“Defining the probability of bank debtors’ default using financial solvency assessment models”

AUTHORS	Yana Kuznichenko https://orcid.org/0000-0003-0815-4939 http://www.researcherid.com/rid/I-8869-2018 Mariia V. Dykha http://orcid.org/0000-0003-4405-9429 Natalia Pavlova http://orcid.org/0000-0002-1572-4648 Serhiy Frolov https://orcid.org/0000-0001-9374-7274 http://www.researcherid.com/rid/C-1635-2018 Olha Hryhorash https://orcid.org/0000-0002-8089-3755 https://publons.com/researcher/1976980/olha-v-hryhorash/

ARTICLE INFO	Yana Kuznichenko, Mariia V. Dykha, Natalia Pavlova, Serhiy Frolov and Olha Hryhorash (2018). Defining the probability of bank debtors’ default using financial solvency assessment models. *Banks and Bank Systems*, *13*(2), 1-11. doi:10.21511/bbs.13(2).2018.01
DOI	http://dx.doi.org/10.21511/bbs.13(2).2018.01
RELEASED ON	Friday, 25 May 2018
RECEIVED ON	Wednesday, 28 March 2018
ACCEPTED ON	Thursday, 17 May 2018

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
27	2	3

BUSINESS PERSPECTIVES

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

www.businessperspectives.org

Yana Kuznichenko (Ukraine), **Mariia V. Dykha** (Ukraine), **Natalia Pavlova** (Ukraine), **Serhiy Frolov** (Ukraine), **Olha Hryhorash** (Ukraine)

DEFINING THE PROBABILITY OF BANK DEBTORS' DEFAULT USING FINANCIAL SOLVENCY ASSESSMENT MODELS

Abstract

Due implementation of debtors' financial solvency assessment models by Ukrainian banks with the aim of calculating the probability of their default (PD) is the next step towards the integration of Ukrainian banking system into global banking community, convergence of methodical approaches to assessing the credit risk with standards of international practice, possibility of using IRB-approach (an approach based on internal ratings) for calculating the regulatory requirements to capital adequacy.

The analysis of approaches to bank credit portfolio segmentation according to types of debtors and debtors' financial solvency assessment models, depending on the performed segmentation and accumulated bank statistical data, from the point of view of its suitability for Ukrainian banks, will enable the banks to choose the most suitable ones for implementation taking into account nature and complexity of operations performed.

Such approaches will be more adapted to minimum capital requirements, simultaneously agreeing with national supervisory priorities.

Keywords credit portfolio segmentation, probability of default (PD), heuristic, statistical, and causal financial solvency assessment models

JEL Classification G21, G32, G33

Received on: 28th of March, 2018
Accepted on: 17th of May, 2018

Yana Kuznichenko, Chief Expert of the Methodology Department, National Bank of Ukraine, Ukraine.

Mariia V. Dykha, Doctor of Economics, Professor, Professor of the Department of Economics of Enterprise and Entrepreneurship, Khmelnytsky National University, Ukraine.

Natalia Pavlova, Ph.D. (Law), Senior Lecturer of the Department of Criminalistics, Forensic Medicine and Psychiatry, State University of Internal Affairs, Ukraine.

Serhiy Frolov, Doctor of Economics, Professor, Head of the Department of Finance of Business Entities and Insurance, University of Customs and Finance, Ukraine.

Olha Hryhorash, Ph.D. (Economics), Senior Lecturer of the Department of Finance of Business Entities and Insurance, University of Customs and Finance, Ukraine.

INTRODUCTION

Risk management methods and procedures, used by European banks, are being constantly improved and developed based on approaches and standards of Basel Committee on Banking Supervision, in particular internal assessment of parameters of losses such as debtors' probability of default (PD), loss given default (LGD) and exposure at default (EAD) (National Bank of Ukraine, 2018; Bank for International Settlements, 2005; Bank for International Settlements, 2015).

Integration of the Ukrainian banking system into the world banking community, the need for ensuring the banking system reliability and prevented capital losses require the further approximation of methodological approaches to credit risk assessment to the Basel Committee on Banking Supervision principles and recommendations (National Bank of Ukraine, 2018; Bank for International Settlements, 2005; Bank for International Settlements, 2015), Regulation of the European Parliament and the Council dated June 26, 2013, No. 575/13 (National Securities and Stock Market Commission, 2016), as an integral component of implementing the Ukraine-EU Association Agreement ratified by the Law of Ukraine "On Ratification of the Association Agreement between Ukraine and the European Union, the European

Atomic Energy Community and their member states, on the other hand" as from September 16, 2014 No. 1678/VII (LigaZakon, 2014), and advanced international practice.

