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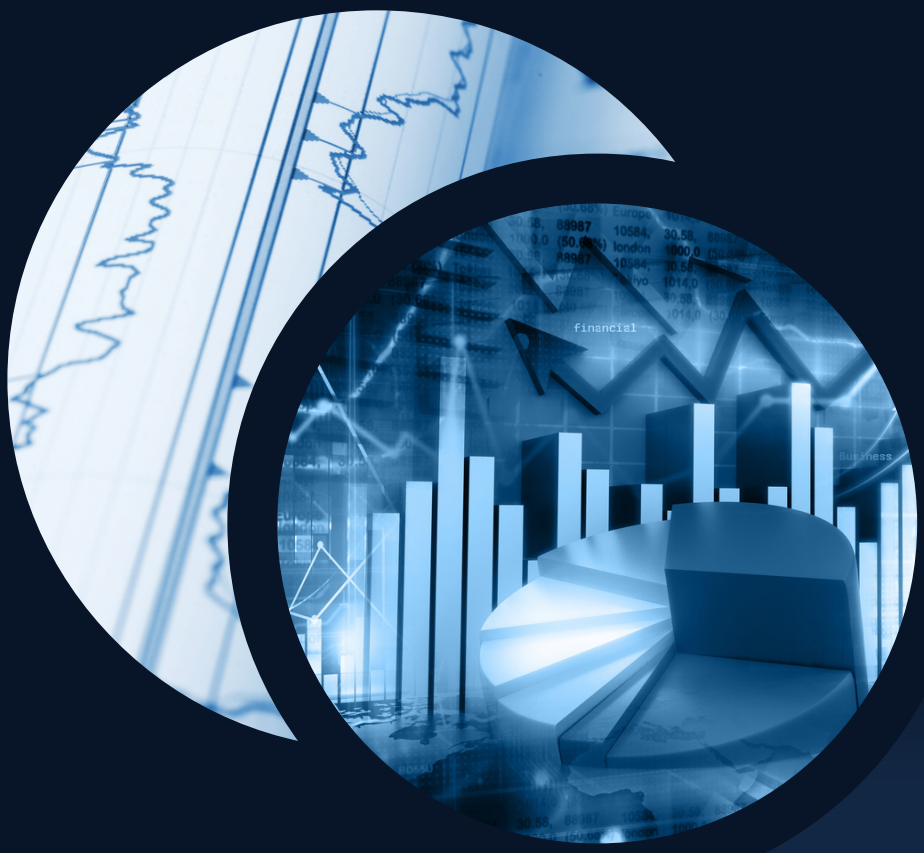
Том 1, № 1, 2023

SMART ECONOMY, ENTREPRENEURSHIP AND SECURITY

Vol. 1, № 1, 2023



НАУКОВИЙ ЖУРНАЛ

SCIENTIFIC JOURNAL

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ЗМІСТ

Vol. 1, № 1 2023 SMART ECONOMY, ENTREPRENEURSHIP AND SECURITY

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JEL: G30

Klymenchukova Nataliia
PhD (Economics), Associate Professor, Doctoral Candidate,
National Academy of Management
Ukraine
ORCID: 0000-0003-0611-4343

Riashchenko Viktoriia
Dr. oec, prof., expert of academy science of Latvia,
Director of the study program Business administration
ISMA University of Applied Sciences (ISMA)
Isma.lv
Latvia
ORCID: 0000-0003-1783-3079

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MODELLING THE FINANCIAL MANAGEMENT STRATEGY OF AN INNOVATIVE ENVIRONMENTAL ENTERPRISE

Abstract. *The modern conditions of the functioning of entrepreneurship are characterized by a high level of uncertainty, in particular, significant fluctuations in the market situation, intensifying competition, and actualization of security aspects of functioning. In addition, a significant anthropogenic impact on the environment and its destructive consequences increase public demand in the greening of economic activity. Therefore, the enterprise's innovative activity is a response to modern challenges. However, in the context of entrepreneurship, innovative activity is associated with additional risks. Such an aggressive functional environment requires enterprises to ensure a high level of management efficiency, so the role of financial management is growing. It is thanks to the effective management of financial flows that the innovative enterprise manages to achieve the minimization of financial risks and maximization of profit. The study was carried out based on financial reporting, which characterizes the entrepreneurial activity of an innovative enterprise. The analysis of the obtained data made it possible to assess the effectiveness of the financial flow management system of the innovative enterprise and to determine reserves for improving the efficiency of financial management. In the research process, statistical and comparative analysis methods were used, statistical modeling and abstraction.*

The assessment of the effectiveness of financial management is a critically important element of the management system, which allows for identifying and eliminating management deficiencies.

As a result of the study, a methodology was developed to assess the effectiveness of financial management of an innovative ecological enterprise.

The implementation of innovative activities, such as the greening of economic activity, requires an enterprise to ensure effective management of the enterprise's resources, in particular, the financial resources. The development and implementation of a highly effective mechanism for managing financial processes, which allows the realization of enterprise goals, is the key to the survival of an enterprise in modern conditions. One of the tools for improving the enterprise management system of financial conditions is the assessment of the effectiveness of financial management.

Keywords: *financial management, efficiency, innovative entrepreneurship, integrated assessment, ecology, reserves, system.*

1. Introduction

The functioning of national enterprises has always taken place under difficult conditions, but the last few years have been characterised by increasing turbulence in the functional environment and levels of uncertainty. The crisis caused first by the COVID-19 pandemic and later by the military aggression of the Russian Federation against Ukraine has brought many national enterprises to the brink of survival. In particular, innovative environmental enterprises are being forced to make excessive efforts to achieve a certain level of operational efficiency that will enable enterprises to survive in an unprecedentedly difficult environment. A significant role in solving this problem is played by the effective management of the innovative enterprise's resources, namely the effective management of financial resources. The purpose of financial management is to level out financial risks and their consequences and to maximise profits. The key elements of the financial management system are the management of the profitableness and profitability of the innovative eco-enterprise and the evaluation of the effectiveness of financial resource management.

The analysis of financial management effectiveness is a complex task that requires the construction of a comprehensive evaluation system to provide information in a convenient form on the available reserves for improving management effectiveness.

Financial management is a set of principles and mechanisms for managerial decision-making on the formation, implementation and development of the financial potential of an enterprise, i.e. it involves a wide range of functions, in particular in the implementation of innovation activities and the greening of production.

Enterprise innovative activity is the key to economic growth and the integration of national enterprises into the global economic system. The implementation of innovative activities is carried out by generating innovative technologies, products or management methods that increase the competitiveness and efficiency of the enterprise.

Many academic studies focus on the financial management problems of enterpreneuership, in particular innovation. For example, a search on Lens.org "("financial management" OR "finance management" OR management of finance") AND (innovations OR innovation OR innovative OR modernization)" has yielded 15,222 research papers from a total of 252.1 million research papers. Accordingly, to the bibliometric analysis, publications on financial management date back to the early 1970s, but a rapid increase in the number of publications on the topic occurred in the early 2000s. The highest number of publications was registered in 2020. A visualisation of a scientometric map reflecting the intensity of the usage of one keyword with others — was constructed using the VOSviewer application. The resulting map is shown in Figure 1.

The map visualises four thematic clusters, comprising objects and the links between them. The size of the object characterises the strength of the overall relationship of the terms and the width of the lines characterises the strength of the relationship between the two terms. The formation of clusters takes place on the basis of the detected keywords. However, the division into clusters is quite conditional, because the clusters are quite strongly related to each other.

A considerable amount of academic work is devoted to the study of the general principles of financial management.

The various aspects, implementation problems, contradictions and benefits of financial management

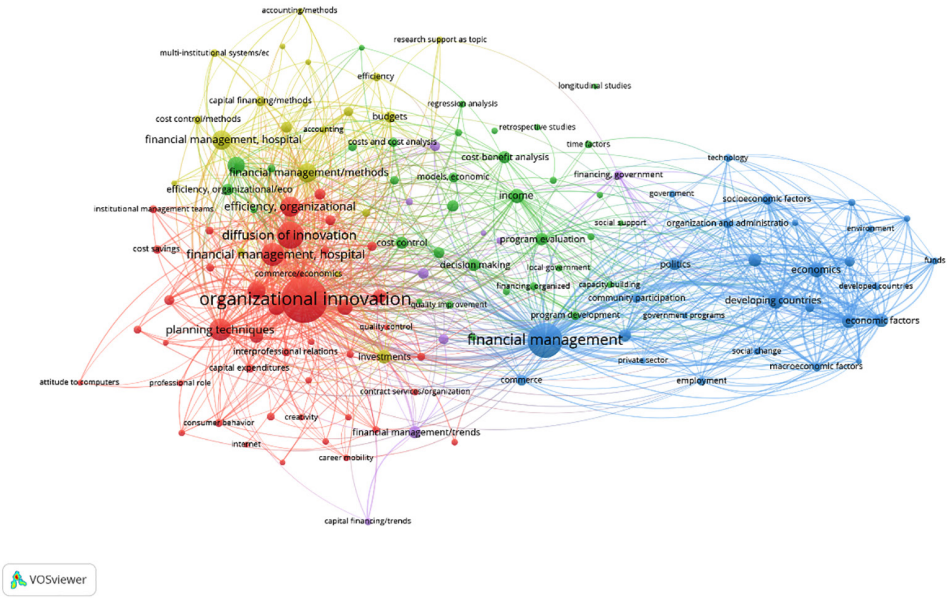

Figure 1. Scientometric map of the subject area "financial management"

Source: Developed by the author based on https://www.lens.org/ using VOSviewer

have been investigated by many scholars around the world, notably Peel and Wilson, [1], Zopounidis, [2], Brounen *et al.*, [3], Brinckmann *et al.*, [4], Kioko *et al.*, [5], Abanis *et al.*, [6], Karadag, [7], and many others. In recent years, there has been an increase in the number of academic papers investigating the implementation of information technology into enterprise financial management practices. For example, Hao, [8], examines the development of an enterprise financial management platform using cloud technology and artificial intelligence. The implementation of innovative technology can improve information management and the quality of enterprise financial management. The author recommends a specific neural network and a bayesian regularisation algorithm for an application, and his work evaluates and analyses asset management in enterprise financial management process. Gao, [9], also notes in his paper the critical role of cloud technology in financial management practices. This is particularly important for small and medium-sized enterprises to reduce operational costs and achieve greater efficiency in financial management. Yang *et al.*, [10], Ren, [11], explore the optimization of enterprise financial management through the implementation of big data in financial management decision-making. Ren, based on information asymmetry theory and risk management theory, explores the role of big data in enterprise financial management. He analyses the impact of big data on the quality of forecasting, the relevance and speed of financial decision-making and the creation of competitive advantages. Ren concludes that the application of big data tools can improve the quality of an enterprise's financial management.

Some scholars separately research the financial management of innovative enterprises, so Bai, [12], in his study looks at the development of financial sector tools that enable the financing of scientific and innovative enterprises. The author stresses that in order to improve the efficiency of financing for innovative enterprises, it is necessary to constantly analyse the available financial tools and to improve financial management and information support for financing at the enterprise level. In addition, according to the author, at the level of the financial sector, it is important to improve the quality of personnel, to establish cooperation between financial institutions and science institutions, and to develop new financial products oriented towards the innovation sector.

Pan, [13], analyses the impact of the financial system on the development of scientific and technical innovation using China as an example. According to the author, the financial system and its efficiency are closely related to scientific and technological development. According to the degree of development of the financial system, the pattern of innovation development can change from a bouncing to a stable pattern.

The specifics of financing an individual innovation industry are considered in their research paper by Zhao *et al.*, [14]. The authors make a factor analysis of the efficiency of enterprise research and development investments using the example of enterprises developing smart home products. Zhao, Meng, and Cai analyse the impact of market, technical and political factors. At the enterprise level, the authors note the impact of financial management on innovation performance. In particular, they emphasise the significant influence of the budgetary mechanism. The development of a new product requires adequate estimation of financial costs, determination of the necessary amount of investment in research and development, and a well-developed planning and management decision-making system. According to the authors, in the context of financial management, it is important to have an internal audit that can identify weaknesses in financial management and prevent the misuse of financial resources. The problems of green or ecological financial management are also the subject of academic research. For example, Dong, [15], researches the concept of green financial management in the context of greening mainstreaming. The author proposes measures to improve the effectiveness of the implementation of this concept, in particular, conducting advanced training for managers in the field of finance and sustainable development, optimisation of accounting in order to obtain a better information resource. Dong also draws attention to the problem of copyright enforcement in the context of new product development. For example, Liu, [16], analyses the importance of optimising the financial management system. In particular, after examining the readiness of enterprises to implement green financial management, the author proposes optimisation measures aimed at optimising financial management staffing.

Tao *et al.*, [17], identify in their scientific paper using a SWOT-analysis the challenges of implementing the concept of green financial management, namely the lack of government support to implement the concept, the lack of sufficient qualified managers and accounting shortcomings.

In the context of economic activity management, the management of a company's financial resources plays a critical role, which makes the issue of measuring the effectiveness of financial management relevant. Kuzmina-Merlino and Savina, [18], Świrska, [19], Raman *et al.*, [20], echamines the problems of efficiency assessment in thir works. The analysis of publications indicates that, despite the large number of scientific papers, some aspects of financial management remain insufficiently covered, in particular, the effectiveness of financial management of innovative environmental enterprise. The purpose of the study is to analyse the features of financial management of an innovative ecological entrepreneurship, as well as to develop a methodology for assessing the effectiveness of financial management of an innovative environmental enterprise.

A significant part of innovative projects is aimed at developing and introducing new technologies,

techniques, principles of production organisation and management solutions aimed at improving the efficiency of nature management, in particular by reducing the resource and energy intensity of production, and reducing the eco-destructive impact of production on the environment. After all, the ecologisation of the economy becomes a particularly urgent task in the context of the growth of negative anthropogenic and technogenic impacts on the environment.

Adequate financial resources support is a prerequisite for the introduction and effective implementation of enterprise innovation activity, particularly greening. It is important to note that the relevance of the problem of greening the national economy is increasing due to the requirements of the European integration process and the lack of public funds to finance ecological projects. Ecologisation of the economy is the key to sustainable development of the country, increased national competitiveness and harmonious use of natural resources. The state policy in the area of innovation and ecology defines the conditions for innovative activity and rational usage of resources by enterprises.

General trends in the development and realisation of national innovation potential are reflected in the global innovation index. Analysis of the dynamics of the index over the past five years indicates that there has been a deterioration in the innovation sphere in recent years (Figure 1).

Thus, between 2018 and 2021, Ukrain's ranking dropped by 6 points to 49th place, and in 2022 it dropped by a further 8 points to 57th place. Importantly, Ukraine scored higher in the innovation output group than in the innovation expenditure group. Ukraine's innovation performance is better than that of its corresponding level of economic development. Ukraine's strongest points in terms of innovation performance are the development and diffusion rates of new knowledge and innovative technology and the productivity of creative activity. The worst indicators are mainly related to the level of market development, institutions and infrastructure, in particular credit and investment policy, and environmental sustainability. Environmental sustainability problems are to some extent the result of the high-energy intensity of the gross domestic product and low implementation level of ISO 14001 certificates.

Innovation and environmental activity of national enterprises are constrained by economic instability in the country. Economic instability reduces the ability of enterprises to make additional expenditures to finance innovation projects, particularly environmental ones. Shortcomings in credit and investment policy at the macro level affect the financial strategy of the innovative enterprise and the efficiency of financial management at the micro level. Financial support of innovation activity is one of the key tasks of the financial management of the enterprise. The sources of financing innovative activity may include the following: own funds of enterprises formed from depreciation charges and profits; public funds accumulated from budgetary or extra-budgetary funds; investment funds; credit resources provided by lending institutions.

Analysis of statistical data on the financing of innovative activities of industrial enterprises during 2016–2020 indicates a significant decrease in financing in 2017 as a whole, but the structure of financing sources saw an increase in financing from budgetary funds and non-resident funds. In 2018–2019, there has been an increase in funding from all

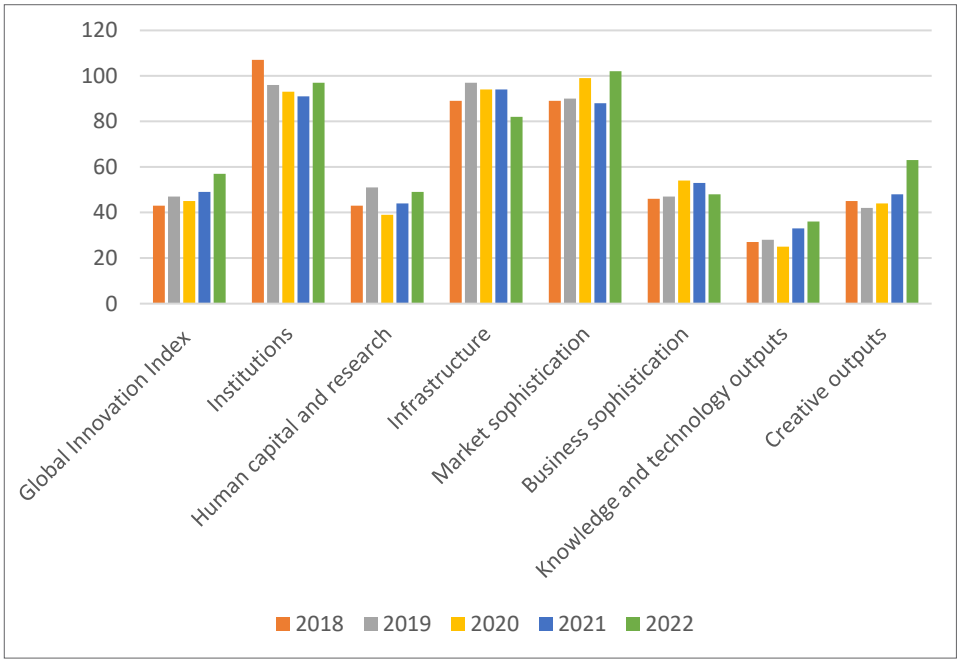

Figure 2. Dynamics of the Global innovation index for Ukraine 2018–2022.

Source: Built by the author research based on data from https://www.wipo.int/directory/en/details.jsp?country_code=UA

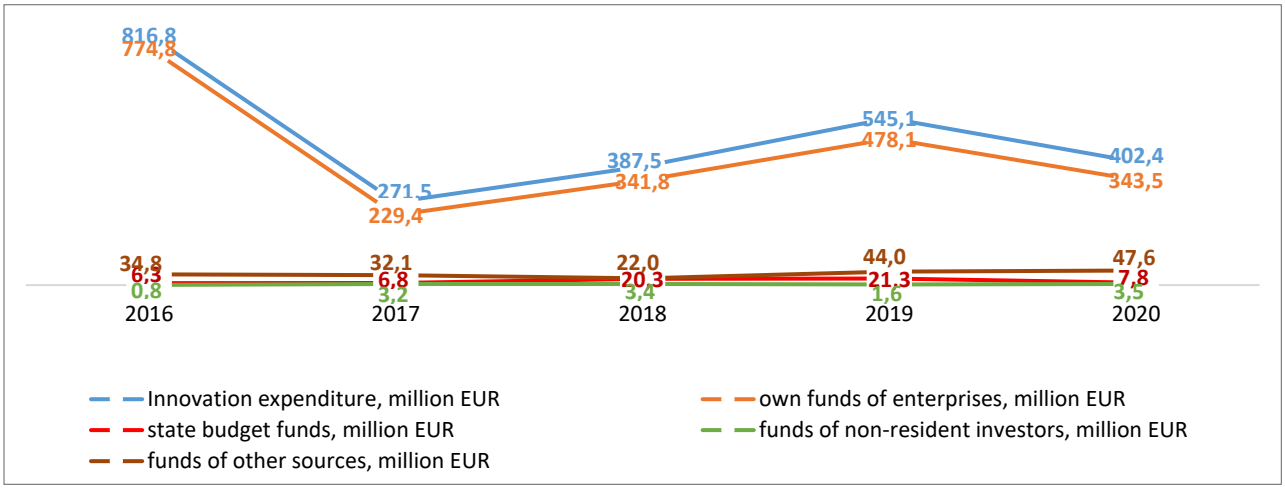

Figure 3. Financing sources of innovation activities of industrial enterprises

Source: Built by the author based on data from https://ukrstat.gov.ua/operativ/menu/menu_u/ni.htm

sources except funding from other sources in 2018 and from non-residents in 2019. In 2020, however, there was a decrease in funding for innovation, in particular, due to the COVID-19 pandemic crisis. The increase in funding came only from non-residents and unstructured sources.

