Decision Making in the System of Assessment and Insurance of Credit Risks

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***Abstract*–The aim of this research paper is to study the system of assessment and insurance of bank's credit risks and develop a task on the assessment of credit risks in banks of the region. To achieve the stated goal, the paper proves the topicality of decision making in formalization and software implementation of credit risk assessment in commercial banks. The theoretical background and practical experience on ensuring the system of credit risk insurance are reviewed; the methodological recommendations on the evaluation and insurance of credit risks of banks on the basis of the task statement, formalization and implementation with use of simulation modeling via the Monte Carlo method are presented. The Russian segment of retail lending keeps growing at a high rate, which is accompanied with a much lower growth rate of household income alongside with a high market competition, which requires more careful attention towards mathematical modelling of the processes of assessment and insurance of credit risks of commercial banks aimed at loss reduction. This provision determines the topicality of the considered problem. The paper states the necessity of objective forecasting of credit risks. The task of credit risk management was set, formalized and implemented in the region's banks through calculation of the value of the required economic capital with account of unexpected risks generated by the bank's loan portfolio. The constituent part of the proposed methodology is rating of bank's borrowers on the basis of the model of rating functionality dependence on the factors characterizing different aspects of the borrower's activity (financial and economic analysis), which determine the current credit score of a borrower and hardly formalized characteristics of the borrower's risks, which identify the financial capability (qualitative analysis).**

Keywords*–*credit risks of banks, simulation modeling, Monte Carlo method, risk management

I. INTRODUCTION

The binding principle of assessment and management of risks, first of all the credit risk as the most important risk in the banking business, is the founding principle, which ensures the stability of the world banking system. The task of adequate assessment of the credit risk is a priority direction of modern banking risk management. In accordance with the requirements of the international banking standards fixed by the Basel Accords, the capital stock of a bank should meet the risks of its business [10].

The credit risk level determines the adequacy of the bank's own capital and the volume of set-up provisions for possible loan losses. At the moment the national bank standards in Russia are being made consistent with the Basel II in part of possible evaluation of credit risks on the basis of internal rating methodology of banks, which determined a considerable development of the institute of complex (rating) estimates of credit risks. The above-said conditioned the significant development of the tool for credit risk assessment [12, 13, 16, 18].

However, despite the efforts directed by the bank community to the evaluation and management of credit risks, the statistical data of the Bank of Russia demonstrate a considerable growth of the share of "bad" loans (4th and 5th quality categories – troubled and unrecoverable ones) in the structure of a loan portfolio of Russian commercial banks. The quantity of "bad" loans in 2018 in Russia increased by 6%, up to 12.4 million items, the highest increment was demonstrated by mortgage loans, POS-credits, credits by cash and credit cards, as testified by the data of the United Credit Bureau.

According to the Credit Bureau, the quantity of loans overdue by more than 90 days according to the results of the previous year increased by 6% up to 12.4 million units. The highest increment was shown by mortgage loans, the quantity of 'bad' loans increased by 13% and was less than 62 thousand items. The second position was occupied by POS-credits: the quantity of overdue loans in this segment increased by 10% up to 1.75 million items. On the whole, the dynamics of bad debts in 2019 will depend on two factors – the total economic situation through the year and the growth rate of credit lending.

In case of economic slowdown, many borrowers that got loans in 2018 will fail paying towards loans, then the growth rate of 'bad debts' could be high, and in the background of loan growth rate reduction, which is expected due to the increase of an interest rate, the share of 'bad' loans will also grow [14, 3].

The specificity of the banking segment in RF is expressed in a high level of territorial and institutional concentration, which conditioned the development of the banking services market due to large crediting organizations with a center in Moscow and a wide network of branch offices in regions. The developed regional branch network conditioned the necessity in improving the methods of evaluation of credit risks in the regions of Russia as a determinant risk of the banking business.

