DOI: 10.55643/fcaptp.6.59.2024.4486

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Received: 12/07/2024
Accepted: 23/11/2024
Published: 31/12/2024

MODERN INSTRUMENTAL APPROACHES TO MODELLING THE COMMERCIAL BANK'S FINANCIAL INVESTMENT POLICY

ABSTRACT

The article considers a complex of modern analytical approaches to the systematic modelling of the commercial bank's financial investment policy based on international practice. The authors examine the key aspects of modelling and analytical technologies that determine the strategic decisions of banking institutions in the field of financial investment, in particular, taking into account global economic and financial trends.

The article highlights model and methodological approaches and tools used to analyze and forecast market conditions, risks and profitability in the context of banks' financial investments.

The research purpose is to expand the instrumental apparatus and prove the significance of the technology's role and the implementation of a wide range of methods and modern international approaches to modelling the commercial banks' financial investment policy in the direction of strategic development in the context of global megatrends.

The research is based on the tools of models of spatial econometric analysis (panel data), adaptive forecasting of dynamic series, multivariate data analysis, cluster and discriminant analysis.

The paper presents an aggregated instrumental basis for the main key directions, namely analysis of the bank's financial indicators; assessment of the stock market's business activity level; classification and grouping of economic objects according to the investment attractiveness level. The data of the studied area interact and complement each other, allowing us to comprehensively generalize and objectively present the fundamental basis for decision-making.

As a result of these stages' implementation, we can determine the optimal financial investment strategies, which contribute to increasing the commercial banks' efficiency and stability in the modern conditions of globalization and financial instability. An analytical view of the study of international approaches makes the article relevant for specialists in the fields of finance, economics and banking.

Keywords: commercial banks, financial sector, economic and mathematical modelling, investment analysis, correlation, models, stock market, forecasting, decision-making

JEL Classification: C24, M31, G21

INTRODUCTION

The world's financial sector is developing rapidly, and commercial banks are becoming key players in the field of financial investment. The constant changes and economic globalization conditions require adapting approaches to modelling the commercial banks' financial investment policy. The relevance of the study of modern international approaches to modelling commercial banks' financial investment policy is determined by the fact that in the modern economic environment, these institutions act as key financial intermediaries. The growing instability of world markets, the dynamics of economic changes and constant innovations in the financial sector require effective strategies and adaptive investment models from banking institutions. The analysis of modern approaches allows us to understand what factors influence the processes of strategic

decision-making in the field of financial investment. In particular, the growing role of technology, regulatory changes and global risks determines the need to study modern trends and optimize banking strategies to ensure stability and competitiveness in the financial sector. Thus, this research is important for economic science and financial management practice, providing important insights for management decisions in the banking industry in the conditions of constant transformations in the world economy.

LITERATURE REVIEW

The issue of modelling the commercial banks' financial investment policy attracted the attention of researchers in the financial field. There are studies on various aspects such as strategic portfolio management, risk optimization, the use of technology in the financial sector and the impact of the regulatory environment on investment decisions.

Some articles focus on the analysis of technological innovations in the financial sector and their impact on banks' investment strategies. Others examine aspects of regulation and how these aspects affect commercial banks' financial investment decisions. Despite the existence of a large number of articles devoted to financial investment, there is a lack of a comprehensive approach to modelling the commercial banks' investment policy taking into account current global trends and challenges.

Repko M. [16] analyzes the problems of the banking system of Ukraine, which are related to shortcomings in the justice system. The author claims that the weakness of the banking system is largely due to the insufficient efficiency of the judicial system, which does not provide adequate protection of the rights of creditors and depositors. This, in turn, leads to a decrease in trust in banks and contributes to the instability of the financial sector. Kirchner R., Kravchuk V., Repko M., Poluschkin G. [8] analyze Ukraine's banking system state, in particular assessing the impact of previous reforms and the COVID-19 pandemic consequences. The report contains recommendations for the banking sector's further development, emphasizing the importance of stable macroeconomic conditions and effective regulation.

Ramskyi A., Loiko V., Sobolieva-Tereshchenko O., Loiko D., Zharnikova V. [15] study the process of integration of Ukraine's banking system into the European one. The authors analyze measures to clean up the banking sector, restructuring and implementation of Basel III standards. The results of the study show that for successful integration, it is necessary to improve the regulatory environment and increase the transparency of financial transactions.

Melnyk L., Dehtyarova I., Kubatko O., Karintseva O., Derykolenko A. [11] consider the impact of innovative technologies on the transition to sustainable digital economies. The authors discuss the role of financial technologies in promoting sustainable development and increasing the efficiency of financial services.

Some authors [13, 14, 17] offer a practical approach to survival analysis using a software package and analyze various risk factors, including political instability, economic conditions, and the legal environment, which may influence investors' decisions to invest in a particular country. The use of such non-traditional data can help banks more accurately assess the solvency of customers.

Sergienko O., Volosnikova N., Reshetnyak N., Mashchenko M., and Baranova V. [18] analyze modern approaches to managing financial flows to ensure corporate security. The authors propose a conceptual model that takes into account various aspects of financial management and their impact on the enterprise's sustainability.

The authors [1, 3, 5] propose a new method of credit risk assessment using survival trees with gradient boosting. This method makes it possible to increase the accuracy of forecasting defaults. The authors emphasize the importance of both public and private investment in stimulating economic growth.

Hutorov A., Lupenko Y. and others [7,9,12,19] propose strategies to ensure sustainable economic growth, taking into account social and economic factors, using structural modelling and exploring risk management.

Based on the literature review, several unsolved tasks and challenges facing modern international approaches to modelling the commercial bank's financial investment policy can be identified. Despite the availability of modern credit risk assessment methods, there is a need to improve these methods to better account for economic instability. Modern models often do not take into account all aspects related to rapid changes in the economic environment and global crises.

Using non-traditional data sources such as web browsing data to predict credit risk requires further research and the development of new methodologies, which make it possible to effectively use this data to reduce risks and increase the forecast's accuracy. The importance of implementing innovative technologies for the digital economy sustainable development requires the development of effective strategies for their implementation. This applies to both the internal processes

DOI: 10.55643/fcaptp.6.59.2024.4486

of banks and their interactions with clients. There is a need to improve the management of financial flows to ensure corporate security and banking operations stability. This requires the development of new approaches and models that take into account modern challenges and risks. These unsolved tasks indicate the need for further research and development of new methodologies to improve the commercial banks' financial investment policy.

AIMS AND OBJECTIVES

The research purpose is to expand and implement a wide range of methods and modern international approaches to modelling the commercial bank's financial investment policy in the direction of strategic development in the context of megatrends. In addition, our research is aimed at:

- conducting a detailed analysis of previous studies, identifying their main conclusions and gaps;
- establishing the main factors affecting the formation of the commercial banks' financial investment policy at the international level;
- analysis of the role of technologies in solving financial investment tasks and their impact on bank strategies;
- considering the effects of the regulatory environment on investment decisions in commercial banks.