Moreover, military aggression on the part of the Russian Federation has resulted in a difficult situation for innovation activity. On the one hand, the financial resources that can be used to finance innovative projects, in particular environmental projects, the risks associated with martial law have increased, and uncertainty has increased. On the other hand, the need to find, develop and implement new solutions to enable national enterprises to adapt to modern conditions, to level out the negative effects of war, and to ensure the survival of the enterprise in such difficult conditions has increased.

Based on the above, the factors that influence the financial management system of an innovative enterprise include: the availability of funding sources; the maturity of the banking system; the degree of enterprise integration into the global economy; the development of venture capital financing; the level of private ownership; the level of motivation for innovation activities.

Under current conditions, the financial management system of an innovative enterprise addresses the following problems: lack of funding sources; in particular the reduction of public funding; low access to long-term credit resources due to imbalances in the banking system; low access to venture capital; low level of innovation infrastructure development due to lack of financial resources; low level of private property institution development, in particular the unprotected rights of intellectual property. The effectiveness of the financial management of an innovative enterprise depends on the degree to which the enterprise's innovative activity, in particular its green manufacturing projects, are provided with financial resources. Assessing the effectiveness of a company's financial management allows the identification of systemic weaknesses and possible ways to eliminate them. An effective evaluation generates an information resource that allows for more adequate management decision-making in conditions of high uncertainty.

2. Materials and Methods

The study was carried out based on the universal financial statements of an innovative environmental enterprise. The financial management of the enterprise is based on the fact that the economic and financial processes occurring in the enterprise form a single complex system. With this approach, management's influence on the financial and economic processes of the enterprise forms some specific qualities of this system and allows achieving more effective implementation of the financial management functions of the enterprise due to the resulting synergistic effect. Therefore, in the context of assessing the results of financial management functioning, it is important to develop such an assessment methodology that will take into account the impact of emergent qualities of the system.

Therefore, in order to study the level of financial management efficiency of an innovative ecological company, it is advisable to use a methodology involving the usage of dynamic normative in a systematic analysis of structural configurations. A similar technique was used by Lazko, who continued the Syroezhyn scientific school of system analysis. The essence of the method consists in modelling a normative system of ordered indicators reflecting the effectiveness of financial resources management and carrying out a comparative analysis of actual values [21]. Analysis of the dynamics of changes makes it possible to assess the effectiveness of implementation of the financial strategy over time. The general algorithm for this methodology involves the following steps:

1. Formation of a set of indicators that comprehensively characterise the business activity of an

enterprise, in particular, innovation and environmental activity;

2. Design a target matrix reflecting the normative values of the selected indicators according to the chosen strategy.

3. Formation of a current results matrix, which is compiled based on the actual values of the selected indicators;

4. Conducting a comparative analysis and generating a correspondence matrix and a discrepancy matrix;

5. Calculation of the integral indicator characterising the efficiency of the financial management of an enterprise.

The first stage is the selection of financial indicators accumulated from accounting records. It is advisable to include in the model those indicators that reflect the goal of financial management of the innovative enterprise, e.g. increasing profitability, ensuring financial sustainability, etc. It is important to note that most financial indicators that reflect the objectives of financial management are represented by ratios, namely: profitability ratios, liquidity ratios, financial independence and sustainability ratios.

The second step involves the design of a target matrix incorporating the selected financial data. The selected ratios are represented in the target matrix by the ratios of the growth rate of the numerator and denominator of an individual financial ratio. After all, based on the fact that financial ratios are represented by fractions, the growth of the ratios occurs if the growth rate of the numerator exceeds the growth rate of the denominator. According to the set of indicators, the target matrix is formed in the following quadratic -form (1):

$$\mathbf{A} = \begin{bmatrix} \alpha_{11} & \cdots & \alpha_{1m} \\ \vdots & \vdots & \vdots \\ \alpha_{i1} & \alpha_{ij} & \alpha_{im} \\ \vdots & \vdots & \vdots \\ \alpha_{m1} & \cdots & \alpha_{mm} \end{bmatrix}, \quad (1)$$

where A — is the target financial matrix;

α_{ij} — normative value of the ratio between the growth rate of i indicator and the growth rate of j indicator, with $\alpha_{ij} \in [-1;2]$;

m — the order of the matrix A, determined by the number of indicators selected for the model.

The definition of the element α_{ij}, is determined by the following system of conditions (2), which is shaped by the strategic objectives of the financial management of the enterprise:

$$\alpha_{ij} = \begin{cases} -1, \ T(X_i) < T(X_j); \\ 1, \ T(X_i) > T(X_j), \ T(X_i) \cdot T(X_j)^{-1} - 1 \le k_{ij}, \ k_{ij} > 0; \\ 2, \ T(X_i) > T(X_j), \ T(X_i) \cdot T(X_j)^{-1} - 1 > k_{ij}, \ k_{ij} > 0; \\ 0, \ \textit{collaration beetwen } T(X_i) \textit{ and } T(X_j) \textit{ has not been established, or } X = 0; \end{cases} \quad (2)$$

where $T(X_i)$, $T(X_j)$ — growth rate of i indicator and j indicator;

k_{ij} — the target limit value, determined in accordance with the strategic financial objectives. If no value k_{ij} not set, the element α_{ij} is defined within the values of [–1; 1].

So, if the growth rate of the i indicator $T(X_i)$ does not exceed the growth rate of j indicator $T(X_j)$, then $\alpha_{ij} = -1$ if the growth rate of i indicator $T(X_i)$ exceeds the growth rate of j indicator $T(X_j)$ by more than the threshold value k_{ij}, then $\alpha_{ij} = 2$; the growth rate of i indicator $T(X_i)$ exceeds the growth rate of j indicator $T(X_j)$ is less than or equal to the threshold k_{ij} value, or equal to it, then if the ratio between the growth rate of i and j indicators has not been established, then $\alpha_{ij} = 0$. Thus, the strategic objectives of the financial management of the enterprise are aggregated.

The following formula (3) should be used to determine the growth rate of the financial indicator:

$$T(X_i) = X_i^t \cdot \left(X_i^{t-1}\right)^{-1}, \quad (3)$$

where X_i^t — is the value of the financial indicator in the current period,

X_i^{t-1} — value of the i financial indicator in the previous period.

The next step is to calculate the results matrix $\mathbf{R}$ (4):

$$\mathbf{R} = \begin{bmatrix} \rho_{11} & \cdots & \rho_{1m} \\ \vdots & \vdots & \vdots \\ \rho_{i1} & \rho_{ij} & \rho_{im} \\ \vdots & \vdots & \vdots \\ \rho_{m1} & \cdots & \rho_{mm} \end{bmatrix}, \quad (4)$$

where $\mathbf{R}$ — the matrix of actual results,

ρ_{ij} — the actual value of the ratio between the growth rate of indicator i and the growth rate of j indicator, with $\rho_{ij} \in [-1;2]$;

m — the order of the matrix $\mathbf{R}$ determined by the number of indicators being monitored. Calculation of the element ρ_{ij} is calculated according to the following diagram (5):

$$\rho_{ij} = \begin{cases} -1, \ T(X_i) < T(X_j); \\ 0, \ T(X_i) = T(X_j); \\ 1, \ T(X_i) > T(X_j), \ T(X_i) \cdot T(X_j)^{-1} - 1 \le k_{ij}, \ k_{ij} > 0; \\ 2, \ T(X_i) > T(X_j), \ T(X_i) \cdot T(X_j)^{-1} - 1 > k_{ij}, \ k_{ij} > 0; \end{cases} \quad (5)$$

Thus, if the growth rate of the i indicator $T(X_i)$ does not exceed the growth rate of j indicator $T(X_j)$, then $\rho_{ij} = -1$ if the growth rate of i indicator $T(X_i)$ exceeds the gwth rate of j indicator $T(X_i)$ by more than the threshold value k_{ij}, then $\rho_{ij} = 2$; the $\alpha_{ij} = 1$ growth rate of i indicator $T(X_i)$ exceeds the growth rate of j — key value $T(X_j)$ by an amount less than or equal to the threshold value k_{ij}, or equal to it, then $\rho_{ij} = 1$; if the value k_{ij} is not set, the element ρ_{ij} is determined within

the limits of values of $[-1;1]$; if the growth rate of i is equal to the growth rate of the j — indicator, then $\rho_{ij} = 0$. The next step involves the calculation of a correspondence matrix C, which reflects the result of checking the normative and actual ratios of the growth rates of the financial indicators for coincidence (6):

$$C = \begin{bmatrix} c_{11} & \cdots & c_{1m} \\ \vdots & \vdots & \vdots \\ c_{i1} & c_{ij} & c_{im} \\ \vdots & \vdots & \vdots \\ c_{m1} & \cdots & c_{mm} \end{bmatrix} \quad (6)$$

where C — the matrix of correspondence of the actual indicators with the normative ones;

c_{ij} — the coincidence of the actual and normative ratios between the growth rate of i indicator and the growth rate of j indicator, at the same time $c_{ij} \in [0;2]$.

Calculation of the C matrix elements is calculated using the following constraint system (7):

$$c_{ij} = \begin{cases} 2, \ \alpha_{ij} > 1 \quad \rho_{ij} \geq 2; \\ 1, \ \alpha_{ij} > 0 \quad \rho_{ij} \geq 1; \\ 1, \ \alpha_{ij} = -1 \quad \rho_{ij} \leq 0; \\ 0, \ \textit{under other conditions}; \end{cases} \quad (7)$$

Next, it is useful to calculate a deviation matrix D, which includes the results of checking for discrepancies of the actual normative ratios of the growth rates of the financial indicators (8):

$$D = \begin{bmatrix} d_{11} & \cdots & d_{1m} \\ \vdots & \vdots & \vdots \\ d_{i1} & d_{ij} & d_{im} \\ \vdots & \vdots & \vdots \\ d_{m1} & \cdots & d_{mm} \end{bmatrix}, \quad (8)$$

where D — is a matrix of deviations of the actual indicators from the normative ones,

d_{ij} — error of coincidence of actual and normative ratios between growth rates of i indicator and the growth rate of j indicator, at the same time $d_{ij} \in [0;1]$.

The elements of the matrix

D are calculated by the following constraint system (9):

$$d_{ij} = \begin{cases} 1, \ \alpha_{ij} > 0 \quad \rho_{ij} < 0; \\ 1, \ \alpha_{ij} = -1 \quad \rho_{ij} > 0; \\ 0, \ \textit{under other conditions}. \end{cases} \quad (9)$$

The resulting matrices make it possible to determine an integral indicator I, which characterizes the efficiency of financial management of the enterprise. The integral indicator is calculated using the formula (10):

$$I = S_c / S_\alpha \quad (10)$$

Components of the integral indicator S_c and S_α calculated by formulas (11) and (12):

$$S_c = \sum C \cdot \bar{B} \quad (11)$$

$$S_\alpha = \sum_{i=1}^{m} \sum_{j=1}^{m} \left| \beta_j \cdot \alpha_{ij} \right| \quad (12)$$

Where $\bar{B} = \begin{pmatrix} \beta_1 \\ \vdots \\ \beta_j \\ \vdots \\ \beta_m \end{pmatrix}$ — is the vector of the weighting coefficients of the financial indicators of the innovative company. In order to determine the reserves for improving the efficiency of financial management of an innovation enterprise, it is advisable to determine the impact of individual factors, in particular the level of deviation of the partial financial result, which is reflected in a separate i indicator from the strategic objectives. The following formula (13) can be used for this purpose:

$$L(X_i) = \left(\sum_{j=1}^{m} \beta_j \cdot d_{ij} \right) \cdot S_\alpha^{-1}. \quad (13)$$

This approach makes it possible to carry out an integral assessment of the effectiveness of financial management of an innovative environmental enterprise. By analysing the impact of individual factors on the integral assessment, it is possible to identify the reserves for improving the effectiveness of financial management, because the elimination of deficiencies that prevent the achievement of strategic objectives will lead to an increase in the effectiveness of the management system. The advantage of the proposed methodology is that the accounting records can serve as a source of information and the calculated integral indicator provides additional information for more adequate management decisions.

3. Results and Discussion

The study of the effectiveness of financial management took place at four companies (N_1, N_2, N_3, N_4), which carry out innovative activity, in particular implementing measures of green production. The following financial indicators were selected to assess the effectiveness of the financial management of the individual company, as shown in Table 1.

In the context of assessing the effectiveness of financial management of an innovative environmental enterprise, it is advisable to analyse, in addition to the main financial indicators, the indicators that characterise the innovative and environmental activities of the enterprise. For example, costs related to the payment of penalties for violations of environmental legislation; losses related to eco-destructive impacts; the cost of current assets necessary for the implementation of environmental protection works;

Table 1

Financial indicators selected for analysis of financial management effectiveness

i, j	Indicator	Symbolic designation
1	Cost of goods sold	f1
2	Net income	f2
3	Net income from sales of products (goods, works, services)	f3
4	Operating profit	f4
5	Assets	f5
6	Administrative expenses	f6
7	Selling expenses	f7
8	Labour costs	f8
9	Material costs	f9
10	Operating costs	f10
11	Long-term liabilities	f11
12	Current liabilities	f12
13	Current assets	f13
14	Non-current assets	f14
15	Equity	f15
16	Cash	f16
17	Receivables	f17
18	Environmental mandatory payments and fines: expenses on payment of fines related to destrictive environmental impact and violation of environmental legislation; losses related to destructive environmental impact	f18
19	Production greening costs: the cost of current assets required to implement environmental protection activities; repair, maintenance and depreciation costs for environmental equipment; costs of innovative activities related to greening; maintenance and disposal of eco-destructive waste	f19
20	Expenditure on the development and implementation of innovative technologies	f20
21	Net income generated from the implementation of innovative projects	f21

Source: compiled by the author

costs of repair works, maintenance and depreciation of environmental equipment; costs of innovative activities related to greening; costs of maintenance and disposal of harmful waste; costs of development and implementation of innovative technologies; income received from the implementation of innovative projects.

After selecting the financial indicators for analysis, the next step is to build the target matrices A_{n1}, A_{n2}, A_{n3}, A_{n4} for the surveyed enterprises N_1, N_2, N_3, N_4 respectively. The target matrices should reflect the goals of financial strategies for the year 2021. The constructed target matrices are presented in Table 2.

It is important to note that only at enterprise N were the boundary coefficients applied $k_{21\,5} = 0,05$ and $k_{21\,20} = 0,03$.

The next step was to build the results matrices R_{n1}, R_{n2}, R_{n3}, R_{n4}, which characterise the actual implementation of the financial strategies of the enterprises. The results matrices are presented in Table 3.

In the next step, compliance matrices C_{n1}, C_{n2}, C_{n3}, C_{n4}, were calculated to assess the extent to which the objectives of the company's financial strategies have been achieved. The calculated compliance matrices are shown in Table 4.

In the interim stage of identifying reserves for improving the efficiency of the company's financial management, deviation matrices were constructed D_{n1}, D_{n2}, D_{n3}, D_{n4}. The constructed deviation matrices are shown in Table 5.

The proposed approach involves the calculation of an integral indicator to assess the effectiveness of financial management of the enterprise. So at the enterprise N_1 the integral index is equal to:

$$I_{n1} = \frac{3.362}{13.388} = 0.251.$$

The obtained value is much lower than 0.5, i.e. the objectives of the financial strategy were achieved by 25.1%. This is a critically low level of efficiency and requires revision of the financial strategy of the enterprise.

For company N_2 the integral index is equal to $I_{n2} = 0,515$, for company N_3 the integral index is equal to $I_{n3} = 0,468$, for company N_4 the integral index is equal to $I_{n4} = 0,659$.

That is, the highest level of financial management efficiency is at enterprise N_4, a slightly lower level of efficiency is at enterprises N_2 and N_3. The lowest level is at N_1.

In order to improve the efficiency of financial management, it is advisable for all companies to analyse the level of variance for individual financial indicators. The results of the calculation of the levels of variance for individual financial indicators for companies N_1, N_2, N_3, N_4 are shown in Table 6.

Table 2

Target matrices for enterprises N_1, N_2, N_3, N_4

$$A_{n1} = \begin{bmatrix}
0 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & -1 & -1 & -1 \\
1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
1 & -1 & 0 & -1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & -1 \\
1 & -1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & -1 \\
0 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 & -1 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & -1 \\
0 & -1 & -1 & -1 & 0 & 0 & -1 & -1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & -1 & 0 & -1 \\
0 & -1 & -1 & -1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & -1 & 0 & -1 \\
0 & -1 & -1 & -1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\
0 & -1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & -1 & 0 & -1 \\
0 & -1 & -1 & -1 & -1 & 0 & 0 & 0 & -1 & 0 & 0 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \\
-1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \\
0 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & -1 & -1 & -1 & 0 & -1 & -1 & -1 & -1 & -1 & -1 \\
0 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 & -1 \\
0 & -1 & -1 & -1 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\
0 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & -1 \\
0 & -1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & -1 \\
0 & -1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\
0 & -1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\
0 & -1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\
0 & -1 & -1 & -1 & 0 & 1 & 1 & 0 & 1 & 1 & 1 & -1 & 0 & 0 & -1 & 0 & 1 & 0 & 0 & -1 & -1 & -1 \\
1 & -1 & -1 & -1 & 0 & 1 & 1 & 0 & 1 & 1 & 1 & -1 & 0 & 0 & -1 & 0 & 1 & 0 & -1 & -1 & -1 & -1 \\
1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & -1 & 0 & 0 & -1 & 0 & 1 & 1 & 0 & 0 & -1 \\
1 & -1 & 1 & 1 & 2 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 2 & 1 & 0 & 0
\end{bmatrix},$$

$$A_{n2} = \begin{bmatrix}
0 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & -1 & -1 & -1 \\
1 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
1 & -1 & 0 & -1 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & -1 \\
1 & -1 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & -1 \\
0 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 & -1 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & -1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & -1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & -1 & 0 & -1 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & -1 & 0 & -1 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\
0 & -1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & -1 & 0 & -1 \\
0 & -1 & -1 & -1 & -1 & 0 & 0 & 0 & -1 & 0 & 0 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\
0 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & -1 & -1 & -1 & 0 & -1 & -1 & -1 & -1 & -1 & -1 \\
0 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 & -1 \\
0 & -1 & -1 & -1 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\
0 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\
0 & -1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & -1 \\
0 & -1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\
0 & -1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\
0 & -1 & -1 & -1 & 0 & 1 & 1 & 0 & 1 & 1 & 1 & -1 & 0 & 0 & -1 & 0 & 1 & 0 & 0 & -1 & -1 & -1 \\
1 & -1 & -1 & -1 & 0 & 1 & 1 & 0 & 1 & 1 & 1 & -1 & 0 & 0 & -1 & 0 & 1 & 0 & -1 & -1 & -1 & -1 \\
1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & -1 & 0 & 0 & -1 & 0 & 1 & 1 & 0 & 0 & -1 \\
1 & -1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0
\end{bmatrix},$$

$$A_{n3} = \begin{bmatrix}
0 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & -1 & -1 & -1 \\
1 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
1 & -1 & 0 & -1 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & -1 \\
1 & -1 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & -1 \\
0 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & -1 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & -1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & -1 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & -1 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & -1 & 0 & -1 \\
0 & -1 & -1 & -1 & -1 & 0 & 0 & 0 & -1 & 0 & 0 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \\
-1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \\
0 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 & -1 \\
0 & -1 & -1 & -1 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\
0 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\
0 & -1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & -1 \\
0 & -1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\
0 & -1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\
0 & -1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\
0 & -1 & -1 & -1 & 0 & 1 & 1 & 0 & 1 & 1 & 1 & -1 & 0 & 0 & -1 & 0 & 1 & 0 & 0 & -1 & -1 & -1 \\
1 & -1 & -1 & -1 & 0 & 1 & 1 & 0 & 1 & 1 & 1 & -1 & 0 & 0 & -1 & 0 & 1 & 0 & -1 & -1 & -1 & -1 \\
1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & -1 & 0 & 0 & -1 & 0 & 1 & 1 & 0 & 0 & -1 \\
1 & -1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0
\end{bmatrix},$$

$$A_{n4} = \begin{bmatrix}
0 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & -1 & -1 & -1 \\
1 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
1 & -1 & 0 & -1 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & -1 \\
1 & -1 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & -1 \\
0 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & -1 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & -1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & -1 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & -1 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & -1 & 0 & -1 \\
0 & -1 & -1 & -1 & -1 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & -1 & -1 & -1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\
0 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 & -1 \\
0 & -1 & -1 & -1 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\
0 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\
0 & -1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & -1 \\
0 & -1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\
0 & -1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\
0 & -1 & -1 & -1 & 0 & 1 & 1 & 0 & 1 & 1 & 1 & -1 & 0 & 0 & -1 & 0 & 1 & 0 & 0 & -1 & -1 & -1 \\
1 & -1 & -1 & -1 & 0 & 1 & 1 & 0 & 1 & 1 & 1 & -1 & 0 & 0 & -1 & 0 & 1 & 0 & -1 & -1 & -1 & -1 \\
1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & -1 & 0 & 0 & -1 & 0 & 1 & 1 & 0 & 0 & -1 \\
1 & -1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0
\end{bmatrix},$$