The proper implementation of debtors' solvency assessment models by Ukrainian banks to calculate their default probability (PD), which is in line with advanced international practice, will allow the banks to get close to their IRB approach (internal ratings approach) to calculate regulatory capital adequacy requirements.

1. LITERATURE REVIEW

Matters related to approaches to assessing the debtors' solvency, the construction of models for calculating the probability of defaulted debtors (PDs) and their embedding into the bank's risk management system, including credit, are addressed by both Ukrainian and foreign scientists.

In addition, companies providing audit, taxation, consulting, corporate finance, and risk management services focus on the issues of solvency model development.

So, the Deloitte experts (Deloitte, 2016) developed the main methodological steps for creating a credit scoring model that outlines various ways of measuring the model performance (capacity and predicted power) and provides some typical specifications that help to improve it and to interpret the model in a proper way. The purpose of the credit scoring model is to classify borrowers into "good" and "bad". In practice, this means that statistical models are needed to identify a dividing line between the two categories within explanatory variables.

Edward (2012) emphasizes the negative consequences of a lack of corporate credit rating or credit bureau, which means that the bank remains dependent on its own internal data to verify the credibility of the borrower's data, which is why the ratings for the borrower conflict with other lending institutions. The authors developed a methodology based on logistic regression modeling of corporate credit, which does not require cross-referencing data.

Shkodra and Ismajli (2017) analyze the components of bank credit risk in developing countries, in particular Kosovo. The research covers seven commercial banks for the 2006–2015 period. The effect of variations in credit risk exposure determinants is based on the use of a multidimensional panel regression model. The empirical results obtained show significant links between credit risk and variables such as ROE and ROA, inefficiency (IE), loan-to-deposit ratio (LDR), credit growth (CG) and deposit rate (DR); at the same time, variables of solvency (SR) and credit rate (CR) are not statistically significant in terms of credit risk.

Gurný and Gurný (2013) assessed the default probability of American banks through statistical models of credit scoring. Given the considered models with the use of linear discriminant analysis and regression models and taking into account the statistical significance of the estimated parameters, the authors analyzed the sample of three hundred US commercial banks, which are divided into two groups (with and without default) based on historical information. Subsequently, scoring models were applied to this sample to obtain several models for assessing the default probability and determine the most appropriate model.

Genriha and Voronova (2012) classify all methods for assessing credit risk, reveal all the technical problems of the application of each method in practice, and try to evaluate which method is better. The authors use a comparative analysis to show that, in addition to the most popular parametric methods of regression and discriminatory analysis, nonparametric methods can be also used. The analysis is considered based on the assistance to banks in Latvia in preventing default risks.

Blanco-Oliver et al. (2016) also develop a mixed bankruptcy model, combining parametric and non-parametric approaches that utilize logistic regression (LR) to identify bankruptcy. Next, alternative non-parametric methods are used for companies classified as "bankrupt" or "not bankrupt". The results show that mixed models provide better performance and accuracy interpretation.

Abdou, El-Masry, and Pointon (2007) conducted a somewhat similar analysis. They assess credit risk in Egyptian banks through lending models. Three statistical methods were used: discriminatory analysis, probit analysis and logistic regression. Credit scoring is based on personal loans of one bank. The results showed that all proposed models gave a better average correct classification than one used. The expenses for incorrect classification in the event of type I and II errors are also estimated.

Al-Shawabkeh and Kanungo (2017) investigated the credit risk of individual borrowers of Jordanian banks. The authors analyzed 2,755 incomplete or inactive profiles of individual loans received from Jordanian banks during the years 1999–2014. The results show that low wage loans for the unemployed are very likely to become defaulted and contribute to non-fulfillment of credit obligations by increasing the risk of lending. In addition, it has been found that unmarried, younger borrowers and a moderate amount of credit increase the likelihood of receiving bad loans. On the contrary, borrowers employed in the private sector and undereducated ones, most likely, mitigate the credit risk.

Bunker, Naeem, and Zhang (2016) investigated how the characteristics derived from bank statements issued by applicants for loans and not claimed as an application could improve the loan scoring model for a New Zealand loan company. The authors constructed two models: a base model (based solely on existing evaluation functions obtained on the loan application form) and a model based on data obtained from the bank statement. Based on two models, a combined functional model is created. The experimental results show that the combined functional model works better than each of the two basic models, and some of the bank's functions are important for improving the loan scoring model.

Borio (2011) notes that the financial crisis has led to a significant rethinking of analytical approaches and policies on financial stability, while stressing that the detection of macroeconomic roots of financial instability is underdeveloped.

Wezel et al. (2012) examine the impact of various methods of ensuring the banking services reliability, and show that this increasingly popular macroprudential tool can smooth out the cost of servicing the credit cycle and reduce the likelihood of bank default.