METHODS

The theoretical and methodological bases of this research are fundamentals and the provisions of modern economics, scientific papers and methodological developments of leading Ukrainian and foreign scholars in the finance field. The research is based on tools of models of spatial econometric analysis (panel data), adaptive forecasting, multivariate data analysis, cluster and discriminant analysis.

RESULTS

One of the most important stages of the financial investment process is conducting an investment analysis before making a sound decision to invest the bank's funds in the appropriate financial instruments.

In turn, one of the most common areas of investment analysis is fundamental analysis, the main purpose of which is to determine the actual (real, "fair") value of a security. It includes the following levels:

- macroeconomic analysis;
- industry analysis;
- analysis of the issuer's financial condition;
- forecasting the price of a financial instrument.

In the first stage, the state of the economy and the stock market in general is considered. It allows us to find out how favourable the general situation is for investing, and to determine the main factors that determine the specified situation. The general economic situation reflects the situation in most spheres of the economy, however, each of these spheres is subject not only to general, but also to its own internal patterns of development, and, accordingly, the conclusions made regarding the macroeconomic situation need to be specified and adjusted taking into account internal features. Even if the results of the analysis of the economic situation in general state that it is unfavourable for investment, this does not mean that it is not possible to find sectors of the economy where it would be more profitable to invest funds [16].

The study of the general economic situation at the first stage of the analysis is based on the comparison of indicators characterizing the dynamics of production, the level of economic activity, consumption and accumulation, the dynamics of inflationary processes, and the country's financial state. At the same time, attempts are made to determine specific mechanisms of influence on the state of affairs in the economy in relation to the most important political and social events. Identifying the factors that determine the economic situation in general, and those that directly reflect the events on the stock market, makes it possible to determine the general conditions against which investment policy should be carried out, and to build forecasts regarding the prospects for their change. Since the macroeconomic situation is the subject of close attention from wide circles of economists, when conducting its fundamental analysis, one should rely on the conclusions and assumptions made by leading experts in the field of the stock market.

After studying the stock market situation, in general, the analysis of individual segments of the securities market is carried

out in order to identify among them those that, in the general economic conditions, are the most favourable for investing funds from the point of view of the chosen investment goals and priorities. At the same time, the state of the sectors and sub-sectors of the economy represented on the stock market is considered. The identification of the most optimal directions for the investment resources allocation creates a basis for choosing within their framework specific types of securities, investments which would ensure the most complete achievement of investment goals. The normal development of industries is subject to the corresponding laws, which are expressed in a certain way in the dynamics of industry indicators or indices of individual issuers. The initial stages of their formation, associated with the rise and rapid increase in profitability, are gradually replaced by more or less long periods of sustainable development. Over time, a number of industries may stagnate and for some time they may not develop. At each moment taken for the analysis, they try to identify an industry that is on the rise and, within the framework of the established investment priorities, offers the best, compared to other areas, opportunities for profitable investment of funds.

After the industries which are most suitable for investing funds have been determined, from all the variety of companies included in these industries, those whose securities allow the most complete implementation of the investment goals should be selected. So, in the third stage, the individual firms and companies whose stock instruments are traded on the market are analyzed in detail, and preference is given to companies from investment-attractive industries. This makes it possible to solve the question of which securities are attractive, and which of those already purchased are better to sell [8].

One of the key factors affecting the value of any company's securities is its current financial and economic condition and development prospects. Therefore, the fundamental analysis at its final stage focuses primarily on studying the issuer’s affairs state. The main sources of information used for fundamental analysis are:

- data from the company's annual and quarterly financial reports;
- materials about the company from the press;
- data received through the channels of electronic information systems;
- the results of research carried out by specialized organizations and other stock market participants.

At the last stage of fundamental analysis, the bank must forecast the true price of the financial instrument and compare it with the market price. When predicting exactly what share of profit will be allocated to the payment of dividends, bank managers must take into account such points as the expected increase in profit and cash inflows, the possibility of access to financial markets, the fee for using external sources of financing, the future financial needs of the corporation that may be caused by the growth of volumes sales, assets, etc.

Modern methods of economic and mathematical modelling of fundamental investment analysis are determined by a high degree of complexity and accuracy, aimed at providing an objective assessment of the financial stability and prospects of investment objects. Several key modern approaches include, which is shown in Figure 1 [15, pp. 163-165; 4, pp. 23-26].

These methods interact and complement each other, allowing for a comprehensive and objective fundamental analysis of investment objects, which is key to making decisions in the field of financial investment [13].

Modern methods of economic and mathematical modelling of fundamental investment analysis are used to understand and forecast price movements in financial markets based on the analysis of fundamental factors, such as macroeconomic indicators, financial reporting of companies, global trends, and others. These methods combine elements of economic theory, mathematical modelling, statistical analysis, and computational techniques to study market dynamics and make investment decisions. One of the main approaches is fundamental analysis, which is based on assessing the potential value of assets based on their fundamental characteristics, such as profitability, profitability growth, competitiveness, etc. Various mathematical methods are used to model such factors, including regression analysis, financial reporting, general financial and economic postulates, and others.

The main tools used for modelling include stochastic processes, differential equations, optimization methods and others. They allow us to analyze the relationships between various fundamental factors and predict their impact on asset prices in the future. The use of modern methods of economic and mathematical modelling in fundamental investment analysis allows investors to obtain more objective and balanced forecasts of market dynamics, which contributes to the adoption of better investment decisions.

The construction of models for the analysis of the bank's financial indicators begins with the definition of key performance indicators (KPI), which best reflect the bank’s financial condition and performance. Such indicators may include return on assets (ROA), return on equity (ROE), capital investment, liquidity, credit portfolio quality and other key aspects of financial activity [14, p. 237-257; 7].