Source: Calculated by the author

Table 3

Results matrices for companies N_1, N_2, N_3, N_4

$$R_{n1} = \begin{bmatrix}
0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & -1 & -1 \\
-1 & 0 & -1 & 1 & -1 & -1 & -1 & -1 & -1 & -1 & 0 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \\
-1 & 1 & 0 & -1 & 1 & -1 & -1 & -1 & -1 & -1 & 0 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \\
-1 & -1 & -1 & 0 & -1 & -1 & -1 & -1 & -1 & -1 & 0 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \\
0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & -1 & 0 & 0 & 0 & 1 & 0 & -1 & 1 & 0 & 0 & 0 & 0 & 1 & \\
0 & 1 & 1 & 1 & 1 & 0 & 0 & 1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 & 0 & -1 & \\
0 & 1 & 1 & 1 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & \\
0 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & \\
0 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 1 & 0 & 0 & -1 & 1 & 1 & 1 & -1 & 1 & 1 & 1 & 1 & 1 & \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \\
0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & \\
0 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & -1 & 0 & 1 & 1 & -1 & 1 & 1 & 1 & 1 & 1 & \\
0 & 1 & -1 & 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & \\
0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & \\
0 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & \\
0 & -1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & -1 & 0 & -1 & -1 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & -1 & -1 & \\
0 & 1 & 1 & 1 & 0 & -1 & 1 & 0 & -1 & -1 & 0 & -1 & 0 & 0 & -1 & 0 & 0 & 0 & -1 & -1 & -1 & -1 & \\
1 & 1 & 1 & 1 & 0 & 1 & 1 & 0 & -1 & -1 & 0 & -1 & -1 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 1 & \\
1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & -1 & -1 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 1 & \\
1 & 1 & 1 & 1 & -1 & 1 & 1 & -1 & -1 & -1 & 0 & -1 & -1 & 1 & -1 & -1 & -1 & 0 & & & & &
\end{bmatrix},$$

$$R_{n2} = \begin{bmatrix}
0 & -1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 1 & 1 \\
1 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
-1 & -1 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & -1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & -1 & 1 & 1 \\
-1 & -1 & -1 & 0 & -1 & 0 & 0 & 0 & 0 & -1 & -10 & -1 & -1 & 1 & -1 & -1 & -1 & 1 & 1 & -1 & -1 & -1 \\
0 & -1 & -1 & 1 & 0 & 0 & 0 & 0 & 0 & -1 & -10 & 0 & 0 & 1 & 0 & -1 & -1 & 0 & 0 & 0 & 1 & \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
0 & -1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 & 0 & 1 \\
-1 & -1 & -1 & 1 & 1 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & -1 & -1 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \\
0 & -1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & -1 & 1 & 0 & -1 & 1 & 1 & 1 & -1 & 1 & 0 & -1 & 1 & \\
0 & -1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & -1 & 1 & 1 & 0 & 1 & 1 & 1 & -1 & 1 & 1 & -1 & 1 & 1 \\
0 & -1 & -1 & -1 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\
0 & -1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & -1 & 1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
0 & -1 & -1 & 1 & 0 & -1 & 0 & -1 & -1 & -1 & 0 & 0 & -1 & 0 & 0 & 0 & -1 & 1 & 1 & -1 & -1 & \\
1 & 1 & 1 & 1 & 0 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 1 & 0 & 1 & 0 & 1 & 1 & \\
-1 & -1 & -1 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 1 & 0 & 1 & -1 & 0 & 1 & \\
-1 & -1 & -1 & 1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & 1 & -1 & -1 & -1 & -1 & 1 & -1 & -1 & 0 &
\end{bmatrix},$$

$$R_{n3} = \begin{bmatrix}
0 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 & 1 \\
1 & 0 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & 1 & 1 & 1 & -1 & 1 \\
1 & 1 & 0 & -1 & -1 & 0 & 0 & 0 & 0 & 1 & 0 & -1 & -1 & -1 & -1 & -1 & -1 & 1 & 1 & 1 & -1 & 1 \\
1 & 1 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & -1 & 1 & 1 & 1 & -1 & 1 & 1 & 1 & 1 & 1 \\
0 & 1 & 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & -1 & 1 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & -1 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 & 0 & 0 & -1 \\
0 & -1 & -1 & -1 & -1 & 0 & 0 & 0 & 1 & 0 & 0 & -1 & -1 & -1 & -1 & -1 & 1 & 1 & 1 & -1 & 1 & \\
1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & -1 & -1 & -1 & -1 & 1 & 1 & 1 & -1 & 1 & \\
0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 1 & 1 & 0 & -1 & 1 & 1 & 1 & 1 & \\
0 & 1 & 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & -1 & 0 & 1 & 1 & -1 & 1 & 1 & 1 & 1 & \\
0 & 1 & 1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & \\
0 & 1 & 1 & -1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & \\
0 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & \\
0 & -1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & -1 & -1 & -1 & -1 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 1 & \\
0 & -1 & -1 & -1 & 0 & -1 & -1 & 0 & -1 & -1 & -1 & -1 & -1 & 0 & 0 & -1 & 0 & 0 & 0 & -1 & -1 & \\
-1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 1 & -1 & -1 & -1 & -1 & -1 & 0 & 0 & -1 & 0 & 1 & 0 & 1 & \\
1 & 1 & 1 & -1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & -1 & -1 & 0 & 0 & -1 & 0 & 1 & 0 & 0 & 1 & \\
-1 & -1 & -1 & -1 & -1 & -1 & 1 & -1 & 1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -11 & -1 & -1 & 0 &
\end{bmatrix},$$

$$R_{n4} = \begin{bmatrix}
0 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 & -1 & & \\
1 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & -1 & -1 & 1 & 1 & 1 & 1 & & \\
1 & -1 & 0 & -1 & -1 & 0 & 0 & 0 & 0 & 1 & 1 & -1 & -1 & -1 & -1 & -1 & -1 & 1 & 1 & 1 & -1 & \\
1 & -1 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 1 & 1 & -1 & -1 & 1 & 1 & 1 & 1 & & \\
0 & -1 & 1 & -1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & -1 & 0 & -1 & 1 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & -1 \\
0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & -1 & -1 & \\
0 & -1 & -1 & -1 & -1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & -1 & -1 & -1 & -1 & 1 & 1 & -1 & -1 & \\
-1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & -1 & -1 & 1 & 1 & -1 & -1 & \\
0 & -1 & 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 & -1 & 0 & 1 & 1 & 1 & 1 & 1 & \\
0 & -1 & 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & -1 & -1 & -1 & 1 & 1 & 1 & 1 & 1 & & \\
0 & -1 & 1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & \\
0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & \\
0 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & \\
0 & -1 & 1 & -1 & -1 & 0 & 0 & 0 & 1 & 1 & -1 & -1 & 0 & 0 & -1 & 0 & 0 & 0 & 1 & -1 & & \\
0 & -1 & -1 & -1 & 0 & -1 & -10 & 1 & -1 & -1 & -1 & -1 & 0 & 0 & -1 & 0 & 0 & 1 & -1 & & & \\
-1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & -1 & -1 & -1 & -1 & -1 & 0 & 0 & -1 & 0 & -10 & -1 & -1 & & \\
1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & -1 & -1 & 0 & 0 & -1 & 0 & 1 & 1 & 0 & -1 & \\
1 & -1 & 1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 & -1 & -1 & 1 & 1 & 1 & 0 &
\end{bmatrix},$$

Source: Calculated by the author

Table 4

Compliance matrices for companies N_1, N_2, N_3, N_4

$$C_{n1} = \begin{bmatrix} 00000000000000000111 \\ 00010000000000010000 \\ 00011000000000010000 \\ 01000000000000010000 \\ 00000001000000010000 \\ 00000001000000000101 \\ 00000000000000001101 \\ 00001000000000000000 \\ 00001000000000000000 \\ 00000000000010001000 \\ 00000000000000000000 \\ 00000000010000000000 \\ 00000000000010101110 \\ 00100000000100000001 \\ 00000000000000000000 \\ 00000000010010001110 \\ 01111000000000100001 \\ 00000010000010010111 \\ 10000110000010010101 \\ 10000000000010010100 \\ 10110110000001011000 \end{bmatrix},$$

$$C_{n2}\text{N1, N2, N3, N4} = \begin{bmatrix} 01000000000000000100 \\ 10111000110111111011 \\ 01001000010111111010 \\ 01000000000010001001 \\ 01100000000000000000 \\ 00000011000000000100 \\ 00000100000000000100 \\ 00001000000000000000 \\ 01000000010000000100 \\ 01100001000000000110 \\ 00000000001111111111 \\ 01100000010100010110 \\ 01100000011010011000 \\ 01110000010100000001 \\ 01100000010000000000 \\ 01100000010000001000 \\ 01100000011100000000 \\ 01110000010100100111 \\ 10000110111000001000 \\ 01100000011000001000 \\ 01010000001001000100 \end{bmatrix},$$

$$C_{n3} = \begin{bmatrix} 01110000001000000111 \\ 10000000100000011101 \\ 10010000100000011100 \\ 10101000010011011110 \\ 00010000100000010000 \\ 00000001000000000000 \\ 00000000000000000001 \\ 00000100000000000000 \\ 00000000000000000101 \\ 01111000000111100010 \\ 00000000000111100010 \\ 00000000011000000000 \\ 00010000110010101110 \\ 00010000010100000000 \\ 00010000110000000000 \\ 00000000110100011110 \\ 01111000000000100000 \\ 01110000000100100111 \\ 01110000100100101010 \\ 10010000110100101100 \\ 01000010100000001000 \end{bmatrix},$$

$$C_{n4} = \begin{bmatrix} 01110000001000000011 \\ 10111000011110011111 \\ 11010000110000001111 \\ 11100000101110011110 \\ 01010000100010010000 \\ 00000000000000000000 \\ 00000000000000000001 \\ 00000000000000000000 \\ 00000000000000001011 \\ 01111000000011110011 \\ 11100000000001110011 \\ 01010000000011000000 \\ 01010000000001101110 \\ 01010000001000000000 \\ 00000000011100000000 \\ 00000000011010011110 \\ 01011000011000100000 \\ 01110000100100100011 \\ 01110000000100100011 \\ 11110000111010101101 \\ 11100010111000001110 \end{bmatrix},$$

Source: Calculated by the author

Table 5

Deviation matrices for companies N_1, N_2, N_3, N_4

$$D_{n1} = \begin{bmatrix} 01110000000000000111 \\ 10101111110111101111 \\ 11000111110111101111 \\ 10101111110111101111 \\ 01110000100010100001 \\ 01110010100000001000 \\ 01110100000000000000 \\ 01110000000000000001 \\ 01110000010000001101 \\ 01111000100011011111 \\ 00000000000000000000 \\ 01110000000111011111 \\ 01110000010100101001 \\ 01011000000100000000 \\ 01110000010110000001 \\ 01111000000000000001 \\ 00000000010110000000 \\ 01110100111010000000 \\ 01110000110100000001 \\ 01110000010100000001 \\ 01001001110110110011 0 \end{bmatrix},$$

$$D_{n2} = \begin{bmatrix} 00110000000000000011 \\ 00000000000000000100 \\ 10010000100000000101 \\ 10101000110110111011 0 \\ 00010000110010110001 \\ 00000000100000001001 \\ 00000000000000001001 \\ 00000000000000000001 \\ 00111000000000001001 \\ 10011000000111111001 \\ 00000000000000000000 \\ 00010000010011001001 \\ 00010000010000110111 \\ 00001000000100000000 \\ 00010000010110000001 \\ 00011000010010001111 \\ 00011000010000010001 \\ 00000110110100000000 \\ 01110000000010010011 \\ 10010000000010010101 \\ 10101111110110111011 0 \end{bmatrix},$$

$$D_{n3} = \begin{bmatrix} 00000000000000000000 \\ 00111000001111100010 \\ 01001000000111100011 \\ 01000000000100010001 \\ 01100000000010100001 \\ 00000010000000000001 \\ 00000100000000000001 \\ 00000000000000000000 \\ 00000000010000000100 \\ 00000000100000011101 \\ 11000000000000011101 \\ 01110000000111011111 \\ 01100000000100101001 \\ 01101000000100000001 \\ 01100000000110000001 \\ 01111000000000000001 \\ 00000000011110000001 \\ 00000110111100000000 \\ 10000000011100000001 \\ 01100000000100000001 \\ 10111101011111111011 0 \end{bmatrix},$$

$$D_{n4} = \begin{bmatrix} 00000000000000000100 \\ 00000000000000001100000 \\ 00001000000111110000 \\ 00000000000000100001 \\ 00100000000000100001 \\ 00000011000000001001 \\ 00000100000000001000 \\ 00000100000000000001 \\ 00000000010000000100 \\ 00000000100000001100 \\ 00000000000000001100 \\ 00100000000100111111 \\ 00100000000101001001 \\ 00101000000100000001 \\ 01110000000000000001 \\ 01111000000000000001 \\ 00100000001100000001 \\ 00000110011100000100 \\ 10000000111100001000 \\ 00000000000100000000 \\ 00011101000111110000 \end{bmatrix},$$

Source: Calculated by the author

Table 6

Levels of deviation for selected financial indicators for enterprises N_1, N_2, N_3, N_4

Indicator	Enterprise			
	N_1	N_2	N_3	N_4
f1	0,029	0,019	0,000	0,004
f2	0,057	0,004	0,038	0,008
f3	0,054	0,022	0,038	0,028
f4	0,057	0,044	0,028	0,016
f5	0,029	0,030	0,028	0,012
f6	0,026	0,015	0,013	0,016
f7	0,020	0,011	0,006	0,008
f8	0,023	0,007	0,006	0,008
f9	0,032	0,022	0,006	0,004
f10	0,049	0,041	0,019	0,012
f11	0,000	0,000	0,032	0,008
f12	0,043	0,026	0,051	0,028
f13	0,034	0,030	0,032	0,020
f14	0,017	0,007	0,028	0,016
f15	0,000	0,022	0,028	0,024
f16	0,026	0,033	0,032	0,028
f17	0,009	0,022	0,019	0,016
f18	0,029	0,018	0,019	0,024
f19	0,032	0,030	0,022	0,024
f20	0,029	0,026	0,025	0,000
f21	0,034	0,055	0,060	0,036

Source: Calculated by the author

The analysis of deviation levels indicates that enterprise N_1 needs to focus its efforts on enterprise profitability management because the highest levels of deviation 0.057, 0.057, 0.054 are characteristic of indicators f2, f4, f3 respectively. For enterprises N_2, N_3, N_4 the reserves for increasing the efficiency of financial management are also within the limits of profitability management, however, it is advisable to focus on innovative activity and its profitability because high levels of deviation 0.06 0,06 (N_3), 0,055 (N_2), 0,036 (N_4) are determined for indicator f21. Also for enterprise N_3, it is advisable to increase the efficiency of current enterprise liabilities management, because for f12 the deviation level is 0.51.

4. Conclusions

In today's environment, companies' innovative activities help to solve both environmental and economic problems and contribute to the country's sustainable development. To achieve a competitive advantage in the global marketplace, for national enterprises it is necessary to ensure the transition to an innovation-oriented business model. However, for many enterprises, the introduction of environmental innovations is associated not only with gaining advantages, but also with certain risks, in particular, with a decrease in profitability due to increased costs of greening production. The main factors complicating greening are: reduced state incentives and support for innovation activity; a lack of sufficient sources of funding for the development and implementation of innovation, and imperfect human rights legislation. In such circumstances, the role of a company's financial management, in particular, the evaluation of the effectiveness of cash flow management is growing. After all, assessing the effectiveness of financial management allows you to identify deficiencies in the management system and eliminate them.

In order to assess efficiency, it is advisable to use the methodology proposed, which involves analysing structural changes in the financial results of an innovative enterprise.

The current study assessed the financial management efficiency of four innovative enterprises using the proposed methodology. According to the results of the analysis, the efficiency level in the two enterprises is below 0.5, which indicates the need for immediate measures to improve the efficiency of financial management, in particular by improving the profitability management of the enterprise. The efficiency level of the other two enterprises is between 0.5 and 0.6. For these enterprises, the reserves for improving the efficiency of financial resources management are in the area of profitability management of innovative activities and current liabilities. The search for an optimal set of financial indicators could be the subject of further research.

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Клименчукова Наталія
кандидат економічних наук, доцент, докторант
ВНЗ «Національна академія управління»
Україна
ORCID: 0000-0003-0611-4343

Рященко Вікторія
професор, експерт академії наук Латвії,
директор програми Управління підприємницькою діяльністю
Латвія
ORCID: 0000-0003-1783-3079

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МОДЕЛЮВАННЯ СТРАТЕГІЇ ФІНАНСОВОГО УПРАВЛІННЯ ІННОВАЦІЙНОГО ЕКОЛОГІЧНОГО ПІДПРИЄМНИЦТВА

Анотація. *Сучасні умови функціонування підприємництва характеризуються високим рівнем невизначеності, зокрема значними флуктуаціями ринкової кон'юнктури, загостренням конкурентної боротьби та актуалізацією безпекових аспектів функціонування. Крім того, значний антропогенний вплив на довкілля та його руйнівні наслідки має результатом зростання суспільного попиту на екологізацію господарської діяльності. Тож інноваційна діяльність підприємства є відповіддю на виклики сучасності. Проте інноваційна діяльність в контексті підприємництва пов'язана з додатковими ризиками. Таке агресивне функціональне середовище вимагає від підприємств забезпечення високого рівня ефективності управління, зокрема зростає роль фінансового менеджменту. Саме завдяки ефективному управлінню фінансовими потоками інноваційному підприємству вдається досягти мінімізації фінансових ризиків та максимізації прибутку.*

Дослідження здійснено на базі фінансової звітності, яка характеризує підприємницьку діяльність інноваційного підприємства. Аналіз отриманих даних дозволив оцінити ефективність системи управління фінансовими потоками інноваційного підприємства та визначити резерви підвищення ефективності фінансового менеджменту. В процесі дослідження були використані статистичний та компаративний методи аналізу, статистичного моделювання та абстрагування.

Оцінка ефективності фінансового менеджменту є критично важливим елементом системи управління, який дозволяє виявити та усунути недоліки управління. В результаті дослідження була розроблена методологія оцінки ефективності фінансового менеджменту інноваційного екологічного підприємства.

Здійснення інноваційної діяльності, зокрема екологізація господарської діяльності, вимагає від підприємства забезпечувати ефективне управління ресурсами підприємства, зокрема фінансовим станом. Розробка та імплементація високоефективного механізму управління фінансовими процесами, який дозволяє реалізовувати цілі підприємства, є запорукою виживання підприємства в сучасних умовах. Одним із інструментів вдосконалення системи управління фінансовим станом підприємства виступає оцінка ефективності фінансового менеджменту.