The adequate comprehensive assessment of the regional credit risk ensures the relevance of decision making in economically heterogeneous territorial conditions of branches' activities, forms the tools to control the spatial structure of the national banking system, which serves as the basis for increasing the efficiency and stability of the banking system of Russia. Insufficient theoretical development of the issue of regional credit risk assessment of the banking business and its high practical value confirm the urgency of the chosen research direction [11,16].

The aim of the research paper is to study and develop the methodological principles and practical recommendations on the problem solution on the assessment and insurance of credit risks of banks using the simulation modeling via the Monte Carlo method.

To achieve the set goal, the following tasks were fulfilled:

-statement of the need for objective forecasting of credit risks;

-analysis of the definition of the system of credit risk management in commercial banks;

-analysis of the methodological support of the assessment and management of credit risks of banks;

-development of methodological recommendations on the evaluation and management over credit risks of banks with the help of simulation modeling.

II. MATERIALS AND METHODS

The transition of the world banking system to the standards of Basel III was implemented gradually in the period from 2013 to 2018. The adaptation of Basel Accords to the peculiarities of the country banking systems is performed by the national regulators. At the moment in Russia of all the approaches envisaged by the Basel Accords to the assessment of credit risks, two approaches are recognized by the Central Bank of RF to be used:

1) simplified standardized approach, in accordance with which the coefficients of assets weighing by risks – 100%, 50%, 20%, 150% and others - are set by the regulator for all banks;

2) for derivative financial instruments and repo operations - the so-called “comprehensive” approach, which envisages a special order of accounting of the collateral via the discount system. The standardized approach based on the evaluation of credit risks by external rating agencies was not applied in Russia. The causes are historical underdevelopment of the system of functioning of rating agencies and extremely insignificant number of borrowers that passed the procedure of independent credit rating.

The IRB approach is introduced in parallel with the existing simplified standardized approach to the assessment of the credit risk at the moment in the Russian banking system. The conditions of IRB-approach application is meeting the requirements towards the sizes of bank assets, minimal quantitative and qualitative requirements to internal models of the assessment of credit risks and requirements to the system of risk management in the bank on the whole.

At the moment the Bank of Russia develops the regulatory system in this direction. The IBR-approach is planned to be introduced in Russia, which in the whole volume meets the Basel standards, with the aim of total harmonization of national standards with international standards of regulation. Today a number of largest banks in Russia has announced on the wish to use internal credit ratings to assess credit risks.

In accordance with the threshold that allows using the IRB-approach by banks with an assets value of over 500 billion roubles, at the moment the IRB can be introduced by about 20 largest Russian banks, including Sberbank, VTB BankofMoscow, Gazprombank, VTB24, Rosselkhozbank, AlphaBank, UniCreditBank, Promsvyazbank, Reiffeisenbank, Rosbank. The permission to use the IRB approach will be issued by the Bank of Russia to the banks that wish to use internal rating systems in their business proceeding from their evaluation by the regulator. On the whole the development of approaches to the assessment of credit risks has passed a long way of development. Modern trends in the evaluation of credit risks by banks demonstrate a considerable development of the institute of risk rating, which requires the Russian banks to step up actions towards the development of their own methods of evaluation.

The theoretical and methodological background of the research is concepts and hypothesis of Russian and foreign researchers in the field of finances, management, banking business and credit risk management. A lot number of Russian and foreign works is dedicated to the studies on the problem of credit risk management in banking business. T.U Koch, R.M.V. Bass, K.D. Walraven, R.S. Porter, P.S. Rose, S. Frost et al are among foreign authors dealing with bank risks in the banking business. Main Russian works belong to O.N.Antipova, I.T. Balabanova, O.I. Lavrushina, Y.S. Maslenchenkova, G.S. Panova, M.A. Pomorina, V.T. Sevruk, N.E. Sokolinskaya and other researchers.

Mainly risk issues from the point of view of the theory of finances, credit lending and currency circulation are considered in their works. Nevertheless, the study of modern priority directions of the banking business urges to search for new ways in implementation of tasks of credit security and predetermines the comprehensive use of the theoretical heritage of foreign and Russian researchers for objective knowledge of this management process.