DOI: 10.55643/fcaptp.6.59.2024.4486

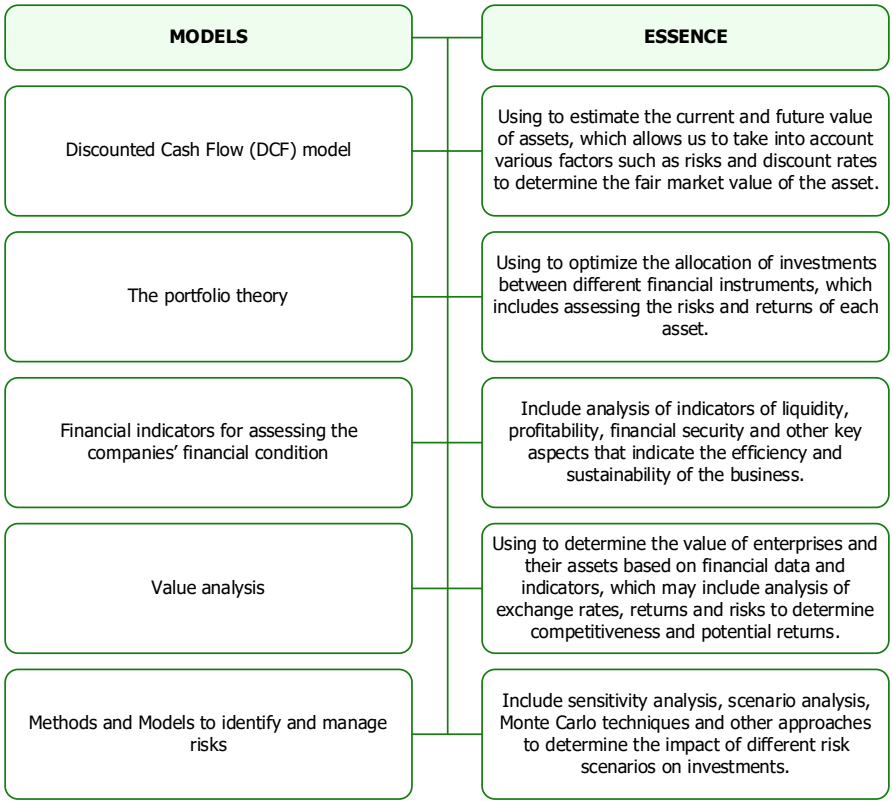

Figure 1. Modern methods of economic and mathematical modelling of fundamental investment analysis.

However, the fundamental investment analysis is poorly researched nowadays. Therefore, we propose a research scheme that uses modern tools of economic and mathematical modelling of fundamental investment analysis, which is shown in Figure 2, which includes the following main stages:

1. Analysis of the bank's financial indicators.
2. Assessment of the stock market's business activity level.
3. Classification and grouping of economic objects according to the investment attractiveness level.

Stage 1. Construction of a set of models for the analysis of the bank's financial indicators

Next, the collection and processing of financial data necessary for analysis is carried out. These data can be obtained from the bank's financial statements, accounting statements and other sources. Particular attention is paid to the data accuracy and relevance, as they are the basis for an objective assessment of the financial condition. After that, an analysis of the selected indicators is performed, which involves comparing their values with previous periods, as well as with industry standards and averages. This stage allows us to identify trends and identify possible problems or advantages. Further, economic and mathematical methods, such as various regression models, factor analysis or clustering methods, are used to identify interrelationships and cause-and-effect relationships between various financial indicators.

The final stage is the interpretation of the results and the development of recommendations for improving the bank's financial activities. This may include strategic adjustments, optimization of processes and risk management to ensure stability and success in the banking sector.

Stage 2. Construction of models for assessing the stock market's business activity level

Building models for assessing the stock market's business activity level is an important task for understanding and analyzing its efficiency and potential. These models make it possible to determine the degree of mobility, liquidity and general activity of stock market participants.

The selection and analysis of key indicators is the first stage of building models for assessing the level of business activity on the stock market. One of the main indicators is the trade volume, which is determined by the amount of transactions concluded over a certain period of time. In addition, the number of transactions, the liquidity of assets, which indicates the ability to quickly convert assets into money, and the speed of order execution, which determines the time between

the resolution and the execution of the order, are also important.

Next, data on trading activity is collected and analyzed. This may include a detailed review of deal volumes and prices, the study of order statistics, assessment of market supply and demand. It is also important to consider the dynamics of these indicators over time to identify trends and seasonality. In the next stage, various models and methods of analysis are applied, such as regression analysis, time series, technical analysis and others. These methods make it possible to identify relationships and regularities between various factors affecting the level of business activity in the stock market.

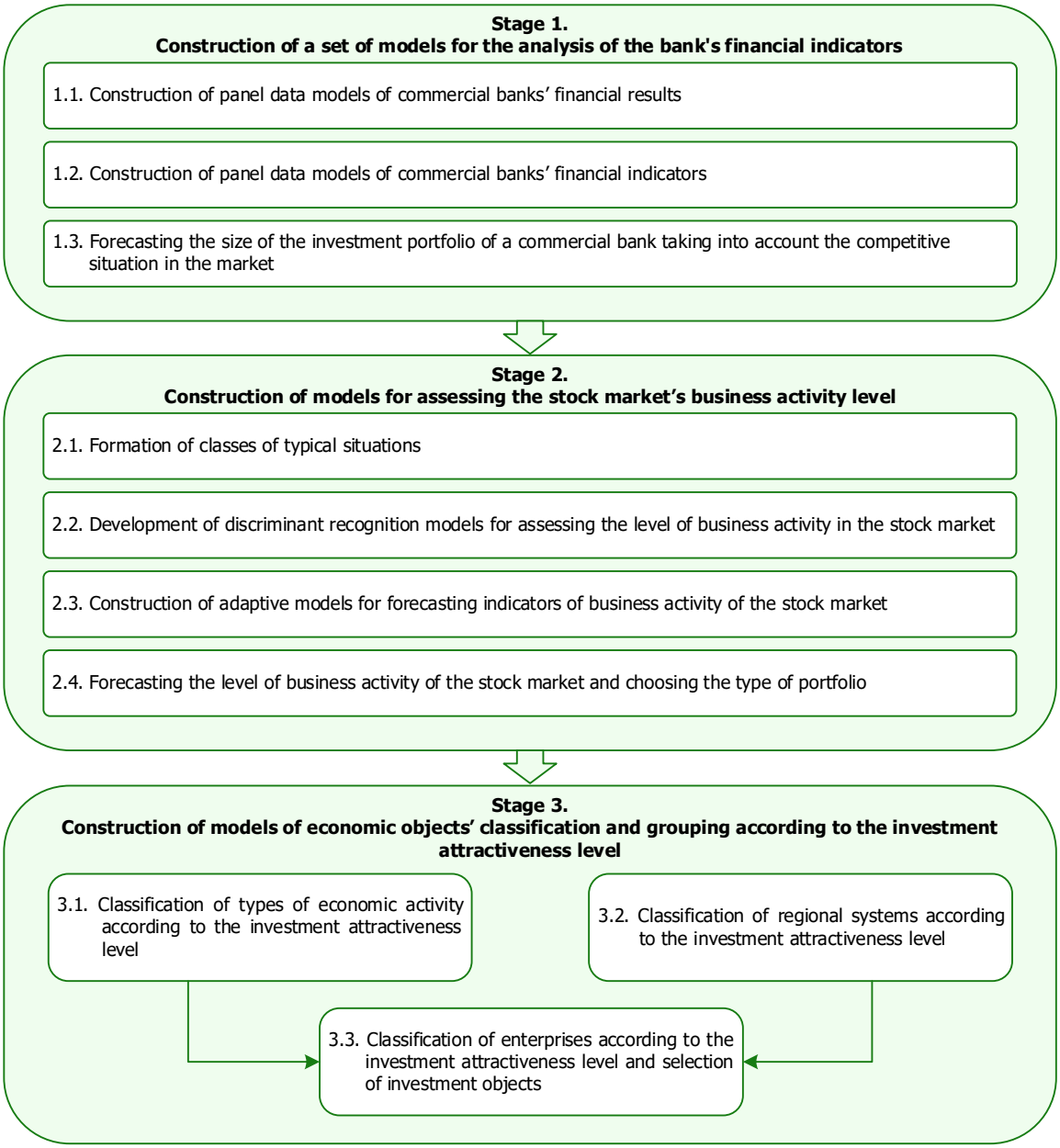

Figure 2. Modern tools of economic and mathematical modelling of fundamental investment analysis. *(Source: [2])*

Stage 3. Construction of models of economic objects' classification and grouping according to the investment attractiveness level

The final stage is the interpretation of the obtained results and the development of recommendations for optimizing business activity. This may include improving trading strategies, introducing new technologies and methods, as well as improving the regulatory environment in order to stimulate activity in the stock market.