Maarse (2012) analyzes Rabobank International's risk management approach to improve the current loss given default (LGD) and exposure at default (EAD) analysis and develops proposals for Rabobank International.

The British Commission for Banking Regulation (Supervisory Statement, 2013) proposed approaches to the analysis of credit risks based on internal ratings.

Tasche (2008) offers a variety of tools for measuring and testing the discriminatory power of the rating system and for testing the correct classification.

In particular, Tereshchenko (2012) investigates the procedure for determining the risk indicator for a loan granted to a legal entity using a unified rating system for debtors, which is proposed for use by a national regulator for the entire banking system. The author notes that the use of the IRB-approach by banks, which is provided for by the Basel Committee on Banking Supervision, should be the next stage in reforming the Ukrainian banking regulation system. One of the steps of this reform is, in particular, a study on the assessing the debtors' solvency models, which are most suitable for use by Ukrainian banks.

Kovalenko and Nenad (2017) pay attention to the methods of credit risk management, its influence on ensuring the solvency of banks, offer directions for improving the work with problem loans as a method of credit risk management.

Dolinskyi (2016) analyzes the current trends in assessing the bank's credit risk, examines the basic indicators that characterize the lending activity of banks and the level of riskiness.

Sofronova (2016) and Karminskyi (2012) consider the issue of analyzing the solvency of debtors using rating systems to differentiate debtors by level of risk based on assessing the debtors' default probability, investigate the effect of financial fac-

Source: Compiled by the authors.

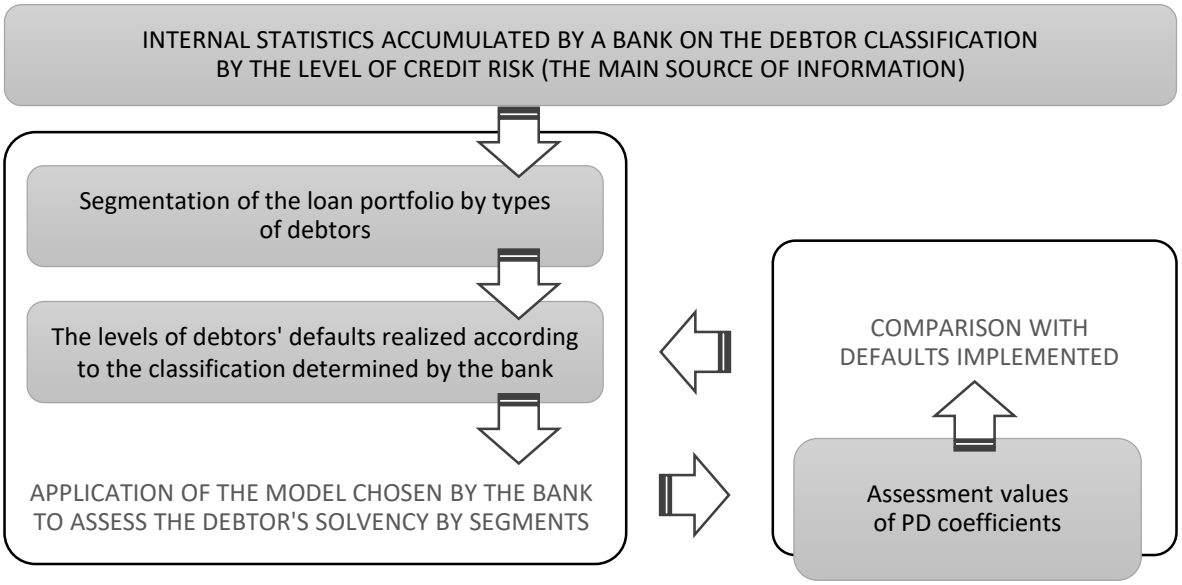

Figure 1. The main stages and the flow of determining the debtors' PD coefficients

tors on the default probability, paying particular attention to expansion of the research horizon and to nonlinear variables

Kazanskyi (2016) analyzes the theoretical background for building rating systems of banks in terms of consistency with Basel standards, examines both the simplest internal ratings and more complex mechanisms of rating assessments based on the probability of default, quantitative and qualitative indicators of the corporate bank customers' activity.

Stezhkin (2015) analyzes the rating systems validation and its individual components, considers mathematical approaches to validation and conducts a comparative analysis of alternative approaches.

That is, the problem under investigation is in its infancy, therefore, needs further study.

The purpose of this article is to analyze and justify debtors' solvency assessment models, which are the most suitable for use by banks, depending on the loan portfolio segmentation and the accumulated statistics of the individual bank, in order to calculate the default probability of debtors (PD) as one of the components of calculating the credit risk that makes direct impact on the capital of banks.