Theissuesofmathematicalmodelingofcreditriskassessment areconsideredintheworksbythefollowingRussianandforeignre searchers: F.T. Aleskerov, I.K. Andrievskaya, S.V. Ivliev, V.A. Letchikov, G.I. Penikas, V.P. Pervadchuk, M.V. Pomazanov, WeberSh., Olaf F., Eichmeier V., Oplotnik Z., YukunLi, XiaofengJu, and others.

WeiRanconsidersthemodelofevaluationofcreditrisksofco mmercialbanksofChinawithuseofthefuzzyanalysis [9]. WangZhenandSunWenjuanusethesupportvectormachinestoas sesscreditrisksofbanks,theresultsoftheirstudieswithuseofthefu zzyintegralsupportvectormachinesaresuccessful [7]. Decision trees are identified among the methods of credit risks assessment. Wei Guo, Song Yingjie, Mu Yan Xi consider the system of credit risk assessment in their work. The system consists of five aspects, each of which includes 25 indicators.

Theirmodelbuiltwiththehelpofthedecisiontreemethodbase donthisprovisionshowstheaccuracyoftheforecastingandreliabi lity [8]. A number of works by de Graaf, C.S. L., Feng, Q., Kandhai, B.D., and Oosterlee, C.W. is dedicated to the evaluation of counterparty credit risks with the help of Monte Carlo method [1, 2]. Basel III regulates the changes in the capital calculation to cover the counterparty credit risk with derivative operations, repo transactions and asset securitization transactions. The document determines the approach to evaluation of this kind of risk through the CVA

(Credit Value Adjustment) [1, 2].Despite the significant atten tion paid tothecreditriskandsufficientpracticalandtheoreticald evelopmentof the problem of its assessment at the microlevel, the issue of comprehensive assessment of the credit risk of banking activity in RF regions still remains insufficiently studied. The urgency of the issues considered in the paper, their insufficient theoretical and methodological development and considerable importance to ensure the stability and efficiency of functioning of the national banking system conditioned the choice of the topic, goal and tasks of the studies.

III. RESULTS

The bank's main risks can be clearly divided into three types, and the credit risk is of major importance. This is directly connected to the fact that loan granting is the basis of the banking business.

One of the key requirements of the Basel Committee (Basel II) is to provide the consistency of the bank capital with its risks that need to be defined in order to formulate the requirements to the capital ensuring the bank security. However, such a fact as a default of single credits will not do severe damage to the bank, if it could be compensated by the reserves allocated for potential losses on credit operations. In addition, there is a certain probability of losses of such a large part of assets in the loan portfolio that this would result in the bank's bankruptcy.

The predictability of credit risks is one of the important terms of efficient management of the commercial bank's capital. The simulation modeling is considered as a very promising tool of risk modelling.

Let us define the objectives of modelling. The maximum probable losses with a specified probability (credit risk) should be estimated.

Let us consider the conceptual model of the system.

1) inputs of the system:

- the number of periods under report (dimension of loan vectors, expected returns and level of losses in case of default);
- the vector of loans by periods for which they were granted $\overline{S}$;
- the vector of expected returns $\overline{\alpha}$;
- the vector of losses level in case of default $\overline{\beta}$;
- the vector of default probability $\overline{p}$ for the components of the loan portfolio. It is calculated according to the formula: $p(t) = 1 - e^{-\lambda t}$;
- the number of tests K;

2) outputs of the system:

- the risk assessment;
- the profit assessment;
- the loss assessment.

The next stage is the formalization of the model. The preparation of the initial data includes collection and processing of the data on the structure of the loan portfolio.

When analyzing the bank's loan portfolio, the rating assignment of loan debtors should first be conducted in order to integrate them into peer groups in accordance with the probabilities of a default.

The task of calculation of the probability of default of a loan debtor is one of the main and challenging problems in risk assessment. Two approaches to calculation of the loan debtor's default are commonly defined. The first one is based on the quantitative and qualitative assessment of the loan debtor's rating on its internal financial indicators and specific business factors. The latter is based on the loan debtor's capitalization in the stock market and the level of its debts to the lenders. Unfortunately, the second approach, being the most objective one, is applicable to a small number of Russian public companies. That is why it is reasonable to apply to the first approach.