The construction of models for the classification of economic objects by the level of investment attractiveness begins with the definition of key criteria that will be used to evaluate these objects. The most important criteria are:

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- the economic stability of the region or country;
- availability of developed infrastructure;
- level of innovation;
- labour availability;
- tax policy;
- legal stability and others.

Next, the necessary data is collected for each object, using the above-mentioned criteria. This may include economic indicators, information on infrastructure projects, data on scientific research and other factors, depending on the specific purpose of the classification. Data analysis and modelling techniques such as classification and machine learning techniques are then used to develop an investment attractiveness assessment model. These methods allow us to take into account the interrelationships between different criteria and the importance of each of them to determine the overall level of attractiveness.

The final stage is the model's validation and optimization, the establishment of a business process for the development of recommendations and their implementation to improve the investment attractiveness of objects. This may include the development of development strategies, risk mitigation measures and other initiatives aimed at attracting investment.

Construction of panel data models of commercial banks' financial results and financial indicators

As we can see in Figure 1, to implement the tasks of the first stage, a toolkit of dynamic-spatial modelling such as panel data is used. Panel data consists of observations of the same economic units or objects made in successive time periods, combining both spatial and time series data. Thanks to a special structure, panel data allows us to build more flexible and meaningful models and get answers to questions that are unattainable for models built only on ordinary spatial data. Dynamic and spatial modelling is an opportunity to take into account and analyze individual differences between fixed and random economic units. Also, models with panel data make it possible to obtain more accurate estimates of parameters [18, p. 177-179].

Panel data models have the following advantages:

- increasing the information base;
- the possibility of taking into account the heterogeneity of data;
- the possibility of taking into account the specifics of process dynamics;
- the possibility of building more complex models;
- solving the problem of multicollinearity of data;
- obtaining robust statistical estimates.

In general, the panel data model has the following form:

$$y_{it} = \alpha_i + x_{it}' \cdot \beta_{it} + \varepsilon_{it}, \quad (1)$$

where α_i – the value of the dependent variable for the i-th object in the t-th period (i); x_{it}' - the order vector, which combines variables; β_{it} - scalar; ε - disturbance for the i-th object in the t-th period; it - model parameters that measure the effects of variables Xin period t for the i-th object.

Depending on the assumptions regarding the nature of the value two models can be considered. In the model with fixed effects, it is assumed that in equation (1) the quantities are unknown parameters.

In a random-effects model, it is assumed that

$$\alpha_i = \mu + u_i, \quad (2)$$

where μ – a parameter common to all units at all times, u_i - errors uncorrelated with and are uncorrelated for different and.

The fixed-effect model is described by equation (1), in which the variables are unknown parameters. Assume that the following conditions are met:

- errors uncorrelated among themselves for all *i* and *t*,

$E(\varepsilon_{it})=0,\ V(\varepsilon_{it})=\sigma_{\varepsilon}^2$ (3)

- errors uncorrelated with regressors for all *i, j, t, s*.

If we introduce dummy variables for each economic unit: $d_{ij}=1$, if $i=j$, and $d_{ij}=0$, if $i\neq j$, then equation (1) can be rewritten in a more usual form of linear regression

$$y_{it} = \sum_{j=1}^{n} a_j d_{ij} + x_{it}^{'}\beta + \varepsilon_{it} \quad (4)$$

Equation (4) can be rewritten in the following matrix form:

$$y = Da + X\beta + \varepsilon \quad (5)$$

This relationship can be treated as a standard regression model and parameter estimates obtained α, β using the ordinary least squares method. If the above assumptions regarding the MNC model are fulfilled, the estimates will be unbiased and effective [1, p.40-47].

Difficulties may arise when implementing this method. In many panel data, the number of economic units *n* is usually quite large (several hundred or thousands). Therefore, directly applying the least squares method to $y = Da + X\beta + \varepsilon$, when estimating the parameters, you may encounter computational problems. However, they can be overcome if we are interested only in the estimations of parameters [3, p.421-345].

If we go to the time-averaged values in the equation we obtain:

$$\bar{y}_i = a_i + \bar{x}_i'\beta + \bar{\varepsilon}_i \quad (6)$$

Subtracting term by term $\bar{y}_i = a_i + \bar{x}_i'\beta + \bar{\varepsilon}_i$ with $y_{it} = a_i + x'_{it}\beta + \varepsilon_{it}$ we will get:

$$y_{it} - \bar{y}_i = (x_{it} - \bar{x}_i)'\beta + \varepsilon_{it} - \bar{\varepsilon}_i \quad (7)$$

$$\beta=(X'MDX)-1X'MDy \quad (8)$$

which coincide with the LSM estimates of parameters β in equation $y = Da + X\beta + \varepsilon$, i.e., with the LSM estimates with dummy variables.

These estimates are also called within-group or fixed-effect estimates: $\beta=\beta W=\beta FE$. They can be provided in the following form:

$$\beta_{FE} = \left(\sum_{i-1}^{n}\sum (x_{it} - \bar{x}_i)(x_{it} - \bar{x}_i)'\right)^{-1} \sum_{i-1}^{n}\sum_{i-1}^{T}(x_{it} - \bar{x}_i)(y_{it} - \bar{y}_i) \quad (9)$$

The conditions imposed on the model guarantee the unbiasedness and validity of estimates with a fixed effect.

As estimates of individual effects can be taken

$$a = \bar{y}_i - \overline{x_i'}\,\widehat{\beta_{FE}},\ i=1, \ldots, n \quad (10)$$

These estimates are unbiased and reasonable for fixed n at $t\to\infty$.

Under sufficiently weak conditions of regularity, estimates with a fixed effect are asymptotically normal (at $n\to\infty$ or at $T\to\infty$), therefore, standard procedures (Student's t-tests, Fisher's F-tests) can be used to test the hypothesis regarding β parameters.

The equation for the random effect model is:

$$y_{it} = \mu + x_{it}'\beta + u_i + \varepsilon_{it} \quad (11)$$

where μ is a constant, u_i is a random error, invariant over time for each economic unit.

DOI: 10.55643/fcaptp.6.59.2024.4486

Therefore, in the random effect model, it is assumed that individual grades are random. Therefore, the following conditions are met:

- errors ε_{it} are uncorrelated with each other, $E(\varepsilon_{it}) = 0$, $V(\varepsilon_{it}) = \sigma^2_{\varepsilon}$;
- errors ε_{it} are uncorrelated with regressors x_{js} for all i, j, t, s;
- errors u_i are uncorrelated, $E(ui)=0$, $V(ui)= \sigma^2_{u_i}$;
- errors u_i are uncorrelated with regressors x_{jt} for all i, j, t;
- errors u_i and ε_{it} are uncorrelated for all i, j, t.