Ключові слова: *фінансовий менеджмент, ефективність, інноваційне підприємництво, інтегральна оцінка, екологія, резерви, система.*

JEL G31

Gribincea Corina
PhD in Economics and Management, Senior scientific researcher,
NIER of the Academy of Economic Studies of Moldova (ASEM)
Moldova
ORCID: 0000-0003-2571-5849

Chernykh Oleksii
PhD student
Poltava State Agrarian University
Ukraine
ORCID: 0009-0001-3389-3701

https://doi.org/10.60022/sis.1.(01).2

MODELLING THE IMPACT OF FACTORS ON THE PROFITABILITY OF BUSINESS ENTITIES ACTIVITY

Abstract. *The instability of the market environment requires business entities to make timely management decisions in order to ensure an appropriate level of profitability of production activity. At present, there are a significant number of methodologies that allow evaluating profitability and forecasting its dynamics for any period in the best possible way. Simultaneously, there is a need to deepen the modelling of the influence of factors that change the profitability of production, which is especially important in the context that profitability is a complex index. That is why accounting of its components will allow identifying the impulses that lead to a decrease or increase in the profitability of an entrepreneurial entity activity.*

The materials for the study are officially promulgated statistical data on the financial activity of business entities, including large, medium, small and micro-enterprises. The assessment of the impact on the level of profitability of all activities of enterprises is carried out with the involvement of factors: the volume of sales, capital investment, the number of employees, labour productivity, labour costs, the value of current assets, and the value of non-current assets. The information base for the evaluation is the data for the retrospective period of 2010–2020. In the process of modelling, we used such methods: analysis, synthesis, induction and deduction, as well as a set of statistical techniques for calculating the correlation coefficient, Student's t-test and Fisher's criteria, regression analysis, coefficient of determination, etc.

The results of the implementation of the proposed methodology of calculating the impact of individual factors of economic activity on the resulting indicator of profitability have revealed the dependence between the main indicators and profitability. In particular, the following results are obtained: for large enterprises the dependence between the profitability of operating activities and all factors is significant; for medium enterprises, the dependence between the profitability of operating activities and the volume of products sold and the volume of capital investment is revealed; for small enterprises, the dependence is found only on the volume of capital investment. Moreover, for microenterprises, the dependence of profitability on individual factors of economic activity was not detected. For all enterprises, the dependence of profitability of operating activity on the volume of products sold, the volume of capital investment, labour productivity and labour costs was revealed. The proposed methodology for modelling the impact of individual indicators on the profitability of business entities has made it possible to identify the impulses that should be addressed to prevent the bankruptcy of an enterprise or a reduction in its profitability. The methodology will be useful for interested stakeholders wishing to systematically monitor profitability and make adequate management decisions on this basis.

Keywords: *modelling, economic activity, business entities, profitability, investment, labour productivity, current and non-current assets, products sold, employment, remuneration.*

1. Introduction

Entrepreneurs are constantly feeling the pressure of the external environment. An unstable market environment, economic changes, and the transition to an innovation-oriented business model require a stable financial state for enterprises. In such a case, the maintenance of an appropriate level of profitability is an important condition for effective business activity. Profitability is not a personified indicator. It consists of a system of factors that influence the bottom line in various ways. This is why there is a need for more in-depth research into modelling the impact on the profitability of individual indicators of economic activity. It is advisable to forecast profitability in order to form future strategies for enterprise development. The mentioned above stipulates the importance of our further research on the selected topic of the article.

The purpose of this article is to model the assessment of the impact of business activity indicators on the profitability of enterprises.

The problematic of modelling the impact of individual activity indicators on profitability has been investigated in the works of many scholars. Louis *et al.,* [1], give an example of calculating the financial independence of institutions and directions of increasing their profitability. The authors have paid special attention to achieving the social efficiency of an institution, which is profitable and in demand on the market. Using financial data from 650 institutions, the authors proposed a "self-organisation map" methodology, where they evaluated profitability, financial performance and social effectiveness, and determined the interdependence between them

Tenge and Hella [2], investigated the costs, financial attractiveness and resulting profitability of implementing a range of soil and water conservation measures in agricultural production on the steep slopes of the Western Usambara Mountains. The researchers dynamically assessed the costs of introducing conservation measures and gave short- and long-term results of improving the profitability of agriculture while conserving natural resources through moderate investment in smallholder labour. The authors present a system of indicators, which allow the best possible analysis of the cause-and-effect relationships of changes in the profitability of production.

Chen *et al.,* [3], investigate the effects of the privatisation of Chinese state-owned companies and the impact of the free market on their operations. The study carefully assessed the operational efficiency of privatised enterprises over the past five years. Using a system of indicators, including those for calculating profitability, the researchers identified the reasons for the decline in profitability and assets, and compared the resulting financial results with enterprises in other countries that have also been privatised. The authors found that the profitability of privatised enterprises increases when private investors have too much control over the firm. The authors conclude by stressing that only a complete relinquishment of control by the state over private businesses can improve the financial performance of a business.

Quite unconventional, but interesting for our study are the scientific conclusions of Luo, [4]. The researcher assessed the profitability of large banks. The study was particularly focused on market efficiency. The paper used a nonparametric marginal method of data analysis, with a sample of 245 large banks. The author performed calculations on the profitability of large banks, which allowed him to draw certain conclusions. In particular, the results indicate that the geographical location of banks does not affect efficiency. Finally, the overall technical efficiency of profitability characteristics can predict the possibility of bank failures. The scholar has refuted the existing hypothesis in the academic world that geographic location and the resource potential of individual territories have no significant impact on banking efficiency. However, banks located in unfavourable geographical locations should be given special attention by the government.

Enqvist *et al.,* [5], calculated the impact of working capital management on the profitability of Finnish firms in different business cycles. The authors estimated the impact of business cycles on working capital — profitability. The data of registered Finnish companies for an 18-year period served as analytical materials. The methodology proposed in the article revealed that the impact of the business cycle on working capital and profitability ratios is more pronounced during economic downturns than booms. Researchers have proved the importance of effective management and planning of reserves, profitability and receivables during economic downturns.

Olson and Zoubi, [6] modelled the profitability assessment of banks in ten countries in the Middle East and North Africa. Using accounting-based efficiency characteristics of banks, they investigated the efficiency of costs and profits. Researchers have proved that there is a need to focus more on profit efficiency than on cost efficiency. In the paper, the researchers proposed a number of approaches to measuring profitability and calculating the impact of individual indicators on profitability.

Significant scientific findings for our study are the findings of Aissa and Goaied, [7] who gave an example of calculating the profitability of Tunisian hotels and assessing managerial efficiency. The authors proved that hotel management efficiency is a determinant for profit generation, which depends on hotel size, debt, investment, location, stage of the business cycle and the international attractiveness of the area for tourists. The article provides an example of the calculation of the profitability of the assets of 27 hotel companies operating in Tunisia. An interesting finding in the article is the authors' view that the education of hotel managers has an impact on hotel profitability.

Syriopoulos *et al.*, [8] provide an example of calculating profitability in the cruise industry. It is undeniable that the cruise industry is recovering from the financial crisis of 2008, as shown by the steady growth in its profitability over the decades. The same cannot be said for commercial shipping. That is why leading cruise companies are implementing ambitious investment plans to expand and renew their ship fleet with large, modern, high-class ships that would meet the most demanding needs of consumers. The researchers in the article propose for the first time a methodology for assessing the impact of investment on the financial performance of large cruise companies. The methodology is useful to the tourism industry because it allows it to calculate the profitability of a cruise company as quickly as possible and to suggest ways of increasing its profitability by attracting investments.

Significant within the scope of our study are the research findings of Le *et al.*, [9]. In the paper, the authors show trends of financial inclusion in Asia and assess its impact on financial efficiency and sustainability. The assessment was carried out using a sample of data from 31 Asian countries for the period of 2004–2016. The estimation methodology proposed by the authors is rather unconventional, as constructed using principal component analysis, based on normalised variables. By testing the methodology, the authors found that trends in financial inclusion vary from country to country, but in some cases, there is no dependence on financial stability. Using the method of least squares, the authors prove that an increase in financial inclusion has a negative effect on financial efficiency but a favourable effect on financial stability.

Le and Ngo propose an interstate comparison of profitability in their article. [10]. In particular, using data on bank profitability in 23 countries from 2002 to 2016 period, the researchers used the to calculate how the number of bank cards issued, ATMs and terminal points can improve bank profitability. Among other results, the authors proved the negative impact of government on bank profitability caused by excessive government intervention in the banking sector.

Eling and Jia, [11] analysed the relationship between firm performance and profitability using the accounts of over 5,000 insurance companies. The authors demonstrated a significant positive correlation between efficiency and profitability. In addition, the researchers proved a significant industry dependence of the profitability of life insurance companies with respect to others.

The topic of profitability and digitalisation is raised in their article by Veltri *et al.*, [12], who review existing methodologies for assessing the profitability of financial institutions and propose their own method for determining the impact of individual enterprise activity indicators on profitability. A similarly themed article by Campanella *et al*,. [13], where the authors rightly point out that digital transformation has led to a multifaceted shift in the financial industry. This is why there is a need to investigate the impact of digital transformation on profitability and the quality of human capital in the European banking system. Using data from 1,250 banks in the European Union, the authors prove that the banking sector is undergoing a transformation of its traditional business model, which in turn leads to increased efficiency and profitability.

Notes the risk factor in the process of realisation of business activity Bielialov, [14], who proposes an innovative toolkit to activate the start-up movement through the modernization of the process of promoting innovative products in the market in the form of start-ups. In the article, the author uses simulation and structural-functional modelling methods to determine the potential market demand for innovative products and planning their promotion in the market. In addition, the author proposes a methodology for assessing the economic efficiency of managing the process of promoting innovative products in the market, which can be useful in the framework of our research.

Zhivko *et al.*, [15], propose to test the efficiency of enterprises to use the Saati scale adapted for this purpose, in which, based on the decomposition of a complex problem, the authors calculated the security efficiency of managerial accounting and defined its dependence on the management decisions taken. Some of the authors' ideas and scientific conclusions are appropriate for implementation in our research.

The study by Tiutiunyk *et al.*, [16] where the authors developed a model for estimating the relationship between the level of shadow economy and social development indicators of the country is noteworthy. The modelling methods proposed by the authors, as well as approaches to assessing the relationship between the level of the shadow economy and social development indicators of the country, are appropriate to use for our study.

The analysis of scientific works of scientists proves their high relevance for modelling the profitability assessment of business entities. However, given the current trends in the turbulent market environment, these studies are severely lacking, which makes our research relevant, timely and important.

2. Materials and Methods

We propose to assess the impact on the level of profitability of all activities of enterprises involving the following factors:

the volume of products sold;
capital investments;
the number of employed workers;
labour productivity;
labour costs;
the value of current assets;
the value of non-current assets.

The assessment will be carried out for all enterprises and separately for large, medium, small and micro enterprises.

Information base for assessment is data for the retrospective period 2010–2020.

Let us introduce a notation:

Y — is the profitability of all company activity;

X_1 — volume of products sold;

X_2 — amount of capital investment;

X_3 — number of employed workers;

X_4 — labour productivity.

X_5 — labour costs;

X_6 — value of current assets;

X_7 — value of non-current assets

The relationship between the level of profitability and the factors affecting it will be assessed by means of correlation coefficients:

$$r_i = \frac{\sum_{t=1}^{T}\left(x_i(t)-\overline{x}_i\right)\left(y(t)-\overline{y}\right)}{\sqrt{\sum_{t=1}^{T}(x_i(t)-\overline{x}_i)^2\sum_{t=1}^{T}(y(t)-\overline{y})^2}}, \quad (1)$$

where r_i — is the correlation coefficient between Y and X_i indicators;

T — is the length of the retrospective period ($T = 11$);

t — is the order number of the year in the retrospective period;

$x_i(t)$, $y(t)$ — the value of X_i, and Y in year t;

$\overline{x}_i$, $\overline{y}$ — the average values of these indicators during the retrospective period.

Check the significance of the calculated correlation coefficients using Student's t-test criteria. The correlation coefficient is considered significant if the empirical value of Student's t-test criteria does not exceed its critical value. The empirical values are calculated according to the formula

$$t_i = \frac{r_i^i}{\sqrt{1-(r_i^i)^2}}\sqrt{T-2}, \quad (2)$$

and the critical value $t(\alpha, k)$ is defined by confidence probability α and number of degrees of freedom $k = T - 2 = 9$. Assuming confidence probability $\alpha = 0.9$, we obtain $t_{кр}(\alpha, k) = 1{,}833$. The values of the correlation coefficients between the indicator of the profitability of all enterprises activity and X_i indicators, and the corresponding empirical values of the Student's t-test criteria are given in Table 1.

Thus, a correlation has been established between the profitability of all enterprise activity and the volume of investments. This relationship holds for all enterprises and separately for large, small and medium enterprises. No correlation between profitability and the volume of investment was found for microenterprises. A correlation between profitability and the volume of sales was found for large, medium, small and micro enterprises. For small enterprises and microenterprises, a relationship was found between profitability and wage costs, and for microenterprises, in addition, a relationship between profitability and labour productivity.

For the above dependencies we write a pairwise linear regression equation $Y = a_i X_i + b_i$. The coefficients of this equation are determined from the system of equations:

$$\begin{cases} a_i\sum_t x_i^2(t) + b_i\sum_t x_i(t) = \sum_t x_i(t)\,y(t) \\ a_i\sum_t x_i(t) + b_i T = \sum_t y(t) \end{cases}. \quad (3)$$

To assess the adequacy of the obtained regression equation to the actual data, we use Fisher's criteria. For this purpose, we determine the coefficient of determination by the formula:

$$R_i^2 = 1 - \frac{\sum_{t=1}^{T}(y(t)-a_i t - b_i)^2}{\sum_{t=1}^{T}(y(t)-\overline{y})^2}. \quad (4)$$

According to Fisher's criteria, a regression equation is considered to be adequate to the actual data if the empirical value of these criteria exceeds the critical value. The empirical value of Fisher's criteria is determined from the equality:

$$F_i = \frac{R_i^2}{1-R_i^2}(T-2), \quad (5)$$

and the critical value $F(\alpha, k_1, k_2)$ is determined by the confidence probability α and the number of degrees of freedom $k_1 = 1$, $k_2 = T - 2 = 9$. Taking probability $\alpha = 0.9$, we obtain $F(\alpha, k_1, k_2) = 3{,}36$.

3. Results and Discussion

The obtained coefficients a_i and b_i of the regression equations, determination coefficients, empirical values of Fisher's criteria and conclusions concerning the adequacy of the regression equations to the initial data for all identified correlation relationships between profitability of all activities and the factors affecting it are given in Table 2.

The resulting regression equations can be used to predict the expected level of profitability under various changes in the factors affecting it. To obtain the predicted value of Y_p, profitability substitute into the regression equation the value of the factor included in the model in the future period of time. Nevertheless, under the influence of many other factors the real value of profitability may differ significantly from the obtained forecast. This is why it is necessary to determine the interval $[Y^{min}, Y^{max}]$, to which future profitability value will relate with a certain probability. To do this, we determine a value Δ equal to half the length of this interval, using the formula:

$$\Delta = \sqrt{\frac{1}{T} + \frac{(X_i^p - \overline{x}_i)^2}{\sum_{t=1}^{T}(x_i(t)-\overline{x}_i)^2}}\,t(\alpha, k)S, \quad (6)$$

where X_i^p — predicted value of the indicator X_i, T — is the duration of the retrospective period, $x_i(t)$ is the value of X_i in the t year of this period, $\overline{x}_i$ — is the average value of this quantity, $t(\alpha, k)$ is the critical

Table 1

Correlation coefficients between the profitability indicator of the whole enterprise activity and the factors affecting it, and the corresponding values of the Student's t-test criteria

Indicator	Correlation coefficient	Student's t-test criteria	Conclusion on the existence of a connection
All enterprises			
X_1	0,516827	1,811121	Not detected
X_2	0,628371	2,423292	Detected
X_3	0,138378	0,419167	Not detected
X_4	0,461186	1,559284	Not detected
X_5	0,501351	1,738299	Not detected
X_6	0,238936	0,738189	Not detected
X_7	0,139167	0,421604	Not detected
Large enterprises			
X_1	0,5337	1,893283	Detected
X_2	0,543655	1,943224	Detected
X_3	-0,12963	-0,3922	Not detected
X_4	0,469957	1,597245	Not detected
X_5	0,48213	1,650942	Not detected
X_6	0,23188	0,715131	Not detected
X_7	0,193873	0,592868	Not detected
Medium enterprises			
X_1	0,531971	1,884723	Detected
X_2	0,639992	2,498727	Detected
X_3	0,368972	1,190949	Not detected
X_4	0,453586	1,526861	Not detected
X_5	0,511953	1,787934	Not detected
X_6	0,243678	0,753755	Not detected
X_7	0,126528	0,382659	Not detected
Small enterprises			
X_1	0,5518	1,984948	Detected
X_2	0,646836	2,544498	Detected
X_3	0,111035	0,335178	Not detected
X_4	0,49277	1,698895	Not detected
X_5	0,565552	2,057269	Detected
X_6	0,322477	1,022031	Not detected
X_7	0,139852	0,42372	Not detected
Micro-enterprises			
X_1	0,592456	2,206258	Detected
X_2	0,345404	1,104169	Not detected
X_3	0,11365	0,343173	Not detected
X_4	0,55451	1,99901	Detected
X_5	0,604588	2,277058	Detected
X_6	0,365017	1,176208	Not detected
X_7	0,100102	0,301822	Not detected

Source: calculated by the authors

value of Student's t-test's criteria, S is the square root of the variance of adequacy defined by equality

$$S^2 = \frac{\sum_{t=1}^{T}(y(t) - a_i x_i(t) - b_i)^2}{T-2}. \quad (7)$$

With the probability α given by determining the critical value of the Student's t-test's criteria, the predicted profitability value will belong to the interval $[Y_p - \Delta, Y_p + \Delta]$. Let us define the interval predictions under the assumption that the factors that have a significant effect on profitability, i.e., the volume of sales (X_1), the volume of capital investments (X_2), labour productivity (X_4) and labour costs (X_5) remain at the level of 2020. We take the probability α to be 0.9. The results of the study are shown in Table 3.

Table 2

Regression equation coefficients, coefficients of determination and empirical values of Fisher's criteria

Type of enterprises	Indicator X_i	Coefficients of the regression equation		R^2	Fisher's criteria	Conclusion
		a_i	b_i			
All	X_2	0,000000029	-8,547505	0,39485	5,87234	Adequate
Large	X_1	0,000003338	-7,383774	0,28484	3,58453	Adequate
Large	X_2	0,000000049	-5,747348	0,29556	3,77611	Adequate
Medium	X_1	0,000002572	-6,050535	0,28299	3,55217	Adequate
Medium	X_2	0,000000069	-6,966824	0,40959	6,24365	Adequate
Small	X_1	0,000008635	-14,855599	0,30448	3,94001	Adequate
Small	X_2	0,000000243	-17,143194	0,41840	6,47448	Adequate
Small	X_5	0,000000064	4,897785	0,31985	4,23236	Adequate
Micro	X_1	0,000034714	-25,028064	0,35100	4,86757	Adequate
Micro	X_4	0,022937257	-23,799046	0,30748	3,99605	Adequate
Micro	X_5	0,000000576	-24,515530	0,36553	5,18500	Adequate

Source: calculated by the authors

Table 3

Projected profitability of all activities at 2020 factor values level

Enterprises	Factor	Factors' value	Lower limit of profitability	Upper limit of profitability
All	X_2	398478079,00	2,631	3,131
Large	X_1	3626388,00	4,388	5,054
Large	X_2	190109186,00	3,321	3,857
Medium	X_1	4359362,10	4,800	5,523
Medium	X_2	163690967,00	4,132	4,649
Small	X_1	2064120,70	2,366	3,571
Small	X_2	44677926,00	-6,589	-6,025
Small	X_5	137136910,40	3,543	4,847
Micro	X_1	704885,60	-1,330	0,213
Micro	X_4	976,70	-2,187	-0,605
Micro	X_5	45013716,80	0,549	2,248

Source: calculated by the authors

Table 4

Elasticity coefficients

Enterprises	Factor	Elasticity coefficient
All	X_2	3,96687
Large	X_1	2,56402
Large	X_2	2,60129
Medium	X_1	2,17222
Medium	X_2	2,58681
Small	X_1	6,00470
Small	X_5	4,32537
Micro	X_5	18,52463

Source: calculated by the authors

Thus, small enterprises are assumed to be unprofitable with investment at the 2020 level and microenterprises are unprofitable with labour productivity and sales volumes unchanged from 2020. Calculations based on the corresponding regression equations show. That profitability requires a 65% increase in investment for small enterprises and a 20% increase in labour productivity and 10% increase in sales for microenterprises.