2. KEY RESEARCH RESULTS

In Ukrainian banking, the use and calculation of loss parameters such as probability of debtor defaults (PD), loss given default (LGD) and exposure at risk (EAD) for assessing credit risk in active banking operations are subject to regulation by the National Bank of Ukraine (LigaZakon, 2018). The regulatory acts adopted by the National Bank of Ukraine in recent years, based on the principles and recommendations of the Basel Committee on Banking Supervision (National Bank of Ukraine, 2018; Bank for International Settlements, 2005; Bank for International Settlements, 2015), formed the basis for further adaptation and improvement of the standards and approaches used by banks to assess the debtor's solvency in order to calculate the PD as one of the components of calculating the credit risk, contributed to the adequacy of such assessment and acceptability in terms of international unification of credit risk assessment procedures applied by banks.

According to the National Bank of Ukraine approaches, banks determine the value of the default probability factor (PD) of debtors, guided by judgments over their own bank experience based on reliable, continuous, complete and integral statistical data of this bank (LigaZakon, 2018).

Table 1. Approaches to the bank's loan portfolio segmentation

Source: Compiled by the authors.

No.	Loan portfolio segmentation according to basic characteristics of debtors	
	According to Basel II requirements and EU Regulation (Bank for International Settlements, 2005)	According to national regulatory requirements (National Securities and Stock Market Commission, 2016), which comply with Basel II requirements and EU Regulation
1	State administrative bodies, authorities and local governments	1. State government bodies 2. Local governments
2	Financial institutions	1. Banking institutions 2. Non-bank institutions 3. Insurance companies 4. Other financial institutions (leasing and factoring companies, asset management companies)
3	Corporate customers	1. Large and mid-sized enterprises 2. International companies 3. Non-commercial organizations 4. Small enterprises 5. Project financing
4	Retail customers	1. Consumer loans 2. Credit cards 3. Real estate loans 4. Auto loans 5. Loans to VIP-clients

Given the generally accepted international practice (Bank for International Settlements, 2005; National Securities and Stock Market Commission, 2016), the main stages and the flow of determining the coefficients of debtors' PD can be schematically presented as in Figure 1.

As can be seen from the scheme, a clear segmentation of the bank's loan portfolio by types of debtors is a prerequisite for an adequate assessment of the debtor's solvency and the calculation of the PD parameter. In order to meet the regulatory segmentation of assets provided by the IRB approach (Bank for International Settlements, 2005; National Securities and Stock Market Commission, 2016), it is advisable for the bank to develop its own methodology, following the principles:

- structuring the loan aggregates of the bank's loan portfolio based on their relevance, taking into account certain solvency factors that may vary depending on the type of debtors (for example, the solvency of public institutions is largely influenced by macroeconomic indicators, while for legal entities this indicator is less significant);
- taking into account the properties of different data sources for different types of debtors (financial statements for legal entities, collection of related data for individuals);
- taking into account the difference between the average values of the PD coefficients calculated based on the data on default debtors of the respective levels of risk and depending on the type of debtor, as well as considering such differences when determining the periodicity of the solvency assessment and the level of risk inherent in each debtor segment.

Table 1 shows the best way to segment the bank's loan portfolio by type of debtors in terms of both Basel II and national regulatory requirements (LigaZakon, 2018).

The next step in the proper assessment of the debtor's solvency is the choice of a bank for the assessment model for each segment of the loan portfolio.

Generally acceptable models used in international banking practice for assessing the solvency of debtors are grouped and given in Figure 2.

Let us analyze them to determine the suitability for use by Ukrainian banks for the relevant segments of the loan portfolio.

The model suitability is the result of the bank's ability to assess the debtor's solvency to meet a number of criteria, the main of which are: finding the desired value (PD); completeness, objectivity, perception, and consistency (Bank for International Settlements, 2005, 2015).

Source: Compiled by the authors.