Random effects model $y_{it} = \mu + x'_{it}\beta + u_i + \varepsilon_{it}$ can be considered as a linear model in which the error $\omega_{it}= u_i+\varepsilon_{it}$ has a special structure.

We can rewrite the equation $y_{it} = \mu + x'_{it}\beta + u_i + \varepsilon_{it}$ as

$$y_i = \mu z_T + X_i\beta + \varpi_i \tag{12}$$

or, using combined observations, in the form

$$y = \mu z_{nT} + X\beta + \varpi \tag{13}$$

To obtain estimates of parameters μ, β, we can apply the LSM model to the equation $y = \mu z_{nT} + X\beta + \varpi$.

The specified conditions guarantee the immutability and validity of these errors.

However, errors $y = \mu z_{nT} + X\beta + \varpi$ are not homoscedastic, therefore, the generalized LSM can be used to construct effective estimates [5, p.225-231; 7, pp. 297-300].

When working with real panel data, there is always the problem of which model (ordinary regression, fixed or random effect) to choose. At the substantive level, the difference between the models can be interpreted as follows:

1. The general OLS model assumes that there is no individual difference among economic units, and in some simple situations, this assumption is justified.
2. In the model with fixed effects, it is taken into account that each economic unit is "unique" and cannot be considered as the result of a random selection from some general population; this approach is correct when it comes to countries, large regions, industries, and large enterprises.
3. If the objects got into the panel "randomly" as a result of sampling from a large population, then a model with a random effect is acceptable (for example, small firms, households, individuals, etc.), but in a similar situation (especially for a small number of economic units) the question of the presence of individual differences may arise, and then the model with a fixed effect is the best, under the condition of equal adequacy [19, p.245-248; 7].

The random effect model assumes that the error a_i is uncorrelated with the regressors x_{jt}, that is, the individual effect is not related to the explanatory variables x_{jt}. This condition is not always fulfilled, even for samples of large data.

Regardless of whether individual effects are correlated with other explanatory variables or not, the fixed-effect estimate is unbiased and robust. Therefore, in any situation, a model with a fixed effect gives an acceptable estimate. However, in the absence of correlation, these estimates will be ineffective, which can be very important for small data samples. At the same time, if there is a fixed effect in the model, then the estimation using the random effect will be unreasonable. Thus, the quality of estimates depends significantly on the correct specification of the model [20, p. 484-489].

Forecasting the size of the commercial bank's investment portfolio taking into account the competitive situation in the market

In practice, estimation using different models often leads to significantly different results. We present statistical tests that allow us to partially solve the problem of model selection using standard hypothesis testing techniques. There is a significant hierarchy in the considered models:

- the ordinary regression model is a special case of the fixed-effect model, when $ai=0, i=1, ..., n$;

- the ordinary regression model is a special case of the random effect model $y_{it} = \mu + x_{it}' \cdot \beta + u_i + \varepsilon_{it}$ when the latter has no u_i errors or (equivalently) when $\sigma_u^2 = 0$;
- the random-effect model is a special case of the fixed-effect model, when in the latter there is no correlation between α_i and x_{jt}.

Therefore, when using statistical tests, the null hypothesis is a partial model, and the alternative is a more general one.

Construction of classification models of typical situations of the level of business activity of the stock market

Cluster analysis methods are used to build classification models of economic objects according to the investment attractiveness level (Figure 1). Cluster analysis is the task of dividing a given sample of objects into subsets, which are clusters, so that each cluster consists of similar objects, and the objects of different clusters differ significantly. The clustering problem belongs to statistical processing, as well as to a broad class of unsupervised learning problems. Cluster analysis is a multivariate statistical procedure that collects data containing information about a sample of objects and then arranges the objects into relatively homogeneous groups. A cluster is a group of elements characterized by a certain common property. The main goal of cluster analysis is to find groups of similar objects in the sample and describe their properties.

Cluster analysis models solve the following main problems [10]:

- development of typology and classification;
- research of useful conceptual schemes for grouping objects;
- generation of hypotheses based on data research;
- hypothesis testing or research to determine whether the types (groups) identified in one way or another are actually present in the available data.

Regardless of the subject of study, the application of cluster analysis involves the following stages:

- sample selection for clustering;
- determination of the set of variables by which the objects in the sample will be evaluated;
- calculation of the values of one or another measure of similarity between objects;
- application of the cluster analysis method to create groups of similar objects;
- checking the reliability of cluster solution results.

Cluster analysis has the following data requirements:

- firstly, indicators should not correlate with each other;
- secondly, indicators should be dimensionless, or have a certain general dimension;
- thirdly, their distribution should be close to normal;
- fourthly, the indicators must meet the requirement of "stability", which means the absence of influence on their value by random factors;
- fifth, the sample should be homogeneous, and not contain "outliers".

If cluster analysis is preceded by factor analysis, then the sample does not need "repair" – the stated requirements are automatically fulfilled by the factor modelling procedure itself (there is another advantage – z-standardization without negative consequences for the sample; if it is carried out directly for cluster analysis, it can cause a decrease clarity of distribution of groups). Otherwise, the sample should be brought to a certain standardized form.

When analyzing the results of economic research, it is recommended to carry out the analysis using the methods of the hierarchical agglomerative family, namely the Ward method, in which the minimum dispersion is optimized within the clusters, as a result, clusters of approximately equal sizes are created. Ward's method is the most successful for analyzing economic data. As a measure of difference, the squared Euclidean distance is better, which helps to increase the contrast of clusters. The main result of hierarchical cluster analysis is a graphical interpretation in the form of a dendrogram or "icicle diagram". In its interpretation, researchers face the same problem as the interpretation of the results of factor analysis – the lack of unambiguous criteria for the selection of clusters. As the main ones, it is recommended to use two approaches – visual analysis of the dendrogram and comparison of the results of clustering performed by different methods.

Now there is a question of the stability of the adopted cluster solution [6, p. 1105-1108; 5, p. 230-232]. In fact, checking

DOI: 10.55643/fcaptp.6.59.2024.4486

the stability of clustering is reduced to checking its reliability. Here there is an empirical rule – a stable typology is preserved when clustering methods are changed. The results of hierarchical cluster analysis can be verified by iterative cluster analysis using the k-means method. If the compared classifications of respondent's groups have a rate of coincidence of more than 70% (more than 2/3 of coincidences), then the cluster decision is adopted.

It is impossible to check the adequacy of the solution without the help of another type of analysis. At least, theoretically, this problem has not been solved. In the paper „Cluster Analysis" the authors Oldenderfer and Blashfield examine in detail and ultimately reject an additional five robustness testing methods:

1. Cophenetic correlation is not recommended and is limited in use.
2. Significance tests (variance analysis) always give a significant result.
3. The method of repeated (random) sampling, which, however, does not prove the validity of the decision.
4. Significance tests for external signs are suitable only for repeated measurements.
5. Monte Carlo methods.