Define the elasticity coefficients, which show by how much the profitability will increase if the factor influencing it increases by 1%, while the other

factors remain unchanged. The elasticity coefficients are determined from the following equation

$$Kel_i = \frac{a_i x_i(t)}{a_i x_i(t) + b_i}. \quad (8)$$

The elasticity coefficients are determined for $t = T$. i.e. for 2020. The results of the calculations are shown in Table 4.

Let us investigate the impact of factors on the profitability of operating activity of enterprises with a breakdown into large, medium, small and micro enterprises. To do this, we determine the correlation coefficients between the profitability of operating activity and indicators X_i, for each type of enterprises and check their significance by Student's t-test criteria. The results of the study are presented in Table 5.

Table 5

Correlation coefficients between the profitability of operations activity indicator of enterprises and the factors affecting it

Indicator	Coloration coefficient	Student's t-test criteria	Conclusion on the existence of a connection
All enterprises			
X_1	0,621096	2,377450	Detected
X_2	0,704709	2,979759	Detected
X_3	-0,096275	-0,290173	Not detected
X_4	0,594593	2,218556	Detected
X_5	0,571942	2,091719	Detected
X_6	0,408023	1,340752	Not detected
X_7	0,314969	0,995579	Not detected
Large enterprises			
X_1	0,785791	3,811482	Detected
X_2	0,698848	2,931120	Detected
X_3	-0,573221	-2,098684	Detected
X_4	0,773934	3,666387	Detected
X_5	0,681906	2,796839	Detected
X_6	0,626777	2,413159	Detected
X_7	0,616195	2,347131	Detected
Medium enterprises			
X_1	0,550541	1,978445	Detected
X_2	0,666428	2,681553	Detected
X_3	0,255718	0,793538	Not detected
X_4	0,495808	1,712769	Not detected
X_5	0,506549	1,762498	Not detected
X_6	0,283608	0,887254	Not detected
X_7	0,149138	0,452476	Not detected
Small enterprises			
X_1	0,492110	1,695890	Not detected
X_2	0,633869	2,458632	Detected
X_3	0,106304	0,320731	Not detected
X_4	0,442081	1,478574	Not detected
X_5	0,487716	1,675997	Not detected
X_6	0,305074	0,961035	Not detected
X_7	0,103023	0,310724	Not detected
Microenterprises			
X_1	0,486924	1,672425	Not detected
X_2	0,356597	1,145070	Not detected
X_3	0,125059	0,378144	Not detected
X_4	0,455015	1,532926	Not detected
X_5	0,490235	1,687381	Not detected
X_6	0,313933	0,991946	Not detected
X_7	0,031988	0,096014	Not detected

Source: calculated by the authors

Comparing the correlation coefficients between profitability of all activities and X_i indicators, with the correlation coefficients between profitability of operating activity and the same indicators, we see that there is a clear difference in the correlation between these coefficients for different types of companies. For large firms, all of these correlation coefficients for profitability of operating activity are higher in absolute value than those for profitability of all activities. For small firms, the coefficients for profitability of all activities are higher. For medium enterprises, the correlation coefficients for profitability of operating activity are higher than all X_i indicators, except the number of employees and labour costs. For microenterprises, the correlation coefficients for profitability of all activities are higher for all indicators except for the amount of capital investment and the number of employees. For all enterprises, the correlation coefficients for profitability of operating activity exceed in absolute value the similar coefficients for profitability of all activities for all indicators X_i, except the number of employees.

For large enterprises, a significant correlation between the profitability of operating activity and all indicators X_i was found. For medium-sized enterprises, a correlation between the profitability of operating activity and the volume of products sold, and the volume of capital investment was found, for small enterprises only on the volume of capital investment, and for microenterprises, no correlation dependence was detected. For all enterprises, a correlation was found between profitability of operating activity and the volume of products sold, the volume of capital investment, labour productivity and labour costs.

For the significant relationships identified, let us write a pairwise linear regression equation $Y_1 = a_i X_i + b_i$, where Y_1 — is profitability of operations.

The obtained coefficients a_i and b_i, of the regression equations, determination coefficients, empirical values of Fisher's criteria and conclusions concerning the adequacy of the regression equations to the initial data for all identified correlation dependences between the profitability of operating activity and the factors affecting them are given in Table 6.

The resulting regression equations can be used to predict the expected level of operating profitability under various changes in the factors affecting it. The results of the study are shown in Table 7.

Thus, small enterprises are assumed to be unprofitable at the 2020 level of investment. A calculation based on the relevant regression equation shows that a 55% increase in investment is required for small enterprises to achieve operating profitability.

4. Conclusions

Thus, we propose modelling the assessment of the impact of certain factors on the level of profitability of business entities, namely: the volume of products sold; capital investment; the number of employees; labour productivity; labour costs; the value of current assets; the value of non-current assets. Using a complex of statistical methods for the calculation of a correlation coefficient, Student's t-test and Fisher's criteria, regression analysis, determination ratio and others, we have developed the forecasting modelling of the expected level of profitability at various changes of the factors influencing it. Practical implementation of the simulation was carried out on the example of small, medium,

Table 6

Regression equation coefficients, coefficients of determination and empirical values of Fisher's criteria for profitability of operating activity

Type of enterprise	X_i indicator	Coefficients of the regression equation		R^2	Fisher's criteria	Conclusion
		a_i	b_i			
All	X_1	0,000000878	-0,71049628	0,38576	5,65227	Adequate
All	X_2	0,000000022	-1,203554	0,49662	8,87896	Adequate
All	X_4	0,006847007	-0,002710	0,35354	4,92199	Adequate
All	X_5	0,000000010	0,804856	0,32712	4,37529	Adequate
Large	X_1	0,000002930	-0,477195	0,61747	14,52739	Adequate
Large	X_2	0,000000038	1,674486	0,48839	8,59147	Adequate
Large	X_3	-0,004495520	15,276760	0,32858	4,40448	Adequate
Large	X_4	0,003568211	1,719096	0,59897	13,44239	Adequate
Large	X_5	0,000000029	1,728047	0,46500	7,82231	Adequate
Large	X_6	0,000000003	3,542770	0,39285	5,82333	Adequate
Large	X_7	0,000000002	3,726670	0,37970	5,50903	Adequate
Medium	X_1	0,000001831	-0,033129	0,30310	3,91424	Adequate
Medium	X_2	0,000000050	-0,718988	0,44413	7,19073	Adequate
Small	X_2	0,000000085	4,638637	0,40179	6,04487	Adequate

Source: calculated by the authors

Table 7

Projected values of profitability of operating activity with the values of factors at the level of 2020

Enterprises	Factor	Value of the factor	Lower limit of profitability	Upper limit of profitability	Elasticity coefficient
All	X_1	11062297,10	8,757	9,250	1,07892
All	X_2	398478079,00	7,330	7,639	1,16080
All	X_4	1238,52	8,242	8,713	1,00032
All	X_5	398478079,00	7,407	7,706	1,25151
Large	X_1	3626388,00	10,003	10,294	1,04702
Large	X_2	190109186,00	8,694	8,966	0,81036
Large	X_3	1574,60	8,052	8,344	-0,86345
Large	X_4	2303,05	2,679	2,910	0,82700
Large	X_5	299116348,40	10,333	10,746	0,83604
Large	X_6	2061443982,40	8,673	8,988	0,59882
Large	X_7	2577268195,10	8,440	8,742	0,56620
Medium	X_1	4359362,10	7,703	8,193	1,00417
Medium	X_2	163690967,00	7,243	7,588	1,09696
Small	X_2	44677926,00	-4,773	-4,270	-2,06366

Source: calculated by the authors

large and micro-enterprises. The results show that, for large enterprises, there is a significant relationship between the profitability of operating activity and all factors. For medium-sized enterprises, the dependence of profitability of operating activity on the volume of products sold and the volume of capital investment is found, while for small enterprises — only on the volume of capital investment. No dependence was found for microenterprises. For all enterprises, the dependence of profitability of operating activity on the volume of products sold, the volume of capital investment, labour productivity and labour costs was found. Our further research will focus on the search for the reserves necessary to increase the profitability of business entities activity.

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Грибінча Коріна
кандидат економічних наук,
старший науковий співробітник NIER
Академія економічних досліджень Молдови (ASEM)
Молдова
ORCID: 0000-0003-2571-5849

Черних Олексій
аспірант
Полтавський державний аграрний університет
Україна
ORCID: 0009-0001-3389-3701

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МОДЕЛЮВАННЯ ВПЛИВУ ФАКТОРІВ НА РЕНТАБЕЛЬНІСТЬ ГОСПОДАРСЬКОЇ ДІЯЛЬНОСТІ СУБ'ЄКТІВ ПІДПРИЄМНИЦТВА

Анотація. *Нестабільність ринкового середовища вимагає від суб'єктів підприємницької діяльності прийняття вчасних управлінських рішень з метою забезпечення належного рівня рентабельності виробничої діяльності. На цей час існує значна кількість методик, які дозволяють у найліпші способи здійснювати оцінку рентабельності та прогнозувати її динаміку на будь-який період. Одночасно існує потреба поглиблення моделювання впливу чинників, які змінюють рентабельність виробництва, що особливо важливо в контексті того, що рентабельність є комплексним показником. Саме тому урахування його складових дозволить виявити імпульси, що призводять до зниження або підвищення прибутковості суб'єкта підприємницької діяльності.*

Матеріалом для дослідження є офіційно оприлюднені статистичні дані щодо фінансової діяльності суб'єктів підприємництва, зокрема великих, середніх, малих та мікропідприємств. Оцінювання впливу на рівень рентабельності всієї діяльності підприємств здійснено із залученням чинників: обсягів реалізованої продукції, капітальних інвестицій, кількості зайнятих працівників, продуктивності праці, витрат на оплату праці, величини оборотних активів, величини необоротних активів. Інформаційною базою оцінювання є дані за ретроспективний період 2010–2020 роки. В процесі моделювання використовувалися методи: аналізу, синтезу, індукції, дедукції, а також комплекс статистичних методик щодо розрахунку коефіцієнту кореляції, критерію Стьюдента та Фішера, регресійного аналізу, коефіцієнту детермінації тощо.

Результати впровадження запропонованої методики розрахунку впливу окремих чинників господарської діяльності на результуючий показник рентабельності дозволили виявити залежність між основними показниками та рентабельність. Зокрема отримано такі результати: для великих підприємств виявлена істотна залежність між рентабельністю операційної діяльності та всіма чинниками; для середніх підприємств виявлена залежність рентабельності операційної діяльності від обсягів реалізованої продукції та обсягів капітальних інвестицій; для малих підприємств залежність виявлено лише від обсягів капітальних інвестицій. При чому, для мікропідприємств залежності рентабельності від окремих чинників господарської діяльності не виявлені. Для всіх підприємств виявлена залежність рентабельності операційної діяльності від обсягів реалізованої продукції, обсягів капітальних інвестицій, продуктивності праці та витрат на оплату праці.

Запропонована методика моделювання оцінювання впливу окремих показників на рентабельність суб'єктів підприємницької діяльності дозволила виявити імпульси, на які слід звернути увагу для недопущення банкрутства підприємства або зниження його прибутковості. Методика буде корисною для зацікавлених стейкхолдерів, які бажають систематично здійснювати моніторинг рентабельності та на цій основі приймати адекватні управлінські рішення.

Ключові слова: *моделювання, господарська діяльність, суб'єкти підприємництва, рентабельність, інвестиції, продуктивність праці, оборотні та необоротні активи, реалізована продукція, зайнятість, оплата праці.*

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Klochan Iryna
Doctor of Economic Sciences University of Economy in Bydgoszcz Wyższa Szkoła Gospodarki (WSG University)
Poland
ORCID: 0000-0003-3210-4763

Filipov Denis
PhD student
Kyiv National University of Technology and Design
Ukraine

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DESIGN OF ASSESSMENT AND FORECASTING OF A COUNTRY'S FINANCIAL SECURITY IN A CHANGE MANAGEMENT CONDITIONS

Abstract. *The competitiveness of any country depends directly on the efficiency of its financial sector. Moreover, the level of financial security determines a country's ability to further develop on an innovative basis. An important need is to model the assessment and forecasting of a country's financial security in order to make timely adjustments to government decisions and allocate resources to improve the country's financial capacity. Methods of monitoring financial security, especially at the macro level, are underdeveloped in the academic world. The tools for selecting the indicators, which are needed to assess financial security, need to be deepened. In addition, in times of innovative discoveries and technologies, the methods of such assessment need to be progressive and unconventional.*

The materials for this article were statistical indicators that characterise the financial development of Ukraine. It is possible to assess the level of security in a timely manner and to calculate forecasts, using these indicators. The authors have proposed such a grouping of these indicators, which will fully cover the financial activity of the country. We propose to model the assessment and forecasting of the country's financial security with the usage of artificial networks. Application package Matlab including the Network Data Manager program was used for making neural networks, their training and application for forecasting the dynamics of financial security indicators. This program allows us to optimally form and select neural networks, topology, activation and training algorithm.

The assessment and forecast of financial security have shown the need for increased government attention to the allocation and accumulation of financial resources. According to our estimates, the banking security indicators are expected to stabilise in 2023–2025. The indicators of the ratio of bank loans to deposits in foreign currency, the share of foreign capital in the share capital of banks, the ratio of long-term loans to deposits, and the share of assets of the 5 largest banks in the total assets of the banking system will stabilize at the level of 2020. Return on assets will slightly decrease and become negative, while the liquid assets to short-term liabilities ratio will increase to 95.6%. The ratio of total public debt service and repayment to government budget revenues is projected to increase significantly. The proposed design for assessing and predicting countries' financial security is based on the usage of artificial neural networks, which are particularly relevant in the present context. The modelling logic is quite user-friendly and understandable for those interested and can be used by government officials to systematically determine the level of a country's financial security. The proposed design can also be adapted for use in other countries to determine the level of financial security and to adjust the existing financial development strategies of the state.

Keywords: *financial security, neural network, forecasting, financial market, loans, liquidity, insurance, public debt, national monetary unit.*

1. Introduction

The sustainable development of a country depends on a timely diagnosis of its current financial situation. Furthermore, security and socio-economic development are integral requirements of a progressive, innovation-driven economy. At the same time, an international assessment of financial security will make it possible to see a country's position in relation to others and to make timely management decisions necessary to improve it. There is a need to identify a set of indicators that will assess the current financial condition of the country best. It is important that these indicators are relevant for all countries to be assessed because otherwise, the results will be misleading. The above issues emphasise the relevance of the subject matter of our research and determine its prospects. The aim of the study is to determine the optimal model for assessing a country's financial security.

Many researchers have dealt with the problem of a comprehensive assessment of a country's financial security. In the work of Zolkover *et al.,* [1], the level of gross output, economic security and innovation capacity of the regions were determined. The authors have developed a mechanism to stimulate economic growth in different regional clusters. The methods used by the authors are interesting for our article: tree-like clustering based on selected Euclidean distances, statistical, indicator grouping, discriminant analysis, etc. The researchers compared the results with EU countries and revealed the problems of non-harmoniousness of gross output and economic development of Ukrainian regions. Sun and Xu, [2], focus their attention on the security, investment and financing of China's energy sector. A genetic algorithm was used in the methodology to assess the financial security of the Chinese energy industry. An innovative way to assess Chinese energy security is to use neural networks, which we will also test in our study. Shah *et al.,* [3], examine the relationship between energy efficiency, trade, financial development and government integrity in G7 economies over the period from 1996 to 2015. By effectively combining a system of indicators, the authors make a significant contribution to statistical analysis theory. The usage of the Driscoll and Cray method strengthens the level of scholarship of the study D'Orazio, [4], has carried out an empirical analysis of the financial policies of G20 countries, which are concerned with global energy usage and CO2 emissions. The author conducts a cluster analysis from 2000 to 2018 and assesses the carbon intensity of the economy and its impact on climate change. Leuz *et al.,* [5], carried out an international assessment of revenue management in 31 countries. Using a system of indicators, the authors predicted individual financial indicators, which led them to conclude that there was an endogenous relationship between corporate governance and the number of revenues. Unconventional approaches to financial analysis were used in their study by Xu *et al.,* [6], who traced the dynamics of financial payments for healthcare at the interstate level. This allowed the authors to identify the direction of policy measures needed for effective healthcare. Using data from 59 countries, the researchers conducted a regression analysis of the variables associated with healthcare costs. In the article, a number of unconventional modelling tools that deserve our attention were used. Kruk and Freedman, [7], evaluated healthcare system efficiency and proposed indicators, which are most important for measuring the effectiveness of online health databases. Interesting for our study is the authors' grouping of indicators into three categories: efficiency, equity and profitability. This grouping and set of indicators are particularly useful for those designing public healthcare policies and assessing the impact of several cost-sharing strategies in developing countries. Chang *et al.,* [8] provide a high-level, scholarly analysis of changes in the affordability index and the energy efficiency index. What is important for our study is the set of indicators the authors analyse. Moreover, the system of such indicators is simple and adaptive for measuring financial security. Tete *et al.,* [9], through a multi-criteria analysis of decisions, value energy security in the electricity sector of the West African Economic and Monetary Union. Using 18 country-reporting indicators for 2010–2019, the researchers assess governance performance, environmental sustainability, and energy security. Moreover, there is some academic interest in the indicators system and how it is assessed. Cheng and Chien, [10], conduct research on the relationship between financial development, the spread of information and communication technologies and economic growth. The authors have used a broad panel of statistics from 72 countries around the world for the years 2000–2015 and have used non-standard approaches to assess them. Among other achievements, the authors have also thoroughly analysed the Cobb-Douglas model and evaluated it in the present context. A thorough analysis of the scientific literature has shown a lively interest among scholars in the issue of assessing a country's financial security. There is a relevant discussion regarding the selection of the optimal group of financial indicators that will fully reflect the level of financial security. Defining a methodology that will be suitable for assessing security is equally important.

2. Materials and Methods

We propose to use artificial neural networks to assess the level of financial security of countries. We divide the set of financial security indicators Q into 6 subsets:

Q_1 — banking security indicators;

Q_2 — non-banking financial market safety indicators;

Q_3 — debt security indicators;

Q_4 — budget security indicators;

Q_5 — currency security indicators,
Q_6 — monetary security indicators

Let us denote the j indicator in the set Q_i, by q_{ij}. The list of indicators selected to assess the level of financial security is shown in Table 1.

To study the dynamics of these indicators, we will take the retrospective period 2010–2020. Let us mark with t the number of the year in the retrospective period, and with $q_{ij}(t)$ the value of the indicator q_{ij}, in the t year. The values of indicators q_{ij}, during the retrospective period are given in Table 2.

The Matlab application package was used to create neural networks, train them and use them in forecasting the dynamics of financial security indicators, including the Network Data Manager program. This software allows creating neural networks, defining their topology, selecting the activation function and the effective learning algorithm.