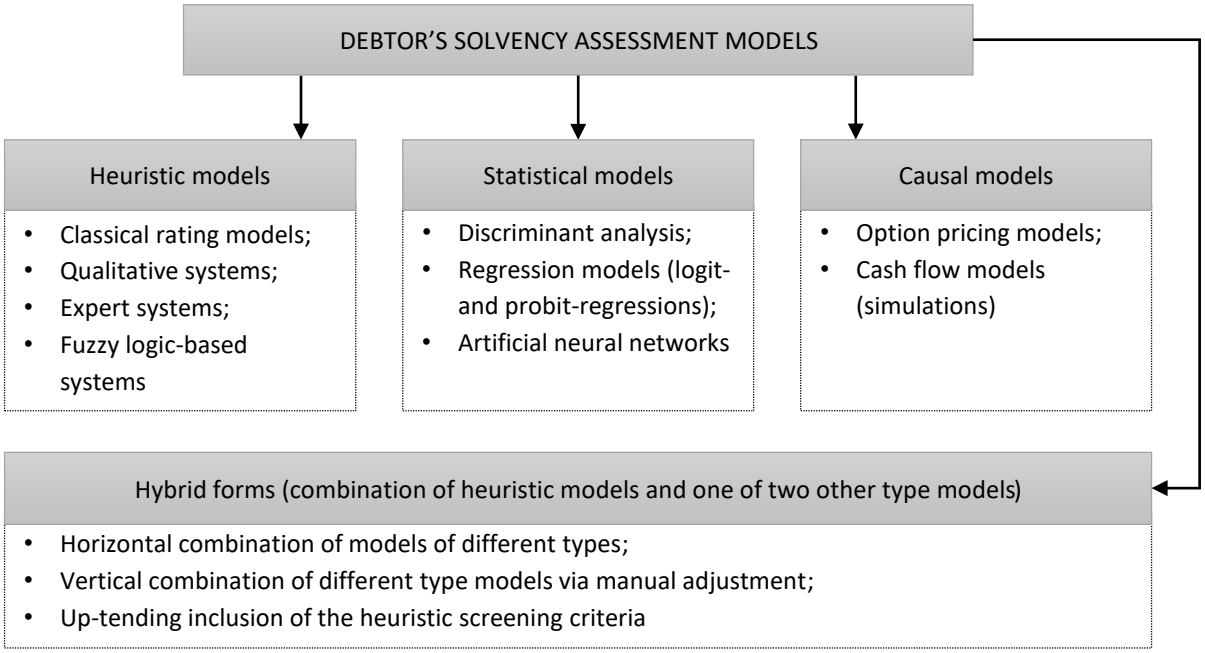

Figure 2. Models used in international banking for assessing the debtors' solvency

Since the construction of heuristic models is based on subjective empirical results of previous experience, observations and assumptions about hypothetical business relations, the debtor solvency, their expedient and efficient application for a certain segment of the bank's loan portfolio depends on the completeness and quality of the data on which they are based, the adequacy of certain factors that are the basis for the evaluation analysis, their ability to adequately reflect the subjective practical experience of the experts responsible for this bank activity.

Classical rating questionnaires – suitability is ensured through the use of justified and understandable criteria for assessing the debtor's solvency through the award procedure (higher scores for higher assessment and lower scores for lower assessment).

Qualitative systems – suitability is ensured by the availability of user instructions based on business experience, which define the conditions for assigning specific ratings/classes in accordance with the solvency characteristics, which secures credit ratings from excessive dependence on the subjective perception of the user, based on the individual level of his knowledge.

At the same time, they are quite limited in terms of objectivity and job opportunities compared to statistical models.

Expert systems may be suitable provided that they are able to ensure the acceptability of the debtors' ratings/classification by simulating the expert experience in a clear and plausible manner, that is, if the developed mechanism of logical conclusion is capable of ensuring its validity. Knowledge accumulation and shaping explanations are additional features of objectivity.

Compared to classical rating questionnaires and qualitative systems, they have more rigorous structuring and greater openness for further development and improvement.

Fuzzy logic systems simulate "fuzzy logic", and are, therefore, more complex to apply, especially in retail lending and small business lending.

Statistical models, such as those formulating hypotheses concerning the potential distribution of debtors depending on their financial capacity, require the verification, approval or rejection of such hypotheses, since the financial capacity of each debtor is determined based on empirical data.

Table 2. Assessing the model suitability for determining the rating/class of different segments of the bank's loan portfolio

Source: Compiled by the authors.

No.	Criterion description	Ability to implement within the framework of the models applied		
		Heuristic	Statistical	Causal
1	**Target value (PD)**			
	Quantification of the PD through the debtor's rating/class	Suitable, subject to the accumulating adequate data set	Suitable, provided that the model is calibrated according to its practical application by bringing the statistical data based results into compliance with the empirical data	Suitable, subject to validation of PD ranges, calculated based on the practical model application
2	**Completeness**			
	Taking into account all information concerning the debtors' solvency assessment	Suitable, provided that computer processing allows taking into account a large number of solvency characteristics	Suitable, subject to the application of a model that will allow the critical examination of a large number of solvency characteristics	Restricted, only for segments such as specialized lending and loans to VIP clients (since the theoretical business-based model is used and only a few quantitative input parameters are used and qualitative data is not taken into account)
3	**Objectivity**			
	The result must be reproduced by different persons/experts based on a unified information, that is, different analysts, as a result of the technique application, should receive comparable results that are as close as possible to the determined rating/class	Suitable, rating/class corresponding to a certain level of solvency is determined by the application of pre-developed algorithms and rules	Suitable, if the characteristics of solvency are selected and weighted using a combination of empirical data and objective algorithms and rules	Suitable, if there are "correct" input parameters
4	**Perception**			
	Providing the user with an accurate assessment of the debtor's solvency	Suitable, providing a high degree of perception, since they are developed on the basis of expert judgments	Suitable, since they have a higher degree of discriminatory ability than heuristic models, but are more difficult to achieve in their perception because they require a large amount of expert knowledge	Limited to fit, only if users understand the basic principles of the theory that is the basis of the model, and if the input parameters are clearly determined. The transparency of the model development process and its modification are also important factors
5	**Congruence**			
	Rating/class should be the result of using internationally recognized approaches and methods by the bank that are correct in terms of application in accordance with the Ukrainian legislation requirements and the NBU regulatory acts	Suitable, because they do not contradict recognized scientific theories and methods, since the experience and results of expert observations on lending issues make their basis	Suitable, subject to screening and exclusion of problem indicators from further analysis that are contrary to real business considerations and between which there may be an interconnection	Suitable, because they directly reflect business relationships and are consistent with the theory underlying them