The methodologies of such established agencies as Standart&Poors, Fitch have been analyzed and the standard methodology of rating of the bank's loan debtor has been developed on their basis.

The model of rating functions dependence on the factors characterizing different aspects of the loan debtor's activity is used to determine the rating assessment. Financial and economic indicators of the loan debtor's activity (financial and economic analysis), which define the current capacity to pay and the hard-to-formalize risk profile of the loan debtor determining its financial sustainability (qualitative analysis) are considered as the factors.

The main sources of data for financial analysis are the loan debtor's sub-ledger account balance sheets, off-balance-sheet data, fixed-term operations, profit and loss statement, auditor's report, annual report and other materials containing financial information.

The key sources of data for qualitative analysis of the loan debtor's activity are legal data including charter documents, licenses, articles of association and other documents, marketing information, also annual reports, promotional materials, media and news agencies materials, questionnaire materials and interviews with management staff.

The procedure of determination of the loan debtor's credit worthiness is based on the principle that at certain figures of some basic financial and economic indicators of the company's activity the loan debtor belongs to the rating group A, B, C or D. The assigned rating of the loan debtor within the group is defined by analysis of additional financial and economic and qualitative indicators of the company's activity.

The rating class defines clearly the financial state of the loan debtor and the quality of its risk management. Depending on the level of credit worthiness loan debtors are divided into four classes A, B, C and D. A, B and C classes are subdivided into several subclasses depending on the indicators of credit worthiness, financial sustainability and forecasts of economic development. Finally, the loan debtor can be assigned a relevant rating. If granted loans are divided by periods (up to 1 month, 1-3 months, 3-6 months, 6-12 months, 1-3 years and more) and by groups of loan debtors, there is a matrix – loan portfolio of the bank.

The important subtask of simulation modeling is generation of random numbers or pseudo-random numbers with predetermined distribution law (execution time of main production operations). For formation of pseudo-random numbers with the predetermined distribution law, the initial material is pseudo-random numbers uniformly distributed in the interval from 0 to 1. In this case X_i, as a possible value of the random variable ξ, having a uniform distribution from 0 to 1, can be converted into the possible value Y_i, of the random number η with the predetermined distribution law. There are two methods of conversion of pseudo-random numbers:

1) direct (some operation is implemented over the number X_i, this operation forms the accurately or approximately predetermined distribution law);

2) modeling of the conditions corresponding to the limit theorem of the probability theory.

The following statement is important for the first method, as in (1).If the random number η has the density of distribution $f(y)$, then the distribution of the random number is ξ, where

$$\xi = \int_{-\infty}^{\eta} f(y)dy \tag{1}$$

is a uniformly distributed one in the interval from 0 to 1.

Based on this theorem in order to obtain the sequence of n numbers $\{Y_i\}$ it is necessary to calculate n equations with regard to Y_i, a sin (2).

$$\int_{-\infty}^{Y_i} f(y)dy = X_i \tag{2}$$

As an example, as in (3) and (4) formulas for generation of pseudo-random numbers distributed according to demonstrative and normal distribution law.

$$Y = -\frac{1}{\lambda} \cdot \ln(1 - X), \tag{3}$$

$$Y = m + \sigma \cdot \left(\sum_{i=1}^{12} X_i - 6 \right). \tag{4}$$

The following algorithm is applied to model a discrete random variable. Let it be necessary to simulate a discrete random variable with distribution law. Z is a non-discrete random, uniformly distributed variable in the interval of $Z \in [0;1)$ .Then Y - a discrete random variable with the above mentioned distribution law– is calculated as in (5) and (6).

$$Y = \begin{cases} b_1, Z \in [0;\pi_0) \\ b_2, Z \in [\pi_0;\pi_1) \\ b_3.Z \in [\pi_1;\pi_2) \\ \ldots \\ b_m.Z \in [\pi_m;1) \end{cases}, \tag{5}$$

$$\pi_i = \sum_{k=0}^{i} p_k \tag{6}$$

The fourth stage (software implementation of the model) is implemented in the mathematical package MathCAD 2000 PRO. The algorithm of calculations is the following:

1) input of initial data;

2) performance of computer tests;

3) statistical processing of test results, receiving assessments of risks, profits, losses.