A Feed-forward back propagation type neural network is used to predict the dynamics of q_{ij} indicators. This network has three layers of neurons. The input layer picks up signals from the external environment

Table 1

Indicators reflecting the level of financial security of a country

Designation	Content of the indicator
Banking security indicators (Q_1)	
q_{11}	Share of overdue loans in the total volume of loans granted by banks to residents of Ukraine, %
q_{12}	Ratio of bank loans to deposits in foreign currency
q_{13}	Share of foreign capital in the share capital of banks, %.
q_{14}	Ratio of long-term (over 1 year) loans and deposits, times
q_{15}	Return on assets, %
q_{16}	The ratio of liquid assets to short-term liabilities, %
q_{17}	Share of assets of the 5 largest banks in total assets of the banking system, %
Non-banking financial market safety indicators (Q2)	
q_{21}	Insurance penetration rate (insurance premiums to GDP), %
q_{22}	Volatility level of the PFTS index, number of critical deviations (–10%)
q_{23}	Share of insurance premiums received by the 3 largest insurance companies in the total volume %
Debt security indicators (Q_3)	
q_{31}	Ratio of public and publicly guaranteed debt to GDP, %
q_{32}	Ratio of gross external debt to GDP, %
q_{33}	Weighted average yield on domestic government bonds in the primary market, %.
q_{34}	EMBI + Ukraine Index
q_{35}	Ratio of official international reserves to gross external debt, %
Budget security indicators (Q_4)	
q_{41}	Ratio of the state budget deficit and surplus to GDP, %
q_{42}	Deficit/surplus of budgetary and extra-budgetary funds of the general administration sector, as a percentage to GDP
q_{43}	The level of GDP redistribution through the consolidated budget, %
q_{44}	Ratio of total payments on public debt servicing and repayment to state budget revenues, %
Currency security indicators (Q_5)	
q_{51}	Index of changes in the official exchange rate of the national currency against the US dollar, average for the period
q_{52}	Gross international reserves of Ukraine, in months of imports
q_{53}	Share of loans in foreign currency in total loans granted, %
q_{54}	Balance of purchase and sale of foreign currency by households, billion USD
q_{55}	Level of dollarisation of the money supply, %
Monetary security indicators (Q_6)	
q_{61}	Specific weight of cash outside banks in the total money supply (M0/M3), %
q_{62}	Difference between interest rates on loans granted by depository corporations to residents of Ukraine in the reporting period and interest rates on deposits attracted by depository institutions
q_{63}	Weighted average interest rate on loans granted by depository corporations (other than the NBU) in national currency relative to the consumer price index
q_{64}	Share of consumer loans to households in the total structure of loans to residents
q_{65}	Specific weight of long-term loans in total loans granted (adjusted for exchange rate differences), %
q_{66}	The volume of legal outflow of financial resources outside the country, billion USD

Source: Indicator grouping system proposed by the authors

Table 2

Values of the country's financial security indicators in 2010–2020

Indicator	Years of the retrospective period										
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
q_{11}	11	10	9	11	16	25	28	55	53	48	41
q_{12}	190	153	119	124	153	169	134	109	117	83	68
q_{13}	41	42	39	34	32	44	49	49	28	29	28
q_{14}	4	3	2	2	3	4	4	3	4	4	3
q_{15}	-1	-1	1	0	-4	-5	-13	-2	2	4	2
q_{16}	1	1	90	89	86	93	92	98	93	91	87
q_{17}	37	37	39	40	43	54	56	60	60	61	59
q_{21}	2	2	1	2	2	1	1	1	1	1	1
q_{22}	2	4	1	0	1	0	0	0	0	0	0
q_{23}	14	14	10	13	16	15	19	21	15	14	16
q_{31}	40	36	37	40	69	79	81	72	61	50	61
q_{32}	86	77	77	77	94	129	120	103	88	79	81
q_{33}	13	9	14	13	15	17	15	15	18	17	10
q_{34}	400	900	550	763	2226	2375	763	564	533	492	651
q_{35}	29	25	18	14	6	11	14	16	18	21	23
q_{41}	-6	-2	-4	-4	-5	-2	-3	-2	-2	-2	-5
q_{42}	-1	-1	-1	0,1	-0,2	-0,1	0,1	0	-0,2	0	1
q_{43}	28	31	32	30	29	32	32	34	33	32	33
q_{44}	18	23	28	33	48	94	34	60	38	46	47
q_{51}	151	100	100	100	149	184	117	104	102	95	104
q_{52}	4	4	3	3	2	3	3	3	3	5	5
q_{53}	46	40	37	34	46	56	49	44	43	37	37
q_{54}	-10	-13	-10	-1	2	1	2	2	1	0	1
q_{55}	29	30	32	27	33	32	33	32	29	29	27
q_{61}	31	28	26	26	30	28	28	27	28	27	28
q_{62}	7	7	4	5	4	6	5	6	6	5	7
q_{63}	6	8	18	17	5	-27	5	2	8	12	11
q_{64}	17	16	15	15	13	11	10	12	14	18	18
q_{65}	29	25	22	19	17	15	24	26	22	20	18
q_{66}	9	11	13	14	11	3	7	10	12	14	11

Source: Calculated by the authors

and passes them on to neurons in the intermediate layer, without converting them. Neurons of the intermediate layer receive signals from neurons of the input layer, transform them and transfer the transformed signals to neurons of the output layer. Neurons in the output layer generate output signals that have to match the existing standards during the learning phase of the network. The intermediate layer contains two neurons N_1 and N_2, each with one input. Neuron N_k corresponds to weighting factor v_k, offset of a_k and activation function of f_k. Having received input signal X, neuron N_k produces output signal $G_k = f_k(v_kX + a_k)$, which is transmitted to the output layer neuron. The output layer contains one neuron N_0, which has two inputs and receives output signals from neurons of the intermediate layer. The inputs of the neuron N_0, perceiving signals from neurons N_1 and N_2 correspond to the weights coefficients w_1 and w_2. Neuron N_0 produces an output signal $G_0 = f_0(w_1G_1 + w_2G_2 + b)$, where f_0 is the activation function of this neuron and b is its offset. We choose the same activation function $\text{tansig}(x) = 2(1 + e^{-2x})^{-1} - 1$ for all neurons in the network. This function is monotonically increasing, the set of its values is the interval $(-1, 1)$, it follows to 1 at $x \to \infty$ and follows to -1 at $x \to -\infty$. Thus, the current state of the network is determined by the parameters v_1, v_2, w_1, w_2, a_1, a_2 and b. When training the network, each value of the input signal X from the defined set is matched with a known value of the output signal L. In the process of network training, the output signal values G_0 obtained by the network, are compared with the corresponding reference values L, the error $\Delta = |L - G_0|$ is determined and the network parameters are changed depending on its value. This ensures that the resulting output signals are sufficiently close to the known reference values.

We select the trainlm function to train the network. This function updates the weights coefficients v_1, v_2, w_1, w_2 and offsets a_1, a_2, b of the network

neurons according to Levenberg-Marquardt optimization. We take the training parameters as follows: the maximum number of epochs to be trained is 1000, the maximum number of verification errors is 6, and the minimum performance gradient is 10^{-5} [11].

In order to use the network to predict the dynamics of q_{ij} indicators the numbers of years t of the retrospective period should be fed to the input during training and the outputs should be compared with the known values of $q_{ij}(t)$ of this indicator. After training is completed in the forecasting process, the numbers of years corresponding to the forecasting period are fed to the input of the network. The output values of the network are taken as the results of the forecasting process. However, for this network to work, the input and output signals have to be in the range [0; 1]. Hence, it is necessary to transform the data so that the values belong to this interval. Let us denote by X(t) the value of the input signal corresponding to the year with number t. For the values X(t) to belong to the interval [0, 1], we define them by equality:

$$X(t) = t/(T_0 + T),$$

where T_0 is the duration of the retrospective period and T is the duration of the forecast period. Since we use data for 2010–2020, then $T_0 = 11$.

Table 3

Input signals for neural network training and operation

t	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
X(t)	0,06	0,13	0,19	0,25	0,31	0,38	0,44	0,50	0,56	0,63	0,69	0,75	0,81	0,88	0,94	1,00

Source: proposed by the authors

Table 4

Reference values of the output signals for neural network training

Indicator	Year numbers of the retrospective period										
	1	2	3	4	5	6	7	8	9	10	11
q_{11}	0,133	0,121	0,109	0,133	0,194	0,303	0,339	0,667	0,642	0,582	0,497
q_{12}	0,667	0,537	0,418	0,435	0,537	0,593	0,470	0,382	0,411	0,291	0,239
q_{13}	0,558	0,571	0,531	0,463	0,435	0,599	0,667	0,667	0,381	0,395	0,381
q_{14}	0,667	0,500	0,333	0,333	0,500	0,667	0,667	0,500	0,667	0,667	0,500
q_{15}	0,481	0,481	0,556	0,519	0,370	0,333	0,037	0,444	0,593	0,667	0,593
q_{16}	0,007	0,007	0,612	0,605	0,585	0,633	0,626	0,667	0,633	0,619	0,592
q_{17}	0,404	0,404	0,426	0,437	0,470	0,590	0,612	0,656	0,656	0,667	0,645
q_{21}	0,667	0,667	0,333	0,667	0,667	0,333	0,333	0,333	0,333	0,333	0,333
q_{22}	0,333	0,667	0,167	0,000	0,167	0,000	0,000	0,000	0,000	0,000	0,000
q_{23}	0,444	0,444	0,317	0,413	0,508	0,476	0,603	0,667	0,476	0,444	0,508
q_{31}	0,329	0,296	0,305	0,329	0,568	0,650	0,667	0,593	0,502	0,412	0,502
q_{32}	0,444	0,398	0,398	0,398	0,486	0,667	0,620	0,532	0,455	0,408	0,419
q_{33}	0,481	0,333	0,519	0,481	0,556	0,630	0,556	0,556	0,667	0,630	0,370
q_{34}	0,112	0,253	0,154	0,214	0,625	0,667	0,214	0,158	0,150	0,138	0,183
q_{35}	0,667	0,575	0,414	0,322	0,138	0,253	0,322	0,368	0,414	0,483	0,529
q_{41}	0,000	0,667	0,333	0,333	0,167	0,667	0,500	0,667	0,667	0,667	0,167
q_{42}	0,000	0,000	0,000	0,367	0,267	0,300	0,367	0,333	0,267	0,333	0,667
q_{43}	0,549	0,608	0,627	0,588	0,569	0,627	0,627	0,667	0,647	0,627	0,647
q_{44}	0,128	0,163	0,199	0,234	0,340	0,667	0,241	0,426	0,270	0,326	0,333
q_{51}	0,547	0,362	0,362	0,362	0,540	0,667	0,424	0,377	0,370	0,344	0,377
q_{52}	0,533	0,533	0,400	0,400	0,267	0,400	0,400	0,400	0,400	0,667	0,667
q_{53}	0,548	0,476	0,440	0,405	0,548	0,667	0,583	0,524	0,512	0,440	0,440
q_{54}	0,167	0,042	0,167	0,542	0,667	0,625	0,667	0,667	0,625	0,583	0,625
q_{55}	0,586	0,606	0,646	0,545	0,667	0,646	0,667	0,646	0,586	0,586	0,545
q_{61}	0,667	0,602	0,559	0,559	0,645	0,602	0,602	0,581	0,602	0,581	0,602
q_{62}	0,667	0,667	0,381	0,476	0,381	0,571	0,476	0,571	0,571	0,476	0,667
q_{63}	0,148	0,198	0,444	0,420	0,123	0,667	0,123	0,049	0,198	0,296	0,272
q_{64}	0,630	0,593	0,556	0,556	0,481	0,407	0,370	0,444	0,519	0,667	0,667
q_{65}	0,667	0,575	0,506	0,437	0,391	0,345	0,552	0,598	0,506	0,460	0,414
q_{66}	0,429	0,524	0,619	0,667	0,524	0,143	0,333	0,476	0,571	0,667	0,524

Source: Suggested by the authors

We choose the duration of the forecast period T-5, i.e. the forecast is made until 2025. Thus, the value of t varies from 1 to 16. The corresponding values of the value X(t) are shown in Table 3.

We denote by $Y_{ij}(t)$ the reference value for comparison with the output value of the network used to predict the dynamics of q_{ij}, and corresponds to the input signal X(t). If q_{ij} indicator can only take positive values, the value of $Y_{ij}(t)$ is defined by the equality

$$Y_{ij}(t) = q_{ij}(t)/(1{,}5\max(q_{ij}(t))) \quad (1)$$

where the maximum is taken for all years of the retrospective period. A factor of 1.5 is introduced to ensure that the network outputs from the forecasting process belong to the interval [0, 1].

If among the values of q_{ij} some are negative, the following equation is used to determine the value of $Y_{ij}(t)$

$$Y_{ij}(t) = v_{ij}(t)/(1{,}5\max(v_{ij}(t))), \quad (2)$$

where $v_{ij}(t) = q_{ij}(t) - \min(q_{ij}(t))$, the minimum is taken over all years of the retrospective period.

The values of value $Y_{ij}(t)$ are shown in Table 4.

The result of network training for the indicator q_{11} — the share of overdue loans in the total volume of loans provided by banks to residents of Ukraine — is shown in figure 1. The R = 0.9576 value is close to 1, which confirms the quality of the predictive model.

3. Results and Discussion

As a result of training the network created to predict the dynamics of indicator q_{ij}, its parameters v_1, v_2, w_1, w_2, a_1, a_2 and b take the values given in table 5.

In order to get the forecast values of the country's financial security indicators, we feed to the input of the neural network configured to forecast a certain indicator q_{ij}, of the values X(t) at values t corresponding to the forecasting period, i.e. from 12 to 16. In the result of work, the network produces output signals $Y_{ij}(t)$. The predicted values $q_{ij}(t)$ of the indicator q_{ij}, are determined from equations (1) and (2).

For indicators taking only positive values, the following equation applies

$$q_{ij}(t) = 1{,}5Y_{ij}(t)\max(q_{ij}(t)), \quad (3)$$

and for indicators taking negative values during the retrospective period as well, the following equation applies

$$q_{ij}(t) = 1{,}5Y_{ij}(t)\max(q_{ij}(t) - \min(q_{ij}(t))) + \min(q_{ij}(t)), \quad (4)$$

where the maximum and minimum are determined for all years of the retrospective period.

The defined predicted values of the indicators are shown in Table 6.

Thus, according to the projections made, a certain stabilisation of banking safety indicators is expected between 2023 and 2025. The ratio of bank loans to deposits in foreign currency, the share of foreign capital in the share capital of banks, the ratio of long-term loans to deposits and the share of assets of the five largest banks in the total assets of the banking system will stabilise at the level of 2020, the return on assets decreases slightly, while

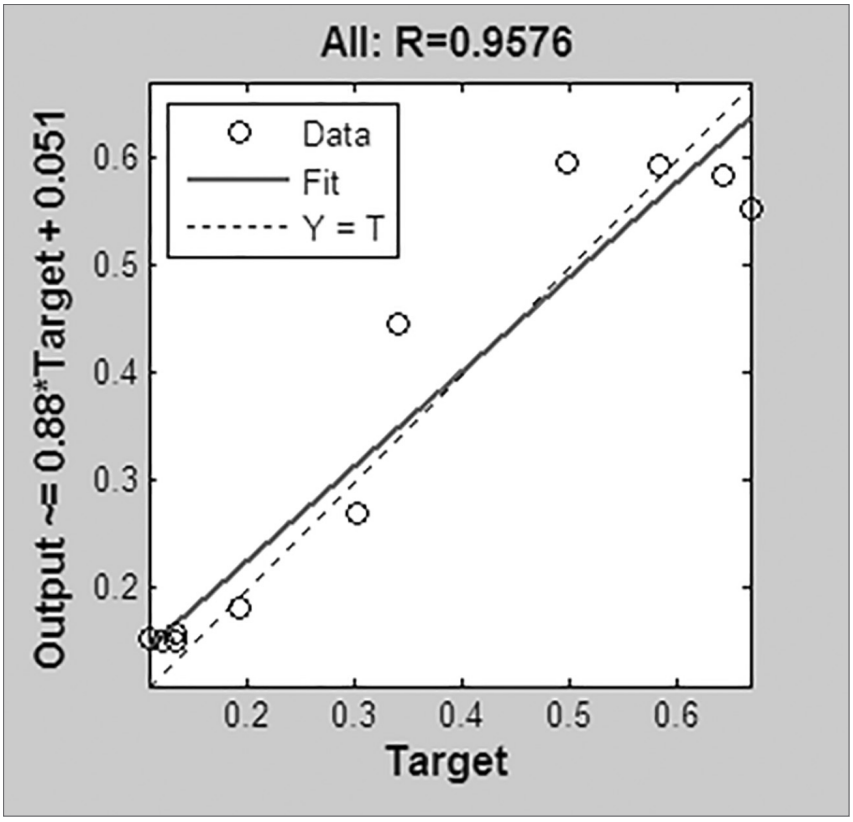

Figure 1. Result of neural network training

Source: Listing of neural network training results

Table 5

Parameters of neural networks designed to predict the dynamics of a country's financial security indicators

Indicator	Neural network parameters						
	v_1	v_2	w_1	w_2	a_1	a_2	b
q_{11}	2,8	2,8	-0,9379	1,0394	-2,8	2,8	0
q_{12}	1,5297	2,6546	-1,8664	0,19076	-1,5109	2,9343	-1,5827
q_{13}	-2,8	2,8	1,0207	-0,95821	2,8	2,8	0
q_{14}	3,5562	-2,3565	-1,4511	-2,5907	-1,5022	-3,6961	3,1974
q_{15}	-2,4827	-7,3345	1,8175	-2,1672	0,56891	2,9916	0,95424
q_{16}	2,2263	-4,0893	0,13871	-1,1384	-3,9827	-2,1621	0,64076
q_{17}	1,8623	-1,46	0,33998	-2,1402	-3,8962	-0,57455	-0,36225
q_{21}	2,8	2,8	-1,1189	0,84141	-2,8	2,8	0
q_{22}	-3,1789	4,809	0,87024	-2,0057	3,6981	2,7759	0,0078222
q_{23}	2,2551	-2,632	0,077406	-0,42383	-3,1321	-3,147	-0,46413
q_{31}	1,4239	8,4167	0,28723	0,89848	-4,0643	2,7268	-0,096515
q_{32}	-2,8	-2,8	1,0715	-0,9011	2,8	-2,8	0
q_{33}	8,7832	3,7755	-1,6716	0,51504	-8,911	1,9595	-1,6019
q_{34}	2,0324	-2,7424	-0,14362	-0,16337	-3,8209	-2,5129	-1,057
q_{35}	0,94092	4,0372	1,6193	-0,88525	-0,85414	1,7213	1,339
q_{41}	3,0871	3,2133	-0,589	0,79078	-2,516	2,4008	-0,65549
q_{42}	0,33156	-0,75058	4,1771	-2,828	0,18531	-5,6903	-3,7808
q_{43}	0,072653	4,9863	2,8168	-0,0531	-5,4753	-0,22255	-4,8214
q_{44}	3,153	3,1183	0,78448	0,96224	-4,0372	2,4864	-0,62592
q_{51}	-0,38795	-3,066	-0,37681	-1,2779	0,41669	-0,65043	-0,67931
q_{52}	-2,5815	-3,0161	1,0073	0,19389	2,8497	-2,3917	-0,12728
q_{53}	3,4543	-1,9895	-1,0062	0,69101	-2,0308	-3,5693	-0,16058
q_{54}	2,9561	-2,9019	0,043945	0,034243	-2,4595	-2,6846	1,0319
q_{55}	-2,5134	-0,81969	2,6058	-2,5099	2,4266	-4,2403	2,4724
q_{61}	2,591	2,4912	1,3565	-0,12583	-0,10255	3,0504	-0,10589
q_{62}	-2,9396	-3,3299	0,883	0,49151	2,1328	-2,1658	-0,22717
q_{63}	1,278	-2,7843	0,51951	-1,0783	-2,0877	-2,8425	-1,0041
q_{64}	-1,6832	-1,6586	-2,1283	-0,30267	1,5471	-5,3726	1,424
q_{65}	5,0355	-3,2258	0,89759	0,34351	-2,6596	-1,0312	0,98987
q_{66}	-4,1095	-0,49957	-2,8614	0,31348	-3,2879	-1,8917	-1,2118

Source: proposed by the authors

the ratio of liquid assets to short-term liabilities will increase to 95.6%. The share of overdue loans in total loans volume extended by banks to residents of Ukraine is forecast to decrease significantly and stabilise at a level of 34–36%.

Among the security indicators for the non-banking financial market, the insurance penetration level is projected to increase by 0.37–0.4%, while the remaining indicators in this group are not expected to change significantly compared to 2020.

Among the debt security indicators, the ratio of public and publicly guaranteed debt to GDP is projected to increase and stabilise at around 70%. Similarly, the gross external debt to GDP ratio is projected to increase and reach a level of 99–100%. The weighted average yield of domestic government bonds in the primary market is forecast to decrease by 1% and the ratio of official international reserves to gross external debt is forecast to increase by around 5%. The dynamic of the EMBI+Ukraine index together with the forecast for 2023–2025 are shown in Figure 2.

Among the budgetary security indicators, the ratio of total public debt service and repayment payments to public budget revenues is projected to increase substantially. Dynamics of this indicator together with the forecast for 2023–3025 is shown in Figure 3.