Therefore, the degree of their suitability largely depends on the empirical data quality used in the development. The quality of empirical data will be considered sufficient if they:

1) comprise a rational set of primary data that provides high representativeness, accuracy of forecasting and does not lead to the final data distortion;
2) finely take into account the features of the bank debtors segment, for which the statistical model is used.

Let's consider the types of statistical models in more detail.

Multiple discriminatory analysis is suitable for determining the rating of all debtor segments with

certain limitations for qualitative data, the processing of which is problematic for this type of analysis. It is most suitable for analyzing quantitative data, for example, corporate debtors financial reporting, data on operations on debtor bank accounts for various segments of the loan portfolio, financial information received from retail debtors.

The prerequisite for applying discriminatory analysis is its compliance with general mathematical requirements, in particular the normal distribution of solvency characteristics. Then the model will show maximum discriminating power.

Regression models are suitable for all segments of the bank's loan portfolio, do not have special requirements for input data, can handle all types of quantitative and qualitative solvency characteristics, provided that sufficient data is available for each segment.

Their advantage is the ability to generate meaningful, statistically justified findings regarding default debtors, interpreting the results to the PD value, which, accordingly, simplifies the model calibration procedure.

Artificial neural networks are suitable for all segments of the loan portfolio, not having specific requirements for input, can handle all types of quantitative and qualitative solvency characteristics. At the same time, they need a much larger amount of data at the development stage than other statistical models, in order to properly communicate.

This method is unsuitable for a small sample size, with suitable models of discriminant analysis and regression.

Causal models, establishing direct analytical connections with the debtor solvency based on financial theory, do not apply statistical methods for testing hypotheses regarding the empirical data set rationality.

Option pricing models are suitable for assessing companies listed on the stock exchange or financial service providers that have necessary input parameters (market value of capital, assets volatility, etc.). Also, in the case of using models (simulation) of cash flows and additional assumptions needed for modeling, they may be suitable for estimating large companies with sufficient time series of corresponding balance sheet data and whose cash flows can be reliably calculated based on planned indicators. Input parameters should be analyzed for their adequacy.

Cash flow simulation models are suitable for assessing specialized lending, since the main source of revenues for loan repayment is the proceeds from funded assets, that is, in a situation where solvency is largely dependent on future cash flows that will be generated by these assets. Also, these models can be used as the primary data processing module in option pricing models.

The criterion for the effective use of the cash flow model (simulation) is the reliable calculation of future expected cash flows and discounting conditions. In this case, having analyzed the predictive ability of past periods, it is necessary to be sure that the data set used is typical for the bank.

Hence, *heuristic models* can be applied to all rating segments, but in terms of discriminatory ability, statistical models, when applied to corporate and retail clients, have a significant advantage.

Statistical models require a sufficient amount of data on debtors in default at the development stage, as well as the data representativeness. For this reason, they cannot be applied to all segments of the bank's loan portfolio (for example, data on defaults of public authorities, international companies, specialized lending operations are not enough to provide sufficient statistical models). Compared to heuristic models, they have the highest discriminatory ability. This means that heuristic models can be supplemented by statistical models.

As for *causal models*, they are ineffective in current economic situation in Ukraine because of the fact that there are no capital markets in Ukraine and, consequently, stock exchange prices, and because of large volumes of work with uncertain outcome.

The results on the models suitability in terms of their use by Ukrainian banks are generalized in Table 3.

In practice, these models are used in their pure form very occasionally. Therefore, while combined, heuristic and statistical models will complement each other adequately.

Table 3. Models suitability for using by Ukrainian banks

Source: Compiled by the authors.