All the subsequent stages are presented below.

If the loan portfolio is the matrix $S = \|s_{t,j}\|$, where $s_{t,j}$ - is the size of j loan ($j = \overline{1,m}$), granted for a period of t. t is the index of loan group by its period. The conformity of the index to the actual period is shown in Table 1.

TABLE 1. CONFORMITY OF THE INDEX TO THE LOAN'S ACTUAL DURATION

t, **index**	**Duration, months**	**Average duration, months**
1	Up to 1	0.5
2	1-3	2
3	3-6	4.5
4	6-12	9
5	12-36	24

Each loan corresponds to a rating assessment of the lending agency, which is the probability of default $r_{t,j}$. However the rating assessment does not take into account the effect of period of loan granting. That is why it is necessary to calculate the generalized probability of default. The generalized probability of defaults for groups of loans as in (8).

$$r'_t = \frac{1}{m} \sum_j r_{t,j} q_t, \tag{8}$$

where q_t is the temporary element of the default risk (includes the time factor – a longer period leads to a higher risk and it is calculated by the formula $q_t = 1 - e^{-\lambda t}$). The characteristics of loan groups are vectors of expected returns $\overline{\alpha}$ and the level of losses in case of default $\overline{\beta}$ (Table 2).

A random variable uniformly distributed in the interval from 0 to 1 is generated in the modeling. If it is lower than the probability of default, the default scenario is implemented, and the losses are calculated the following way $U_t^k = S'_t \cdot \beta_t$, otherwise the profit is calculated by $P_t^k = S'_t \cdot \alpha_t$.

TABLE 2. CONSISTENCY OF THE INDEX AND ACTUAL LOAN PERIOD

index	Expected income, % per annum	Level of losses in case of default, %
1	1.1	100
2	5.6	100
3	10.6	100
4	12.5	100
5	11.5	100

Then the consolidated profit and losses are calculated by the k -the experiment as in (9) and (10).

$$U^k = \sum_t U_t^k , \tag{9}$$

$$P^k = \sum_t P_t^k . \tag{10}$$

These values are random ones. Their characteristics are calculated in minimum and maximum values as in (11), (12), (13) and (14).

$$P_{\min} = \min_k P^k , \tag{11}$$

$$P_{\max} = \max_k P^k , \tag{12}$$

$$U_{\min} = \min_k U^k , \tag{13}$$

$$U_{\max} = \max_k U^k . \tag{14}$$

Variation range as in (15) and (16).

$$RP = P_{\max} - P_{\min} , \tag{15}$$

$$RU = U_{\max} - U_{\min} . \tag{16}$$

The space between the maximum and minimum values is divided into ranges, and the frequency of a random value hitting the given range is calculated. the numerical characteristics of random values are calculated: mathematical expectation as in (17, 18).

$$M[P] = \frac{1}{K}\sum_{k=1}^{K} P^k , \; M[U] = \frac{1}{K}\sum_{k=1}^{K} U^k ; \tag{17,18}$$

Dispersion is calculated as in (19) and (20).

$$D[P] = \frac{1}{K}\sum_{k=1}^{K}\left(P^k - M[P]\right)^2 , \tag{19}$$

$$D[U] = \frac{1}{K}\sum_{k=1}^{K}\left(U^k - M[U]\right)^2 . \tag{20}$$

Mean-square deviation can be calculated as in (21, 22).

$$\sigma[P] = \sqrt{D[P]} , \; \sigma[U] = \sqrt{D[U]} ; \tag{21,22}$$

Variation factor is described as in (23) and (24).

$$CV[P] = \frac{\sigma[P]}{M[P]} , \; CV[U] = \frac{\sigma[U]}{M[U]} . \tag{23,24}$$

Only the mathematical expectation and variation factor are used finally.