According to the forecast, the ratio of the state budget deficit/surplus to GDP will be –1.25 in 2025, the deficit/surplus of budgetary and extra-budgetary funds of the general government sector will stabilise at 0.36% of GDP in 2023–2025 and the redistribution level of GDP through the consolidated budget at 32.73%.

Among the currency security indicators, the index of change in the official exchange rate of the national monetary unit against the US dollar and

Table 6

Projected values of the country's financial security indicators

Indicator	Years				
	2021	2022	2023	2024	2025
Banking security indicators					
Share of overdue loans in the total volume of loans granted by banks to residents of Ukraine, %	43,73	38,32	35,75	34,80	34,48
Ratio of bank loans to deposits in foreign currency	70,29	68,93	68,49	68,32	68,25
Share of foreign capital in the share capital of banks, %	29,04	28,58	28,45	28,41	28,40
Ratio of long-term loans and deposits (over 1 year), times	4,00	4,00	4,00	4,00	4,00
Return on assets, %	0,03	-0,15	-0,21	-0,24	-0,24
Ratio of liquid assets to short-term liabilities, %	94,61	94,76	95,01	95,33	95,61
Share of assets of the 5 largest banks in total assets of the banking system, %	59,68	59,78	59,90	60,06	60,25
Security indicators of the non-banking financial market					
Insurance penetration rate (insurance premiums to GDP), %	1,63	1,47	1,40	1,38	1,37
Volatility level of the PFTS index, number of critical deviations (–10%)	0,06	0,02	0,02	0,01	0,01
Share of insurance premiums received by the 3 largest insurance companies in the total volume %	15,11	15,29	15,47	15,59	15,65
Debt security indicators					
Ratio of public and publicly guaranteed debt to GDP, %	69,25	69,31	69,43	69,62	69,95
Ratio of gross external debt to GDP, %	111,90	103,93	100,45	99,22	98,81
Weighted average yield on domestic government bonds in the primary market, %	9,05	9,04	9,04	9,04	9,04
EMBI+ Ukraine Index	750,37	739,68	721,01	694,65	667,00
Ratio of official international reserves to gross external debt, %	25,67	26,92	27,63	28,03	28,26
Indicators of budget security					
Ratio of the state budget deficit and surplus to GDP, %	-1,59	-1,39	-1,30	-1,27	-1,25
Deficit/surplus of budgetary and extra-budgetary funds of the general government sector, as a percentage of GDP	0,37	0,36	0,36	0,36	0,36
The level of GDP redistribution through the consolidated budget, %	32,73	32,73	32,73	32,73	32,73
Ratio of total payments on public debt servicing and repayment to state budget revenues, %	61,34	76,91	83,87	85,91	86,48
Currency security indicators					
Index of changes in the official exchange rate of the national currency against the US dollar, average for the period	149,27	150,83	152,29	153,65	154,92
Gross international reserves of Ukraine, in months of imports	2,57	2,19	2,06	2,02	2,01
Share of loans in foreign currency in total loans granted, %	32,60	32,58	32,57	32,57	32,57
Balance of purchase and sale of foreign currency by households, billion USD	1,10	1,11	1,11	1,11	1,11
Level of dollarisation of the money supply, %.	32,98	32,90	32,81	32,76	32,73
Monetary security indicators					
Share of cash outside banks in the total money supply (M0/M3), %	26,36	26,36	26,36	26,36	26,36
Difference between interest rates on loans granted by depository corporations to residents of Ukraine in the reporting period and interest rates on deposits attracted by depository institutions	6,86	6,86	6,86	6,86	6,86
Weighted average interest rate on loans granted by depository corporations (other than the NBU) in national currency relative to the consumer price index	12,19	13,55	15,16	16,77	18,16

Continuation of table 3

Share of consumer loans granted to households in the total structure of loans to residents	17,36	17,36	17,36	17,36	17,36
Specific share of long-term loans in total amount of loans granted (adjusted for exchange rate differences), %	18,58	18,55	18,55	18,55	18,55
The volume of legal outflow of financial resources outside the country, billion USD	11,19	11,19	11,19	11,19	11,19

Source: proposed by the authors

the level of dollarization of the money supply are projected to increase. Ukraine's gross international reserves and the share of loans in foreign currency in the total volume of loans granted are forecast to decrease. The balance of purchase and sale of foreign currency by households is forecast at the level of 1.11 billion USD.

Among the monetary security indicators, the level of the weighted average interest rate on loans extended by depository corporations (excluding the National Bank) in national currency is expected to rise relative to the consumer price index. The dynamics of this indicator, together with the forecast for 2023–3025, are shown in Figure 4.

The specific share of cash outside banks in total money supply is forecast to decrease and stabilise at 26.36%. Other monetary safety indicators according to the forecast remain close to the 2020 level.

4. Conclusions

The design of assessing and forecasting the financial security of a country is proposed to be carried out using artificial networks. For creating neural networks, their training and their application in forecasting the dynamics of financial security indicators we used the Matlab application package, including the Network Data Manager program. This program gives the possibility to optimally form and choose neural networks, topology, activation and training algorithm. The grouping of indicators characterizing financial security, we propose to distribute into 6 subsets: indicators of banking security; non-bank financial market security indicators; debt security indicators; budget security indicators; currency security indicators; monetary security indicators. Calculation of financial security level and its forecasting showed the need for increased state attention to the allocation and accumulation of financial resources. Despite the fact that according to the forecasts, some stabilisation of banking safety indicators is expected in 2023–2025, the return on assets will decrease. The weighted average yield of domestic government bonds in the primary market is projected to decrease by 1%, and the ratio of official international reserves to gross external debt is projected to increase by about 5%. The aim of

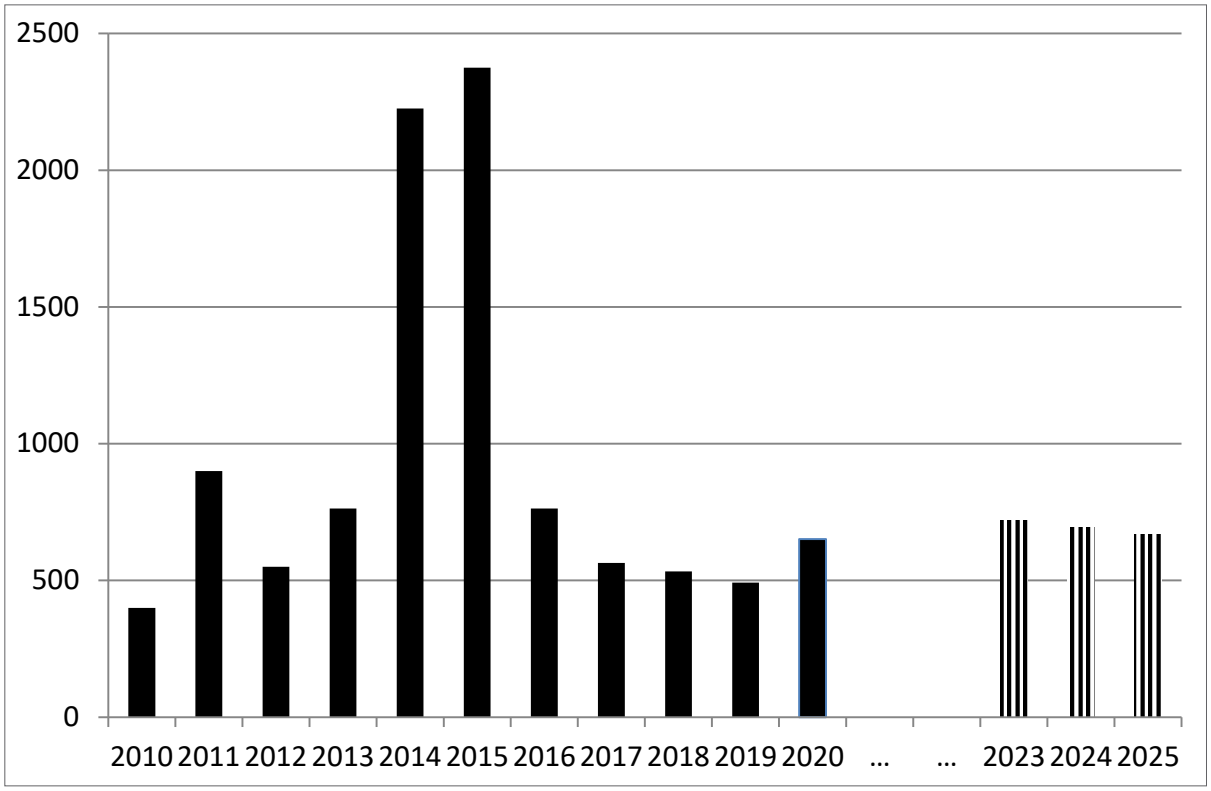

Figure 2. Dynamics of the EMBI+Ukraine Index

Source: forecast data calculated by the authors

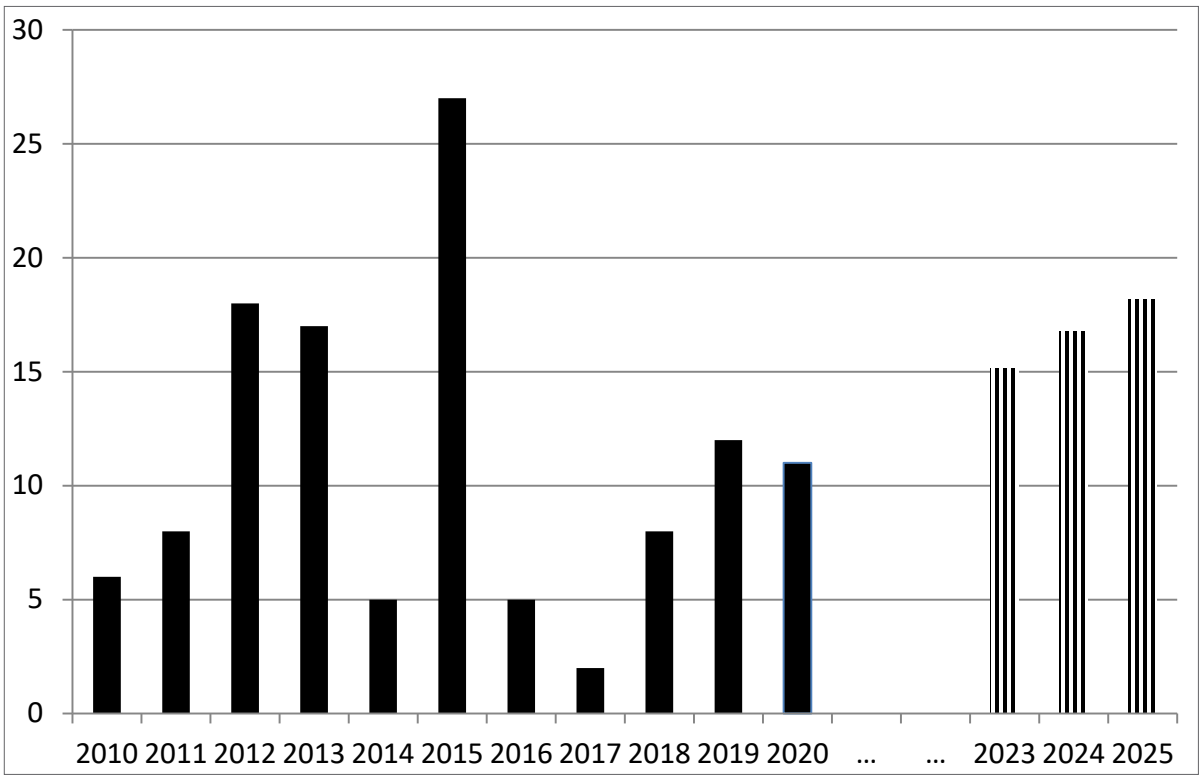

Figure 3. Ratio of total public debt service and repayment payments to public budget revenues
Source: forecast data calculated by the authors

our further researches will be to increase the system of indicators for financial security design and to expand the methodological tools to forecast the phenomenon we are analysing.

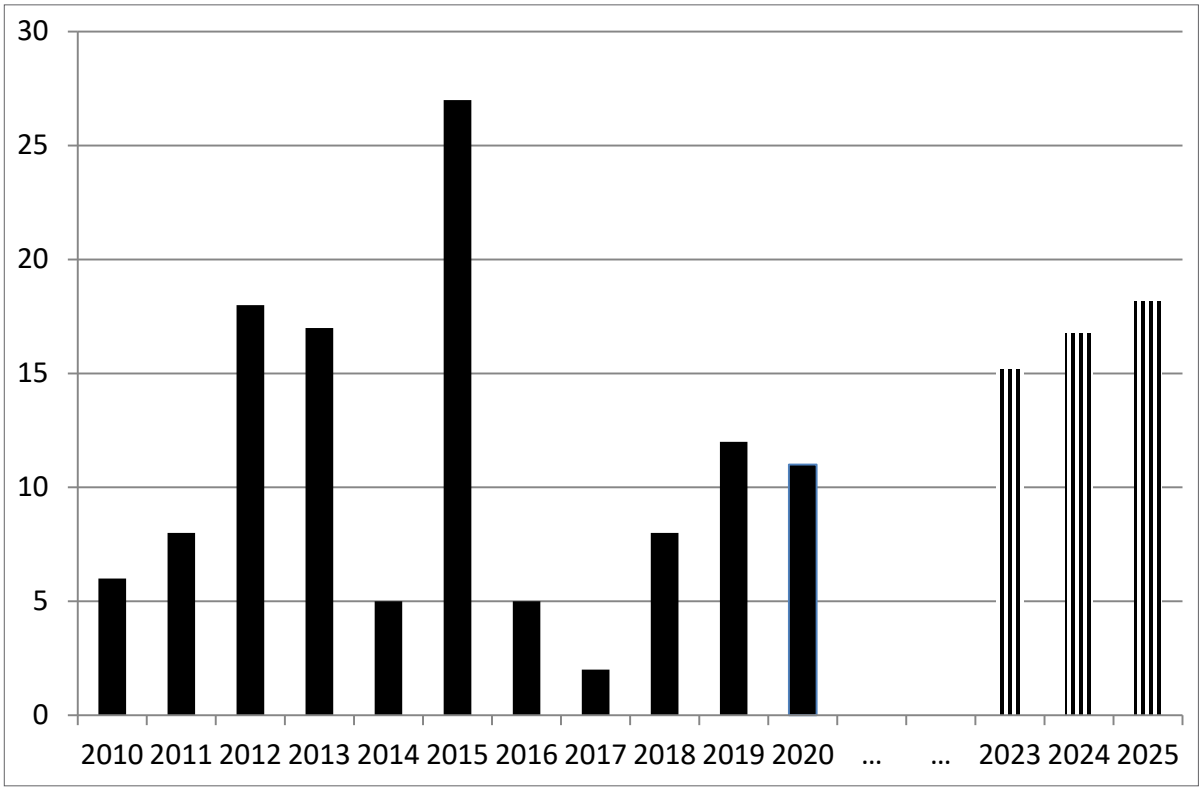

Figure 4. Dynamics of the weighted average interest rate on loans provided by depository corporations (except the National Bank) in national currency relative to the consumer price index
Source: forecast data calculated by the authors

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Клочан Ірина
доктор економічних наук
Університет Економіки в Бидгощі
Польща
ORCID: 0000-0003-3210-4763

Філіпов Денис
Аспірант
Київський національний університет технологій та дизайну
Україна

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ДИЗАЙН ОЦІНЮВАННЯ ТА ПРОГНОЗУВАННЯ ФІНАНСОВОЇ БЕЗПЕКИ КРАЇНИ В УМОВАХ УПРАВЛІННЯ ЗМІНАМИ

Анотація. *Конкурентоспроможність будь-якої країни знаходиться у прямій залежності від ефективності роботи фінансового сектору. При чому рівень фінансової безпеки обумовлює спроможність країни розвиватися далі на інноваційних засадах. Важливою потребою є моделювання оцінювання та прогнозування фінансової безпеки країни, щоб вчасно корегувати державні рішення, розподіляти ресурси країни для підвищення її фінансової спроможності. У науковому світі не достатньо розвинуті методи моніторингу фінансової безпеки особливо на макрорівні. Потребує поглиблення інструментарій відбору показників необхідних для оцінювання фінансової безпеки. Також у часи інноваційних відкриттів та технологій, методи такої оцінки повинні бути прогресивними та нестандартними.*

Матеріалами для написання статті слугували статистичні показники, що характеризують фінансовий стан розвитку України. З використанням цих показників можливо вчасно оцінювати рівень фінансової безпеки та розраховувати прогноз. Авторами запропоновано таке групування зазначених показників, яке у найбільш повній мірі буде охоплювати фінансову діяльність країни. Моделювання оцінювання та прогнозування фінансової безпеки країни пропонуємо здійснювати з використанням штучних мереж. Для створення нейронних мереж, їх навчання та застосування при прогнозуванні динаміки показників фінансової безпеки використано пакет прикладних програм Matlab, що включає програму Network Data Manager. Ця програма дає можливість у оптимальний спосіб формувати та обирати нейронні мережі, топологію, активацію та алгоритм навчання.

Оцінювання та прогноз фінансової безпеки засвідчив необхідність підвищеної уваги держави до розподілу та накопичення фінансових ресурсів. За нашими підрахунками, у 2023–2025 роках очікується певна стабілізація показників банківської безпеки. Показники співвідношення банківських кредитів та депозитів в іноземній валюті, частки іноземного капіталу в статутному капіталі банків, співвідношення довгострокових кредитів та депозитів, частки активів 5-ти найбільших банків у сукупних активах банківської системи стабілізуються на рівні 2020 року. Рентабельність активів дещо зменшиться і стане від'ємною, а показник співвідношення ліквідних активів до короткострокових зобов'язань зросте до рівня 95,6%. Прогнозується істотне зростання відношення обсягу сукупних платежів з обслуговування та погашення державного боргу до доходів державного бюджету.

Запропонований дизайн оцінювання та прогнозування фінансової безпеки країн заснований на використанні штучних нейромереж, які є особливо актуальними в умовах сьогодення. Логіка моделювання є цілком зручною та зрозумілою для зацікавлених та може використовуватися державними посадовцями для систематичного визначення рівня фінансової безпеки країни. Також запропонований дизайн може бути адаптований для використання в інших країнах з метою визначення рівня фінансової безпеки та корегування існуючих фінансових стратегій розвитку держави.

Ключові слова: *фінансова безпека, нейронна мережа, прогнозування, фінансовий ринок, кредити, ліквідність, страхування, державний борг, національна грошова одиниця*

JEL: F 43

Bielialov Taliat
Doctor of Science in Economics, Professor
Kyiv National University of Technologies and Design
Ukraine
ORCID: 0000-0003-4019-755X

Gechbaia Badri
Doctor of Economics, Professor
Batumi Shota Rustaveli State University
Georgia
ORCID: 0000-0003-2815-2228

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STRUCTURAL CHANGE IN ENTREPRENEURIAL DEVELOPMENT IN THE CONTEXT OF GLOBALISATION: ASSESSMENT AND ADAPTIVE FORECASTING

Efficiently functioning entrepreneurship has been considered at all times as an important condition for the development of a market economy. Business enhances a country's security and competitiveness on the world stage in a globalised world. The phenomenon of entrepreneurship is a multidimensional and complex phenomenon. Business development is conditioned by many factors that stimulate or inhibit its functioning. Under such conditions, an urgent issue of modern science is to develop a methodology to identify structural changes in entrepreneurship, as well as to forecast possible variants of its development taking into account current changes in the market environment.

The information base for our study was the reporting data on entrepreneurship development for 2010–2020, officially promulgated on the website of the State Statistics Service of Ukraine. In writing the article, we used a system of methods that allow us to determine the structural changes in entrepreneurship in the context of globalisation best, as an example: scientific abstraction, analysis, hypothetical and logical methods, methods of absolute and comparative advantages. The index method was used to analyse the impact of the number of employees and labour productivity on the volume of sold products. To study the dynamics of structural changes in entrepreneurship in Ukraine and to forecast the corresponding indicators for 2023–2024 an adaptive forecast model of Holt was used.