No.	Segments of debtors' loan portfolio	Heuristic models				Statistical models			Causal models	
		Questionnaires for ranking	Qualitative systems	Expert systems	Fuzzy logic-based systems	Multiple discriminatory analysis	Regression models	Artificial neural networks	Option pricing-based models	Cash flow (simulation)-based models
1	Public authorities Local government bodies	+	+	+	+		+			
2	Banking institutions	+	+	+	+	+	+		+	
3	Non-bank financial institutions Insurance companies Other financial institutions (leasing and factoring asset management companies)	+	+	+	+	+	+			
4	Large and mid-size enterprises	++	++	++	+	++	++	+	+	
5	International companies	++	++	++	+	+	++		+	
6	Non-commercial institutions	+	+	+	+		+			
7	Small enterprises	+	+	+		++	++			
8	Project financing of enterprises	+	+	+	+		+			+
9	Individuals, including individual entrepreneurs	++	++	++			+	+		

CONCLUSION

The article analyzes and substantiates the most suitable models for use by banks to assess the debtors' solvency.

The study allows for summarizing results of the analysis of approaches that are optimal for use by banks in calculating the values of the default probability (PD) coefficient as one of the components for calculating the credit risk, which has a direct impact on the capital of banks, in particular:

- methods (ways) for segmentation of banks' loan portfolios by types of debtors in the context of compliance with both Basel II and national regulatory requirements;
- the most acceptable models of the debtors' solvency assessment, depending on the loan portfolio segmentation, the accumulated statistics of a separate bank, the nature and complexity of their transactions, in order to calculate the debtor default probability.

REFERENCES

1. Abdou, H., El-Masry, A., & Pointon, J. (2007). On the Applicability of Credit Scoring Models in Egyptian Banks. *Banks and Bank Systems, 2*(1), 4-20. Retrieved from https://businessperspectives.org/journals/banks-and-bank-systems/issue-152/on-the-applicability-of-credit-scoring-models-in-egyptian-banks
2. Al-Shawabkeh, A., & Kanungo, R. (2017). Credit risk estimate using internal explicit knowledge. *Investment Management and Financial Innovations, 14*(1), 55-66. http://dx.doi.org/10.21511/imfi.14(1).2017.06
3. Bank for International Settlements (2005). *Basel II: International Convergence of Capital Measurement and Capital Standards: A Revised Framework.* Retrieved from https://www.bis.org/publ/bcbs118.pdf
4. Bank for International Settlements (2015). *Guidance on accounting for expected credit losses.* Retrieved from https://www.bis.org/bcbs/publ/d311.pdf
5. Blanco-Oliver, A., Irimia-Dieguez, A., Oliver-Alfonso, M. D., & Vázquez-Cueto, M. J. (2016). Hybrid model using logit and nonparametric methods for predicting micro-entity failure. *Investment Management and Financial Innovations, 13*(3), 35-46. http://dx.doi.org/10.21511/imfi.13(3).2016.03
6. Borio, C. E. V. (2011). Rediscovering the Macroeconomic Roots of Financial Stability Policy: Journey, Challenges, and a Way Forward. *Annual Review of Financial Economics, 3,* 87-117. http://dx.doi.org/10.1146/annurev-financial-102710-144819
7. Bunker, R., Naeem, A., & Zhang, W. (2016). *Improving a Credit Scoring Model by Incorporating Bank Statement Derived.* Retrieved from https://www.researchgate.net/publication/309606871_Improving_a_Credit_Scoring_Model_by_Incorporating_Bank_Statement_Derived_Features
8. Deloitte (2016). *Credit scoring Case study in data analytics.* Retrieved from https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Financial-Services/gx-be-aers-fsi-credit-scoring.pdf
9. Dolinskyi, L. B. (2016). *Моделювання ризику дефолтів банківських установ [Modeliuvannia ryzyku defoltiv bankivskykh ustanov].* Retrieved from http://econom-law.cdu.edu.ua/wp-content/uploads/2016/03/dolinsky-doklad-2016.pptx
10. Edward, H. K. Ng (2012). Testing the consistency of internal credit ratings. *Banks and Bank Systems, 7*(3), 25-32. Retrieved from https://businessperspectives.org/images/pdf/applications/publishing/templates/article/assets/4863/BBS_en_2012_03_Ng.pdf
11. Genriha, I., & Voronova, I. (2012). Methods for Evaluating the Creditworthiness of Borrowers. *Scientific Journal of RTU, 22,* 42-49.
12. Gurný, P., & Gurný, M. (2013). Comparison of the Credit Scoring Models on PD Estimation of US Banks. *Prague economic papers, 2,* 163-181.
13. Karminskyi, A. M. (2012). Ймовірність дефолту банку і її моделювання [Imovirnist defoltu banku i yii modeliuvannia]. *Finansova Analityka: Problemy i Rishennia, 41,* 2-13.
14. Kazanskyi, A. A. (2016). Функціонування внутрішньої рейтингової системи комерційного банку [Funktsionuvannia reitynhovoi systemy komertsiinoho banku]. *Problemy Suchasnoi Ekonomiky, 9,* 127-131.
15. Kovalenko, V. V., & Nenad, D. O. (2017). Методи управління кредитним ризиком та їх місце в забезпеченні платоспроможності банків [Metody upravlinnia kredytnym ryzykom

ta yikh mistse v zabezpechenni platospromozhnosti bankiv]. *Hroshi, Finansy ta Kredyt, 3*(08), 270-274.