Frequency diagrams and empirical distribution function (on the basis of cumulative frequency) are plotted. Confidential intervals are determined with their use.

The number of experiments was chosen of the terms as in (25).

The implementation of the task has been performed in the mathematical package MathCAD 2000 PRO.

The first stage includes the input of the initial data.

The second stage involves simulation modeling (Simulink procedure) and calculation of numerical characteristics of the random variable (mathematical expectation, dispersion, mean square deviation and variation factor).

$$\begin{cases} \dfrac{\left|M[U]^{N_1} - M[U]^{N_2}\right|}{M[U]^{N_2}} \le \varepsilon \\ \dfrac{\left|M[P]^{N_1} - M[P]^{N_2}\right|}{M[P]^{N_2}} \le \varepsilon \\ \dfrac{\left|CV[U]^{N_1} - CV[U]^{N_2}\right|}{CV[U]^{N_2}} \le \varepsilon \\ \dfrac{\left|CV[P]^{N_1} - CV[P]^{N_2}\right|}{CV[P]^{N_2}} \le \varepsilon \end{cases} \tag{25}$$

Where N_1, N_2 - the number of experiments.

It is known from the probability theory, that at $N \to \infty, \varepsilon \to 0$ (Table 3). It was determined that the required accuracy was achieved at $N = 4000$. At this number of experiments the error was 0.001 and less.

TABLE 3. NUMERIC CHARACTERISTICS OF THE RANDOM VALUE AT DIFFERENT NUMBER OF EXPERIMENTS

Number of experiments	Losses		Profit	
	M	***CV***	***M***	***CV***
500	0.373	2.995	1.422	0.182
1000	0.404	2.948	1.415	0.193
2000	0.364	3.019	1.418	0.178
4000	0.365	3.021	1.419	0.177
8000	0.364	2.02	1.418	0.177

The third stage includes statistical processing of the test results. The analysis of the histogram of the profit frequencies allows concluding that the profit varies slightly in the obtained range. This is proved by the low coefficient of profit variation – 0.177. The mathematical expectation of the profit of 1.419 million rubles is the projected value of the profit of the loan portfolio. If there is no default, the profit is calculated as in (26).

$$\sum_{t,j} \alpha_t S_{t,j} . \tag{26}$$

In this case the value is 1.493 million rubles. Therefore, the level of reserves is 1.493 - 1.419 = 0.074 million rubles.

The losses vary greatly. The mathematical expectation of losses is 0.356 million rubles, the coefficient of variation is 3.081.

The analysis of the obtained values allows to conclude that with the acceptable probability of 0.95 the maximum possible amount of losses can be taken as 0.84 million rubles. That means the value of reserve for the potential losses on loans is 0.84 million rubles.

The amount of the required capital is calculated as the difference between maximum possible losses and formed reserves (0.84 – 0.074 = 0.76 million rubles).

IV. Conclusion

Thus, the paper presents the statement, formalization and implementation of the task of credit risk management in the region's banks through the calculation of the value of required economic capital with account of unexpected risks generated by the bank's loan portfolio. The constituent part of the proposed methodology is rating of bank's borrowers on the basis of the model of rating functionality dependence on the factors characterizing different aspects of the borrower's activity (financial and economic analysis), which determine the current credit score of a borrower and hardly formalized characteristics of the borrower's risks, which identify the financial capability (qualitative analysis).

Mathematical models (simulation modeling via Monte Carlo method) were used during modeling of a large number of different default scenarios. On the basis of the obtained results of simulation modeling of numerical characteristics of the random variable (loss and profit) (mathematical expectation, dispersion, mean square deviation and variation factor), the value was calculated as the difference between the maximum possible losses and formed reserves for possible loan losses (calculated on the basis of mathematical expectation of losses).

The practical value of the proposed method is that it allows recalculating the unexpected credit risk of the loan portfolio and every borrower into direct costs of the economic capital on the risk. This provides additional and convenient tool to analyze the credit risk value.

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