Let X be the set of objects, and Y be the set of numbers (names, labels) of clusters. The given function of the distance between objects is $\rho(x, x')$. There is a finite training sample of objects$X^m = \{x_1, \ldots, x_m\} \subset X$. It is required to partition the sample into non-overlapping subsets, called clusters, such that each cluster consists of objects that are metrically close ρ, and the objects of different clusters differ significantly. At the same time, for each object, $x_i \in X^m$cluster number y_i is assigned.

A clustering algorithm is a function $a: X \to Y$, in which any object $x \in X$matches the cluster number $y \in Y$. In some cases, the set Y is known in advance, but more often the task is to determine the optimal number of clusters, from the point of view of one or another clustering quality criterion.

Clustering (unsupervised learning) differs from classification (supervised learning) in that the labels of the initial objects y_i are not initially specified, and even the set Y may be unknown.

The solution to the clustering problem is fundamentally ambiguous, and there are several reasons for this:

1. There is no unambiguously best criterion for clustering quality; a number of heuristic criteria are known, as well as a number of algorithms that do not have a clearly expressed criterion, but which perform a fairly reasonable clustering "by construction"; they can all produce different results.
2. The number of clusters, as a rule, is unknown in advance and is set according to some subjective criterion.
3. The result of clustering significantly depends on the metric, the choice of which, as a rule, is also subjective and determined by an expert.

The tree clustering method is used in the formation of clusters of dissimilarity or distance between objects. These distances can be determined in one-dimensional or multidimensional space. The most direct way to calculate distances between objects in multidimensional space is to calculate Euclidean distances. If two- or three-dimensional space is considered, then this measure is a real geometric distance between objects in space [4, p. 230-232]. It is simply a geometric distance in multidimensional space and is calculated as:

$$(x, y) = [\sum_i (x_i - y_i)^2]^{\frac{1}{2}} \quad (14)$$

It should be noted that the Euclidean distance (and its square) is calculated from the initial, and not from the standardized data. This is a common way of calculating it, which has certain advantages (for example, the distance between two objects does not change when a new object is introduced into the analysis, which may turn out to be an outlier). However, the distance can be strongly affected by the differences between the axes, the coordinates of which these distances are calculated.

Development of discriminant recognition models for assessing the level of business activity in the stock market

The study is aimed at evaluating the prospects for the development of commercial banks' financial investment models in the international context, using discriminant models and analysis. It examines the key factors affecting investment performance and helps determine the best strategies for successful investing in global markets.

The main point is to analyze various economic indicators and risk factors that influence banks' investment decisions. The use of discriminant analysis makes it possible to clearly distinguish between profitable and unprofitable investment opportunities. This study helps commercial banks:

1. Develop effective investment strategies, taking into account international economic conditions and trends.
2. Minimize risks by better understanding market signals and potential threats.
3. Increase the profitability of investments due to more accurate forecasting and analysis of market data.
4. Improve the management of financial resources and optimize their distribution on international markets.

Discriminant analysis is an important tool for banks, which contributes to making informed decisions, reducing risks and increasing the efficiency of their activities.

First, this method allows banks to accurately assess the creditworthiness of customers. By analyzing characteristics such as income level, credit history and other financial indicators, banks can determine who is a reliable borrower and who is risky. This helps to reduce the probability of issuing loans that may not be returned and thus reduce financial risks.

Secondly, discriminant analysis contributes to increasing the efficiency of banks. Thanks to the accurate classification of customers, banks can optimize their resources and focus their efforts on serving the most promising customers. It makes it possible to reduce costs and increase profitability.

Thirdly, this method helps banks adapt to changes in the market. By using discriminant analysis, banks can quickly respond to economic trends and changes in customer behaviour, allowing them to remain competitive.

Construction of adaptive models for forecasting indicators of business activity of the stock market

To forecast the level of business activity in the stock market (Figure 1), adaptive forecasting models are used. Adaptive forecasting models are techniques that automatically adapt to changes in input data or environmental conditions to provide more accurate predictions in the future. These models are particularly useful in areas where the input data may change dynamically or unpredictably (asynchronously).

The main idea behind adaptive models is to regularly update model parameters based on new data. This may include automatically taking into account recent observations or changing model parameters according to certain rules or criteria. One example of adaptive models is adaptive filters, such as Kalman's filter, which are used to estimate the state of a system based on successive measurements. These filters automatically adjust their scores according to new data that comes in over time. Another example would be neural network models used to make predictions based on large amounts of data. Neural networks can learn from new data and adapt their weights and structures to achieve better predictions.

The advantages of adaptive models are their ability to adapt to changes in the environment and input data without the need for manual reconfiguration. This makes them useful for forecasting in situations where it is impossible to predict all possible options for change. However, it is also important to consider that adaptive models may be less robust to noise in the data or overshoots in the input data, so they should be used with caution and with the specific conditions of the problem in mind. Adaptive methods make it possible to build self-correcting and self-adjusting models that are able to quickly respond to changes in conditions by taking into account the result of the forecast made at the previous step.

The simple moving average method uses a moving average when alignment is carried out in a straight line. The most common in the process of forecasting is the method of determining the moving average, using which the forecast indicators are calculated as the average values of the corresponding indicators for n previous periods. Each subsequent forecast indicator is calculated on the basis of the values obtained in *3, 4, ... n* previous periods by replacing the values of the most distant periods with new ones. However, the problem of choosing these values arises. Regarding this, there are certain recommendations for choosing the smoothing period: if the correlation dependence between the time series equations is large, then a smaller smoothing period will give a smaller error; if the correlation dependence between the levels is insignificant, then a longer smoothing period will give a smaller error. Also, the average absolute percentage error can be used to select the best smoothing period.

$$m.a.p.e. = \frac{1}{n}\sum_{t=1}^{n} \frac{|e_t|}{y_t} \cdot 100\%, \quad (15)$$

where $e_t = y_t - y_{t\text{-forcast}}$, n *– the number of observations.*

Exponential smoothing is one of the methods of short-term financial forecasting, which is based on the analysis of a

DOI: 10.55643/fcaptp.6.59.2024.4486

number of dynamics. A distinction is made between exponential smoothing of the first and higher orders.

Exponential smoothing is calculated using the following formula:

$$S = \alpha \cdot y_{t-1} + (1 - \alpha) \cdot S_{t-1} \quad (16)$$

where α is the adaptation parameter; St is the next value of the time series.

As the initial value of the exponential average, the arithmetic average of the first few levels of the series is taken.

The following rules are used to select the adaptation parameter: when forming a long-term forecast, cyclical changes must be smoothed out, so a smaller adaptation parameter should be used; when forming a short-term forecast, fresh information should be taken into account to a greater extent, so the adaptation parameter should be taken close to 1. In general, the adaptation parameter lies in the interval from 0 to 1. Also, as a choice of the best adaptation parameter, you can use the average absolute percentage error. However, there is a formula for determining the optimal adaptation parameter:

$$\alpha = \frac{2}{m+1} \quad (17)$$

where α is the adaptation parameter; m – the period for which it is necessary to make a forecast.