16. LigaZakon (2014). *Про ратифікацію Угоди про асоціацію між Україною, з однієї сторони, та Європейським Союзом, Європейським співтовариством з атомної енергії і їхніми державами-членами, з іншої сторони: Закон України від 16.09.2014 №1678/VII [Pro Ratyfikatsiiu Uhody mizh Ukrainoiu, z odniiei storony, ta Yevropeiskym Soiuzom, Yevropeiskym spivtovarystvom z atomnoi enerhii i yikhnimy derzhavamy-chlenamy, z inshoi storony: Zakon Ukrainy vid 16.09.2014 No. 1678/VII]*. Retrieved from http://search.ligazakon.ua/l_doc2.nsf/link1/T141678.html

17. LigaZakon (2018). *Положення про визначення банками України розміру кредитного ризику за активними банківськими операціями: Постанова Правління Національного банку України від 30.06.2018 № 351* [*Polozhennia pro vyznachennia bankamy Ukrainy rozmiru kredytnoho ryzyku za aktyvnymy bankivskymy operatsiiamy: Postanova Pravlinnia Natsionalnoho banku Ukrainy vid 30.06.2018 No. 351]*. Retrieved from http://search.ligazakon.ua/l_doc2.nsf/link1/PB18039.html

18. Maarse, B. (2012). *Backtesting Framework for PD, EAD and LGD* (Master thesis) (85 p.). Rabobank. Retrieved from http://essay.utwente.nl/61905/1/master_B._Maarse.pdf

19. National Bank of Ukraine (2018). *Основні принципи ефективного банківського нагляду [Osnovni pryntsypy efektyvnoho bankivskoho nahliadu]*. Retrieved from http://www.bank.gov.ua/control/uk/publish/category?cat_id=45216

20. National Securities and Stock Market Commission (2016). *Регламент Європейського парламенту та Ради (ЄС) No. 575/2013 від 26.06.2013. Про пруденційні вимоги до кредитних організацій та інвестиційних компаній, що вносить зміни до Регламенту (ЄС) № 648/2012 [Rehlament Yevropeiskoho parlamentu ta Rady (YeS) No. 575/2013 vid 26.06.2013 Pro prudentsiini vymohy do kredytnykh orhanizatsii ta investytsiinykh kompanii, shcho vnosyt zminy do Rehlamentu (YeS) No. 648/2012]*. Retrieved from http://www.uaib.com.ua/files/CRD%20IV.pdf

21. Shkodra, J., & Ismajli, H. (2017). Determinants of the credit risk in developing countries: a case of Kosovo banking sector. *Banks and Bank Systems, 12*(4), 90-97. http://dx.doi.org/10.21511/bbs.12(4).2017.08

22. Sofronova, V. V. (2016). Оцінка дефолту боржника [Otsinka defoltu borzhnyka]. *Finansova Analityka: Problemy i Rishennia, 3,* 39-48.

23. Stezhkin, A. A. (2015). Про методи валідації рейтингових систем в рамках підходу внутрішніх рейтингів до оцінки кредитного ризику банків [Pro metody validatsii reitynhovykh system v ramkakh pidkhodu vnutrishnikh reitynhiv do otsinky kredytnoho ryzyku bankiv]. *Finansova Analityka: Problemy i Rishennia, 32,* 29-41.

24. Supervisory Statement (2013). *Credit Risk: Internal Ratings Based Approaches* (23 p.). Bank of England, Prudential Regulation Authority.

25. Tasche, D. (2008). Validation of Internal Rating Systems and PD Estimates. In *The Analytics of Risk Model Valuation* (pp. 171-198). Elsevier.

26. Tereshchenko, O. O. (2012). Оцінка кредитних ризиків: відповідність новацій НБУ міжнародній практиці [Otsinka kredytnykh ryzykiv: vidpovidnist novatsii NBU mizhnarodnii praktytsi]. *Visnyk NBU, 9,* 4-8.

27. Wezel, T., Chan, Lau J. A., & Columba, F. (2012). Dynamic Loan Loss Provisioning Simulations on Effectiveness and Guide to Implementation. *IMF Working Papers, 1*(110), 8-11.