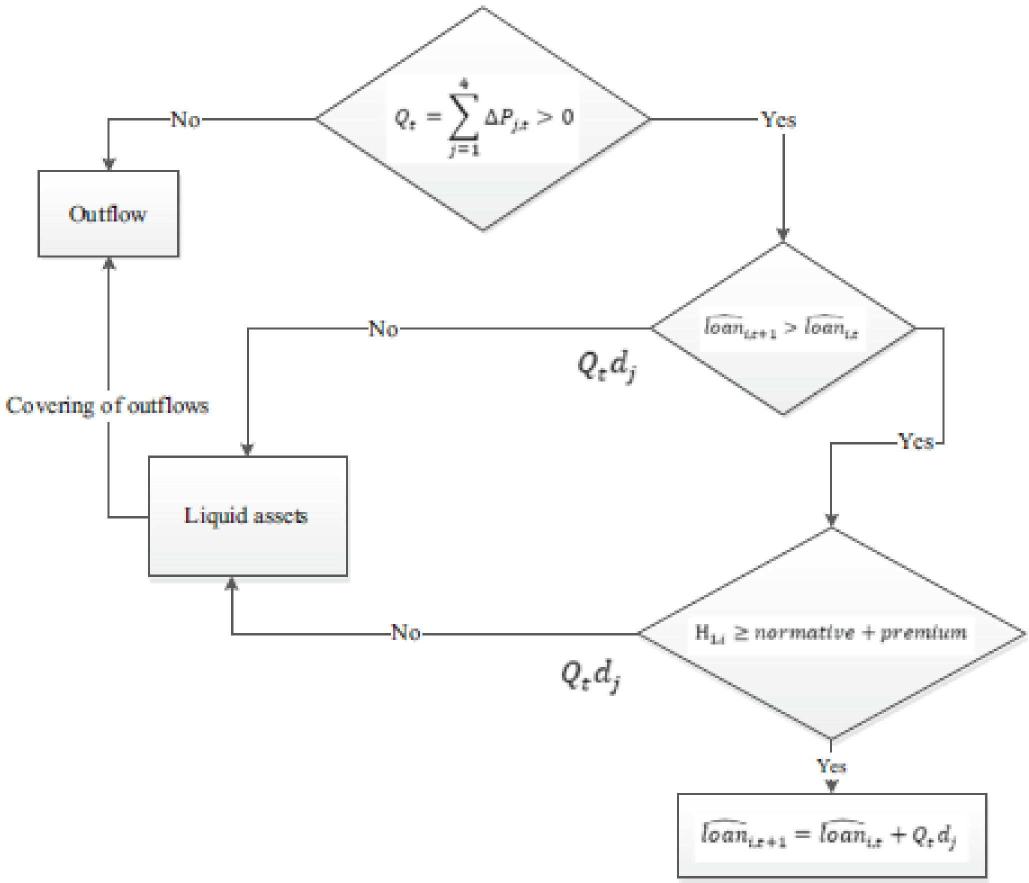

Fig. 1 Cash flow diagram

All investments in assets depend, first of all, on how much the resource base will grow or decrease. At the first stage, the total increment of the variables characterizing the resource base (7) is determined:

$$Q_t = \sum_{j=1}^{4} \Delta P_{j,t} \tag{7}$$

where Q_t – total increase (decrease) of resource base;

$P_{j,t}$ – resource base variable, j = *"dep_corp"*, *"acc_corp"*, "*dep_ind*", "*acc_ind*" at time t. Total number of resource base is 4.
If $Q_t > 0$ then it is necessary to go to the second stage. Otherwise, there is an outflow of funds, which are covered by liquid funds.

At the second stage, using the estimated function of demand for loans, the predicted values of loans is determined. If the forecast value at time $t + 1$ is less than at time t, the surplus is invested in liquid assets proportionally to their part of total assets d_i. Otherwise, go to step 3.

In the third stage, the ability of the bank's capital to meet capital adequacy standards when investing in loans is tested. If there is not enough capital, the surplus is invested in liquid funds proportionally to their part of total assets d_i. Otherwise, it invests in loans proportionally to their part of total assets d_i

In the third step, the capital adequacy ratio is calculated taking into account newly issued loans (8):

$$H_{1,k,t,new} = \frac{C_{k,t,new} - cp_{ret} \cdot \Delta loan_{ret,t} - cp_{corp} \cdot \Delta loan_{corp,t}}{RWA_{k,t,new} + cr_{ret} \cdot \Delta loan_{ret,t} \cdot (1 - cp_{cons}) + cr_{corp} \cdot \Delta loan_{corp,t} \cdot \left(1 - cp_{corp}\right)} \tag{8}$$

where $C_{k,t,new}$ – capital k at time t taking into account additional charge of loan loss provision of existing loan portfolios;

cp_{ret} – provision coefficient of retail loans portfolio;
$\Delta loan_{ret,t}$ – retail loans portfolio increase at time t;
cp_{corp} – provision coefficient of corporate loans portfolio;
$\Delta loan_{corp,t}$ – corporate loans portfolio increase at time t;
cr_{ret} – risk coefficient of retail loans;
cp_{corp} – risk coefficient of corporates loans;
$RWA_{k,t,new}$ – risk weighted assets of capital k at time t taking into account additional charge of loan loss provision of existing loan portfolios.

If the obtained values of capital adequacy ratios are higher than the normative value equal to 8% of risk-weighted assets and mark-ups, it is considered that the bank has successfully passed stress testing of credit risk, otherwise the capital deficit is calculated by formula (9):

$$D = \max\left(norm\text{H}_{1.k} - \text{H}_{1.k,new}\right) \cdot RWA_k \tag{9}$$

where D – capital deficit;

$norm\text{H}_{1.k}$ – normative value of capital adequacy ratio of k capital;
$\text{H}_{1.k,new}$ – predicted value of capital adequacy ratio of k capital;
RWA_k – risk weighted assets of k capital.

6 Future Development Areas

The results of stress testing, in many respects, depend on many parameters that the researcher asks as an assumption. These parameters include risk ratios for loan portfolios, as well as the reserve ratio for new loans. As a further prospect of the study, it is proposed to analyze the sensitivity of the results of stress testing to changes above the indicated parameters. This work does not take into account collateral for loans, which can play an important role in the final result of stress testing. Additional parameters may be the discount factor in the sale of assets, as well as the loan impairment factor for loans.

As a supplement to stress testing of credit risk, liquidity stress testing can also be conducted, the purpose of which is the bank's ability to cover outflows from liquid funds. As part of stress testing of liquidity, discount rates are particularly important when selling liquid funds to cover outflows. Thus, carrying out reverse liquidity stress testing and analyzing the sensitivity of test results to discount rates are becoming an urgent task.

It should also be noted that it is necessary to conduct stress testing using a variety of stressful scenarios to avoid the false illusion of a successful stress test. However, the question arises of analyzing the results of the stress test of many scenarios.

7 Conclusion

Thus, this paper presents the developed multi-stage procedure for stress testing of the credit risk of a Russian commercial bank on the basis of public bank reporting. This approach can be used by investors and creditors to assess the financial soundness of banks in stressful situations. A cash flow model has been developed that takes into account the demand function for the loans of the analyzed bank, the availability of capital for investing in the loan portfolio, and liquid assets. However, the process of developing a stressful scenario remained outside the scope of this work.

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