Brown's adaptive model has an algorithm:

1. For exponential smoothing, an adaptation parameter is set.
2. Initial conditions are determined. For the zero-order model, the initial conditions are given by averaging several first levels of the series. For models of a higher order, the coefficients of the corresponding polynomials, the estimates of which are obtained with the help of LSM, are used as primary values.
3. The exponential average is calculated. For models of the second order:

$$S_1^1 = a_0 - \frac{\beta}{\alpha} \cdot a_1 + \frac{\beta \cdot (2-\alpha)}{2\alpha^2} \cdot a_2 \quad (18)$$

$$S_1^2 = a_0 - \frac{2 \cdot \beta}{\alpha} \cdot a_1 + \frac{\beta \cdot (3-2\alpha)}{\alpha^2} \cdot a_2 \quad (19)$$

$$S_1^3 = a_0 - \frac{3 \cdot \beta}{\alpha} \cdot a_1 + \frac{3\beta \cdot (4-3\alpha)}{2\alpha^2} \cdot a_2 \quad (20)$$

where a_1, a_0 are parameters calculated using LSM, α is the adaptation parameter; $\beta = 1 - \alpha$.

Determination of estimates for the coefficients of the quadratic model:

$$a_0 = 3S_t^1 - 3S_t^2 - S_t^3 \quad (21)$$

$$a_1 = \frac{\alpha}{2\beta^2} \cdot \left((6 - 5\alpha) \cdot S_t^1 - 2 \cdot (5 - 4\alpha) \cdot S_t^2 + (4 - 3\alpha) \cdot S_t^3\right) \quad (22)$$

$$a_2 = \frac{\alpha}{\beta^2} \cdot (S_t^1 - 2 \cdot S_t^2 + 3 \cdot S_t^3) \quad (23)$$

A forecast is made 1 step ahead.

$$y_i(t) = a_0 + a_1 \cdot L + \frac{1}{2} \cdot \alpha 2L^2 + \ldots + \frac{1}{n!} \cdot \alpha n \cdot L^n \quad (24)$$

The disadvantage of Brown's model is that the same adaptation parameters are used to adjust the coefficients of the polynomial. Parameters a_0 and a_1 have different semantic load:

- a_0 reflects changes in the average level of the process;
- a_1 reflects process changes per unit of time.

Because of this, different adaptation conditions must be used to adjust the coefficients that are implemented in the Holt model:

$$y_{t+l} = a_0(t) + a_1(t) \cdot L \quad (25)$$

To determine the initial value of a0 the arithmetic mean of the first few levels of the series is used. For a_1 is the arithmetic mean of the first few differences of the levels of the series.

$$a_0(t) = \alpha_0 \cdot y_t + (1 - \alpha_0) \cdot a_0(t-1) + (1 - \alpha_0) \cdot a_1 \cdot (t-1) \quad (26)$$

$$a_1(t) = \alpha_1 \cdot p(t) + (1 - \alpha_1) \cdot a_1 \cdot (t-1) \quad (27)$$

$$p(t) = a_0(t) - a_0(t-1) \quad (28)$$

The Holt-Winters model is used to describe time series containing a multiplicative seasonal component, which includes the determination of the seasonality coefficient and adjustment for the corresponding seasonal factor:

$$y_{t+j} = (a_0(t) + a_1(t) \cdot j) \cdot S \cdot (t = j - k) \quad (29)$$

where k is the number of phases in this cycle.

Next, Holt's procedure is used. Holt's procedure in economics is used to forecast time series that have a trend and seasonal fluctuations. The main principle of the method is to smooth the trend and seasonality to obtain more accurate forecasts.

Initially, the trend in the time series is determined using exponential smoothing. It can be additive, where the trend changes are constant in absolute units, or multiplicative when the trend changes are proportional to the trend values. Trend smoothing helps model an overall upward or downward trend in a time series. If seasonality is present in the time series, it is also smoothed. Additive seasonality applies when fluctuations in seasonal factors are constant in absolute units. On the other hand, multiplicative seasonality applies if the fluctuations are proportional to the trend values.

After smoothing the trend and seasonality, future values in the time series are forecasted. The forecast can be made for a certain period ahead, taking into account previous trends and seasonality.

The Holt method is an effective tool for forecasting in time series with a complex structure, and its use allows for obtaining more accurate and reliable forecasts for making economic decisions.

If the series contains an additive seasonal component, then the Teil-Wage model is used:

$$y_{t+j} = a_0(t) + a_1(t) \cdot j + S(t + j - k) \quad (30)$$

$$V_t = y_t - a_0(t) \quad (31)$$

$$S(t) = \alpha_2 \cdot V_t + (1 - \alpha_2) \cdot S \cdot (t - k) \quad (32)$$

$$U_t = y_t - S(t) \quad (33)$$

Then the general Holt's procedure is used to find the parameters a_1 and a_0

Economic and mathematical modelling in the context of modern international approaches to the financial investment policy of a commercial bank plays a key role in ensuring effective and strategic management of the bank's financial portfolio [2]. It consists in the application of mathematical models for risk analysis, profitability forecasting and optimization of the portfolio structure in order to maximize profit when making decisions and their implementation regarding the investment of the bank's funds.

DISCUSSION

One of the key elements of such modelling is stochastic risk modelling. Banks must assess and manage various types of risk, such as credit risk, market risk, liquidity risk and operational risk. Modern methods of economic and mathematical modelling allow banks to quantitatively assess these risks, develop strategies for their management and make decisions based on these assessments. In addition, the models analyze the structure of the bank's financial portfolio in order to optimize the allocation of assets taking into account the risk level and expected profitability. This may include choosing the optimal ratio between different types of assets, such as loans, securities, real estate, etc., as well as different financial

DOI: 10.55643/fcaptp.6.59.2024.4486

instruments that allow banks to reduce risks and increase profitability.

Modern financial and economic models also take into account the international aspect, since many banks have a global financial portfolio and carry out operations in various markets. This means that they must take into account a variety of international factors, such as exchange rates, geopolitical events and international economic trends when analyzing and managing their financial portfolio. All this allows commercial banks to make more informed and strategic decisions regarding the management of their financial resources and ensures their stability and efficiency in the face of global competition and challenges in the financial market.

A wide range of applications of economic and mathematical models allow banks to forecast various economic development scenarios, market trends, and changes in the financial environment. This helps to adapt investment strategies to different conditions and increases the preparedness level for possible risks. Models allow banks to optimize financial resource management decisions. They take into account various factors such as risks, returns and liquidity to ensure the most efficient investment decisions. Economic and mathematical models allow banks to carry out a comprehensive analysis of risks associated with the implementation of various investment strategies. This includes taking into account possible financial losses, market volatility, and changes in interest rates. The models enable stress testing to assess the resilience of the bank's portfolio to negative economic scenarios and extreme conditions. This helps to identify possible weaknesses and take measures to reduce risks. The models are used to estimate the value of various financial instruments and investment projects, as well as to forecast the bank's portfolio profitability. It helps to make informed decisions on the selection of optimal assets. Economic and mathematical modelling is used to develop strategic investment management plans and further analyze their performance in dynamics.

In general, the implementation of economic and mathematical modelling tools in the practice of decision-making is an important tool for banks in the modern world of finance, helping them to better understand, adapt and optimize their activities in the conditions of constant changes in the financial environment.

CONCLUSIONS

This paper proposes the conceptual scheme for building a set of investment financial analysis models, which includes:

- models of analysis of financial indicators of the bank's activity;
- models for assessing the business activity level of the stock market;
- models of classification of economic objects according to the investment attractiveness level.

The article proposes a conceptual framework for constructing a set of models for financial investment analysis of commercial banks, based on modern instrumental approaches. The key novelty lies in the development of not just a general research framework, but a comprehensive set of adaptive models that can be used to forecast indicators of business activity in the stock market. These models take into account changing economic conditions, technological innovations, and regulatory shifts, allowing commercial banks to manage investments more effectively and make strategic decisions.

Thus, the novelty of the article is in the development of an integrated system of models that not only analyze the current state of the market but also allow for forecasting its development while considering risks and global trends. This helps banks improve their competitiveness and stability in the dynamic conditions of the financial market. The analysis of modern methods of spatial econometric modelling and forecasting made it possible to justify the choice of methods for building models and to consider algorithms for their implementation.

The article reveals important aspects of modelling the financial investment policy of commercial banks in the modern conditions of the global financial market. The analysis of international approaches and the use of economic and mathematical methods provide a clear overview of risk management strategies, portfolio management and optimization of investment returns, which contributes to increasing the efficiency of banking institutions in the global financial environment. The advantages of the analyzed models include their adaptability and ability to account for dynamic changes in the financial market, such as economic fluctuations, technological innovations, and regulatory developments. These models provide a more comprehensive understanding of the market environment, enabling banks to make informed investment decisions and improve risk management strategies. The capacity to forecast business activity indicators also allows for proactive adjustments to investment portfolios, enhancing overall stability and competitiveness.

However, the models also have some limitations. They may require significant data inputs and sophisticated computational resources, making them more complex and potentially costly to implement. Additionally, while the models can help predict trends, their accuracy depends heavily on the quality and timeliness of the data used. In fast-changing markets, there is

always a risk of model inaccuracies or delays in reflecting sudden market shifts, which could lead to suboptimal decision-making.

The paper highlights the importance of economic and mathematical methods in innovative strategy development, providing grounds for accurate forecasting and making informed decisions in the field of financial management. Special attention to mathematical models in the context of financial risks and portfolio management indicates their key role in achieving banking institutions' stability and competitiveness. In general, the article is an important contribution to the modern understanding of the tools of commercial banks' financial resources strategic management and provides grounds for further research in the field of finance and banking.

The prospect of further research in this direction includes a number of aspects that can expand our understanding and optimization of the commercial banks' financial investment policy. Some of the possible directions for further research may include:

1. Study and analysis of modern and innovative financial instruments that can influence the formation of the banking institutions' financial investment strategy.
2. Investigating the impact of technological innovations such as blockchain on banks' investment strategies and risk management.
3. Consideration of global macroeconomic trends, political events and changes in regulation as factors affecting financial markets.
4. Development and improvement of risk management strategies in unstable geopolitical and economic environments.
5. Research on the possibilities of introducing sustainable investment and its impact on banks' financial activity.
6. Analysis of the impact of regulation and standards on financial investment strategies and risk management.

Detailed research of these aspects can help to improve the practical implementation and production of commercial banks' financial investment models and strategies, providing more effective and sustainable solutions in conditions of uncertainty, changes and shocks in financial markets.

In the modern conditions of constant change and globalization of the world economy, commercial banks are forced to adapt their investment strategies. The rapid development of technology, regulatory changes, and increasing global risks require banks to be flexible and capable of quick response. The study of modern approaches to modelling financial investments allows for a better understanding of the factors influencing strategic decision-making. This enables banks to manage investments more effectively, optimizing their actions in line with economic shifts and new challenges.

The results of the research help banks better adapt to regulatory changes and technological innovations, allowing them to avoid risks and improve management strategies. The analysis of global risks aids banks in maintaining stability and competitiveness in the face of dynamic changes in world markets. Thus, the findings are important for both the development of economic science and the improvement of practical management aspects in the banking sector.

ADDITIONAL INFORMATION

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DOI: 10.55643/fcaptp.6.59.2024.4486

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FUNDING

Funded by the EU NextGenerationEU through the Recovery and Resilience Plan for Slovakia under the project No. 09103-03-V01-00042.

CONFLICT OF INTEREST

The Authors declare that there is no conflict of interest.

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СУЧАСНІ ІНСТРУМЕНТАЛЬНІ ПІДХОДИ ДО МОДЕЛЮВАННЯ ПОЛІТИКИ ФІНАНСОВОГО ІНВЕСТУВАННЯ КОМЕРЦІЙНОГО БАНКУ

У статті розглянутий комплекс сучасних аналітичних підходів до системного моделювання політики фінансового інвестування комерційного банку на основі міжнародної практики. Автори досліджують ключові аспекти моделювання й аналітичних технологій, що визначають стратегічні рішення банківських установ у царині фінансового інвестування, зокрема враховуючи глобальні економічні та фінансові тенденції. Стаття висвітлює модельно-методологічні підходи та методичні інструменти, які використовують для аналізу та прогнозування ринкових умов, ризиків і доходності в контексті фінансових інвестицій банків.

Мета дослідження полягає в розширенні інструментального апарату, доведенні значущості ролі технологій та імплементації широкого спектра методів і сучасних міжнародних підходів до моделювання політики фінансового інвестування комерційних банків у напрямі стратегічного розвитку в контексті глобальних мегатрендів. Дослідження базується на інструментарії моделей просторового економетричного аналізу (панельні дані), адаптивного прогнозування динамічних рядів, багатовимірного аналізу даних, кластерного та дискримінантного аналізу.

У роботі презентований агрегований інструментальний базис за основними ключовими напрямами, а саме: аналіз фінансових показників банку; оцінка рівня ділової активності фондового ринку; класифікації та угрупування економічних об’єктів за рівнем інвестиційної привабливості. Дані досліджуваної царини взаємодіють і доповнюють одне одного, дозволяючи комплексно узагальнити та об'єктивно представити фундаментальну базу для ухвалення рішень.

Результати імплементації дозволять визначити оптимальні стратегії фінансового інвестування, які сприяють підвищенню ефективності й стійкості комерційних банків у сучасних умовах глобалізації та фінансової нестабільності. Аналітичний погляд на вивчення міжнародних підходів робить статтю актуальною для фахівців у царині фінансів, економіки та банківської справи.

Ключові слова: комерційні банки, фінансовий сектор, економіко-математичне моделювання, інвестиційний аналіз, кореляція, прогнозування, ухвалення рішень

JEL Класифікація: C24, M31, G21

DOI: 10.55643/fcaptp.6.59.2024.4486