The implementation of the proposed methods and modelling tools allowed us to analyse the dynamics of changes in entrepreneurship in Ukraine and to forecast its further development. It was determined that a significant feature of the dynamics of the distribution of employees by types of enterprises is a clearly expressed trend of reducing the share of employees of large enterprises with an increase in the share of employees of medium enterprises and individual entrepreneurs with no significant changes in the share of employees of small businesses. The peculiarity of the dynamics of the distribution of products sold by types of enterprises is a clear tendency of a decrease in the share of products of large enterprises with the growth of the share of medium enterprises, small enterprises and individual entrepreneurs. At the same time, the shares of production of large and medium enterprises significantly exceed the shares of small enterprises and individual entrepreneurs. This ratio, in accordance with the received forecasts, also took place in the forecast period for 2023–2024.

The analysis of structural changes in entrepreneurship allows some conclusions and suggestions to be made. Thus, in order to support the development of entrepreneurship, there is a need to form a critical mass of managers able to respond to changes in the external environment in a timely manner and to make effective decisions. In the formation of public policy to stimulate business development, the relevant issue is the provision of preferential loans to business entities to upgrade fixed assets, which will significantly improve production and save entrepreneurial resources. In addition, an important issue is the attraction of human resources into entrepreneurship, especially those working on an innovative basis.

Keywords: *globalisation, entrepreneurship, security, sales, productivity of work, workers, forecasting.*

1. Introduction

Macroeconomic security is an important component of a country's economic security. Significant indicators that reflect this type of security are the difference between Ukraine's productivity index and real average monthly wages, the difference between Ukraine's GDP growth rate and the growth rate of developing economies, and the unemployment rate. To address macroeconomic security problems, it is important to study the structure of entrepreneurship in the country, as large and medium-sized enterprises provide a higher level of labour productivity, and the development of small enterprises, and the activity of individual entrepreneurs is essential for employment. The aim of the article is to investigate, assess and forecast structural changes in entrepreneurship in the context of globalisation.

Wide ranges of academics have been involved in assessing entrepreneurial activity. Each scientist has tried to contribute his or her own understanding of the methodology for analysing changes in entrepreneurship. Mykhailichenko *et al.,* [1], offer an assessment of the activities of the agro-food sector in the context of the globalisation of the national economy, which will ensure its competitiveness. The authors highlight the adaptive strategy of human resource management and motivational mechanism for achieving strategic goals. Using a number of indicators and methods of descriptive statistics, the scientists analyse the specifics of the application of personnel management strategies in agricultural enterprises. Stoliarchuk *et al.,* [2], identify systems of factors associated with the development of innovative entrepreneurship. Using a complex methodological approach based on the methods of economic and mathematical modelling and extrapolation, the authors estimate the influence of the factors of innovative entrepreneurship development on GDP. The findings of Aranchi *et al.,* [3] in which an integral indicator of evaluation of the effectiveness of management of the financial condition of business entities in Ukraine was proposed, are important for our study. The combination of factors influencing the financial development of entrepreneurship is interesting: the volume of capital investment, staff and wage costs, and so on. The adaptation of the model of evaluation of the effectiveness of management of the financial condition has been carried out on the example of large, medium and small enterprises. The logic of the modelling, the system of indicators and their calculation are particularly useful for our study. Gavrish and Akhtoyan [4] analysed a marketing approach that can be appropriately used to assess the management of businesses operating in separate territories. The authors conducted forecasting of the needs of the business audience and developed a system of measures to support entrepreneurship. Of particular interest are the developed indicators of business attractiveness, as well as the expert assessment of the attractiveness of the regions. Expert evaluation is a fairly common method in the process of modelling business analysis, but there is a need for careful selection of experts, who will be impartial and responsible in their duties.

Shpikuliak and Malik, [5], explore the methodology of institutionalism, which can be used to analyse the structure and systematisation of comprehensive and specific indicators to assess the state of development of entrepreneurship in the agricultural sector. The scholars propose indicators of organizational and institutional structure and development of agribusiness efficiency. The article is interesting to us through the authors' usage of a rather non-standard methodology of modelling efficiency indicators, as well as the combination of a number of methods and tools of statistical analysis.

Taran, [6], proposes a comprehensive assessment of regional peculiarities of innovative entrepreneurship development. The scientist notes that the application of the methodology for assessing innovative entrepreneurship based on the analysis of financial indicators allows us to identify the sufficiency or lack of funds for the development of innovative entrepreneurship in a particular territory. The article proposes an integral indicator for assessing the institutional environment of business and uses a graphical method to show the results of calculations.

Khmelyuk, [7], defines the features of accounting of small business entities in Ukraine and analyses the impact of seasonal fluctuations on the volume of sales of products (works, services) by applying the index method. The scientist proposes a non-standard algorithm for assessing seasonal changes and graphically presents the seasonal wave of product realisation by a small business entity. In a rather interesting method of "scoring", the author carried out an analysis of quarterly rhythmicity and seasonal fluctuations of product realization by a small enterprise taking into account supplies. Moreover, the calculated system of indicators — the amplitude of fluctuations, the linear mean and the standard deviation are of particular scientific interest to us.

Nasar *et al.,* [8] assess support factors and barriers to entrepreneurship in the context of the COVID-19 pandemic. Using a qualitative method and interviewing, the researchers conducted 18 types of interviews with entrepreneurs working in micro, small and medium enterprises. Using analytical data and a set of indicators, the researchers modelled how COVID-19 affects entrepreneurial activity in Pakistan.

Important for our scientific paper is the study of Mondal *et al.,* [9] who have conducted a high-level study of the features of green entrepreneurship development in a circular economy for sustainable development. By modelling the development of green business, the authors proposed resource-saving technologies in micro, small and medium-sized enterprises of the manufacturing sector. Innovative within the green business analysis is the usage of

"best and worst method", "interpretive modelling", "fuzzy multiplication matrix", etc. Modelling has made it possible to see the strength of the relationship between the factors contributing to green entrepreneurship development and assess the strength of business dependence on social norms, culture, adoption of new technologies, capacity for research and development innovations, environmental regulation, waste management policy, etc. Researches of Grйgoire *et al.,* [10] have a high methodological level, where a significant number of research experiments in the entrepreneurship sphere, methods, tools and strategies to solve business development problems are presented. Marshall *et al.,* [11], using social and cognitive theory, model the relationship between wealth, access to resources and persistence. Involving 258 entrepreneurial subjects using regression analysis, the researchers proved that happiness, well-being, life satisfaction, and one's mental state have an unconditional influence on entrepreneurial performance. The methods, tools, and logic of modelling that can be used to assess entrepreneurial development have been extensively reviewed in Okudan and Rzasa, [12], Bezverhij *et al.,* [13], Obschonka, [14], Hornsby *et al.,* [15], Kaminski *et al.,* [16] researches. Despite the widespread usage of technologies for modelling structural change in entrepreneurship in the context of globalisation, there is a need for a systematic review of scientific advances as well as the introduction of new analysis tools. This will allow for comprehensively considering the current state of the enterprise, making forecasts and identifying the factors of influence of the institutional environment on business.

2. Materials and Methods

To study the dynamics of entrepreneurship development in Ukraine, data on the number of employees and the volume of products sold in large, medium, small enterprises and for individual entrepreneurs during 2010–2020 were selected. For each type of enterprise let us determine the percentage that represents the number of employees in the enterprises of that type from the total number of employees and the percentage that represents the volume of products sold by these enterprises from the total volume of products sold. The results of the calculations are shown in Table 1.

To study the dynamics of structural changes in Ukrainian entrepreneurship and to forecast relevant indicators for 2023–2024, we use Holt's adaptive predictive model. This model combines the exponential alignment of a dynamic series and the identification of a trend. The model introduces two coefficients: the equalisation coefficient α and the coefficient β, which determines the trend. The user sets these coefficients. They belong to the range from 0 to 1 and are selected empirically.

Let us use this model to forecast the share of workers employed in large, medium, small enterprises and under individual entrepreneurs. Let us denote by $q_i(t)$ the ratio of the number of workers employed in the enterprises of the i type in the t year of the retrospective period to the total number of workers in that year. For large enterprises, we take $i = 1$, for medium enterprises $i = 2$, for small enterprises $i = 3$, for individual entrepreneurs $i = 4$.

Determine the exponentially equivalent dynamic series using the formula

$$L_i(t) = \alpha q_i(t) + (1-\alpha)(q_i(t-1) + T_i(t-1),$$

where $L_i(t)$ is the equalised level of the series in year t ($t > 1$);

$L_i(t-1)$ is the equalised level in the previous year;

$T_i(t-1)$ is the trend value in the previous year. The coefficient α assume equal to 0,9.

At $t = 1$, we consider that $L_i(1) = q_i(1)$. The trend value $T_i(t-1)$ at $t > 1$ is determined from the equality

$$T_i(t) = \beta\left(L_i(t) - L_i(t-1)\right) + (1-\beta)T_i(t-1).$$

At $t = 1$, we consider that $T_i(1) = 0$. The coefficient β we take equal to 0,05.

The values are used for forecasting $L_i = L_i(N)$ and $T_i = T_i(N)$, obtained for the last year $t = N$ of the retrospective period. The forecast for p years is determined by the following equation

$$Q_i(N+p) = L_i + pT_i,$$

where p is the order number of the year, in the period for which the forecast is made.

To estimate the accuracy of the predictive model for each value of t, starting at $t = 2$, we determine the prediction for one period $P_i(t) = L_i(t-1) + T_i(t-1)$, the model error $\Delta_i(t) = q_i(t) - P_i(t)$ and error variance

$$\delta_i(t) = \frac{\Delta_i^2(t)}{q_i^2(t)}.$$

The accuracy of the predictive model is defined by the equation

$$\nu_i = 1 - \frac{\sum_{t=2}^{N}\delta_i(t)}{N-1}.$$

The closer ν_i is to 1, the more accurate the forecast.

3. Results and Discussion

The determination of the projected values for indicator $q_1(t)$ of the share of workers in large enterprises among all employees is shown in Table 2.

Thus, the expected proportion of employees in large enterprises in the total number of employees in 2023 is 17% and in 2024 16.8%. The accuracy of the forecast is 99.65%. Similarly, we determine the forecast values for 2023 and 2024 for the share of employees in other types of enterprises and the share of sales in these enterprises. The results of the calculations are shown in Table 3.

Table 1

Ukrainian enterprise performance indicators in 2010–2020

Years	Number of employees		Volume of products sold	
	Thousands of people	% of the total number	Million UAH	% of the total volume
Large enterprises				
2010	2400,3	22,28%	1401596,8	38,97%
2011	2449	24,09%	1775829	42,26%
2012	2484,2	24,95%	1761086	39,49%
2013	2383,7	24,50%	1717391,3	39,62%
2014	1915,1	21,77%	1742507,9	39,07%
2015	1708,6	20,89%	2053189,5	36,95%
2016	1586,6	19,57%	2391454,3	35,55%
2017	1560,9	19,17%	2929516,6	35,24%
2018	1574,3	18,45%	3515839,5	35,28%
2019	1608,3	17,83%	3631415,3	34,51%
2020	1574,6	17,63%	3626388	32,78%
Medium enterprises				
2010	3393,3	31,50%	1396364,3	38,82%
2011	3252,6	32,00%	1607628	38,25%
2012	3144,2	31,58%	1769430,2	39,67%
2013	3012,1	30,96%	1662565,2	38,36%
2014	2696,5	30,65%	1723151,5	38,64%
2015	2604,7	31,84%	2168764,8	39,03%
2016	2622,8	32,35%	2668695,7	39,67%
2017	2593,1	31,85%	3296417,9	39,66%
2018	2744,2	32,16%	3924059,6	39,37%
2019	3052,6	33,85%	4168439,4	39,61%
2020	3088,4	34,58%	4359362,1	39,41%
Small enterprises				
2010	2164,6	20,09%	568267,1	15,80%
2011	2091,5	20,58%	607782,4	14,46%
2012	2051,3	20,60%	672653,4	15,08%
2013	2010,7	20,67%	670258,5	15,46%
2014	1686,9	19,18%	705000,5	15,81%
2015	1576,4	19,27%	937112,8	16,87%
2016	1591,7	19,63%	1177385,2	17,50%
2017	1658,9	20,38%	1482000,7	17,83%
2018	1641	19,23%	1766150,4	17,72%
2019	1746,6	19,37%	1839875,9	17,48%
2020	1703,1	19,07%	2064120,7	18,66%
Individual entrepreneurs				
2010	2814,5	26,13%	230418,2	6,41%
2011	2371,4	23,33%	211215,8	5,03%
2012	2277,9	22,88%	256649,2	5,75%
2013	2322,6	23,87%	284238,1	6,56%
2014	2498,2	28,40%	289042,3	6,48%
2015	2290,3	28,00%	397473,3	7,15%
2016	2307,2	28,45%	489204,6	7,27%
2017	2328,1	28,60%	604336,7	7,27%
2018	2573	30,16%	760755	7,63%
2019	2610,3	28,95%	884382,2	8,40%
2020	2565,8	28,73%	1012426,3	9,15%

Source: https://www.ukrstat.gov.ua/

The distribution of the number of employees by type of enterprise with a forecast for 2023–2024 is shown in Figure 1.

The share of employees of large enterprises increased between 2010 and 2012. Since 2013, this share has been decreasing and has become the lowest among all types of enterprises since 2017. For the years 2023–2024, it is projected to decrease slightly and stabilise at 17%. The share of employees of medium-sized enterprises is the largest. It is increasing between 2017 and 2020. For 2023–2024, it is projected to increase slightly and stabilise at 35%. The share of employees in small enterprises has not changed significantly during the retrospective period. For 2023–2024, this value is projected to stabilise at 19%, roughly equal to its value in 2019–2020. The proportion of working under individual entrepreneurs increased significantly in 2014. For 2023–2024, this value is projected to stabilise at 29%, roughly equal to its value in 2018–2020. Thus, a significant feature of the dynamics of the distribution of employees by type of enterprise is a clear tendency for the share of workers in large enterprises to decrease with a simultaneous increase in the share of workers in medium enterprises and under individual entrepreneurs, with no significant change in the share of workers in small enterprises.

Distribution of sales volumes by type of enterprise with a forecast for 2023–2024 is shown in Figure 2.

Since 2012, the share of large enterprises in the volume of products sold has been decreasing. Since 2015, this share becomes smaller than that of medium-sized enterprises. For the years 2023–2024, this value is projected to decrease slightly and stabilise at 32%. The share of production of medium-sized enterprises is the largest since 2015. For 2023–2024, it is projected to stabilise at 39.5%. The share of the output of small enterprises starts to grow from 2012. For 2023–2024, this value is projected to continue to grow and stabilise at 19%. The share of products sold by individual entrepreneurs did not change significantly in 2015–2017 and started to grow in 2018. For the years 2023–2024, this value is projected to continue to grow and stabilise at 9.5%. Thus, a significant feature

Table 2

Determining predictive values for indicator $q_1(t)$

Year	t	$q_1(t)$	$L_1(t)$	$T_1(t)$	p	$Q_1(N+p)$	$p_1(t)$	$\Delta_1(t)$	$\delta_1(t)$	v_1
2010	1	0,22281	0,22281	0,00000			0,22281			99,65%
2011	2	0,24094	0,23912	0,00082			0,22281	0,01812	0,00566	
2012	3	0,24948	0,24852	0,00124			0,23994	0,00954	0,00146	
2013	4	0,24501	0,24548	0,00103			0,24977	-0,00476	0,00038	
2014	5	0,21771	0,22059	-0,00027			0,24651	-0,02881	0,01751	
2015	6	0,20888	0,21002	-0,00078			0,22032	-0,01145	0,00300	
2016	7	0,19568	0,19703	-0,00139			0,20924	-0,01356	0,00480	
2017	8	0,19173	0,19212	-0,00157			0,19564	-0,00391	0,00042	
2018	9	0,18451	0,18511	-0,00184			0,19056	-0,00605	0,00108	
2019	10	0,17835	0,17884	-0,00206			0,18327	-0,00492	0,00076	
2020	11	0,17629	0,17634	-0,00208			0,17678	-0,00049	0,00001	
2021					1	0,17426				
2022					2	0,17217				
2023					3	0,17009				
2024					4	0,16801				

Source: calculated by the authors

Table 3

Projected values of employee distribution indicators and sales volume by type of enterprise

Indicator	Type of enterprise	Forecast for 2023	Forecast for 2024	Accuracy of forecasts
Number of employees (% of the total number of employees at the enterprises)	Large	17,01%	16,80%	99,65%
	Medium	34,92%	35,06%	99,94%
	Small	18,96%	18,91%	99,88%
	Idividual entrepreneur	29,11%	29,22%	99,50%
Volume of products sold (% of total products sold)	Large	32,13%	31,86%	99,81%
	Medium	39,50%	39,52%	99,97%
	Small	18,92%	19,04%	99,79%
	Idividual entrepreneur	9,45%	9,57%	98,68%

Source: calculated by the authors

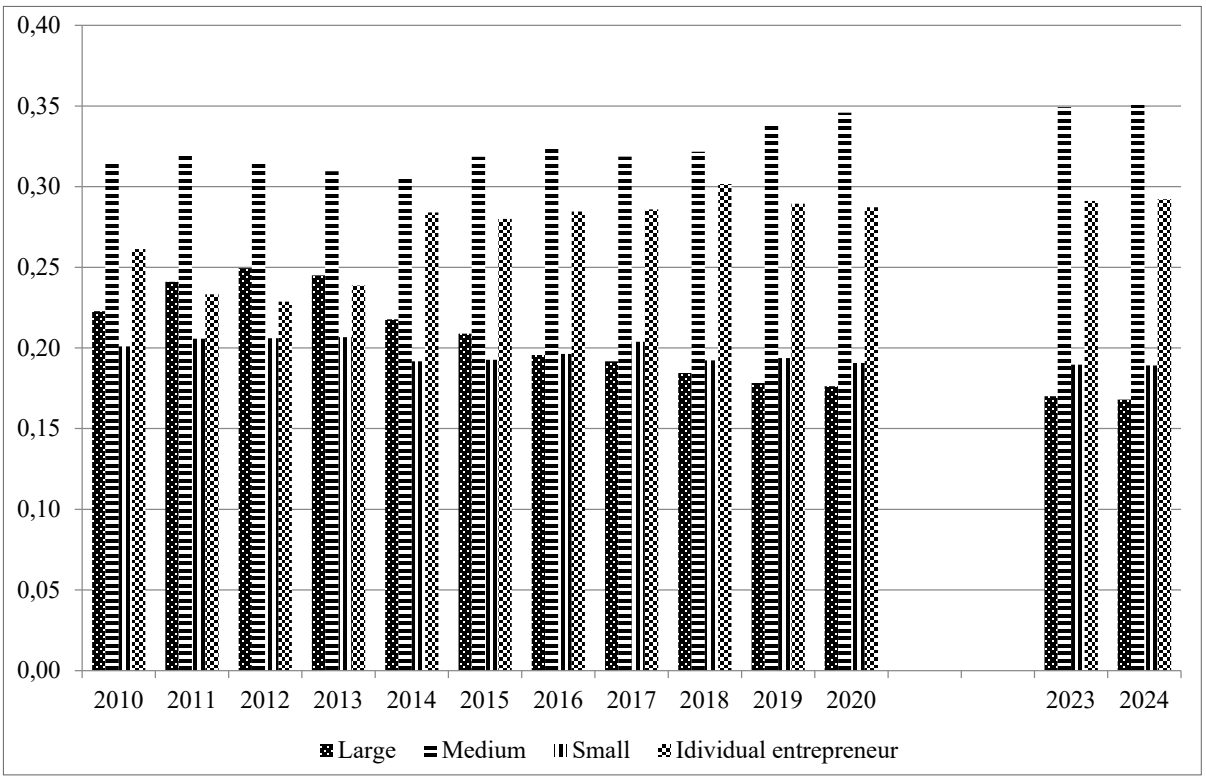

Figure 1. Distribution of the number of employees by type of enterprise with forecast for 2023–2024
Source: calculated by the authors

of the dynamics of the distribution of sales by type of enterprise is a clear tendency for the share of production of large enterprises to decrease with an increase in the shares of medium-sized enterprises, small enterprises and individual entrepreneurs. At the same time, the shares of production of large and medium enterprises significantly exceed the shares of small enterprises and individual entrepreneurs.

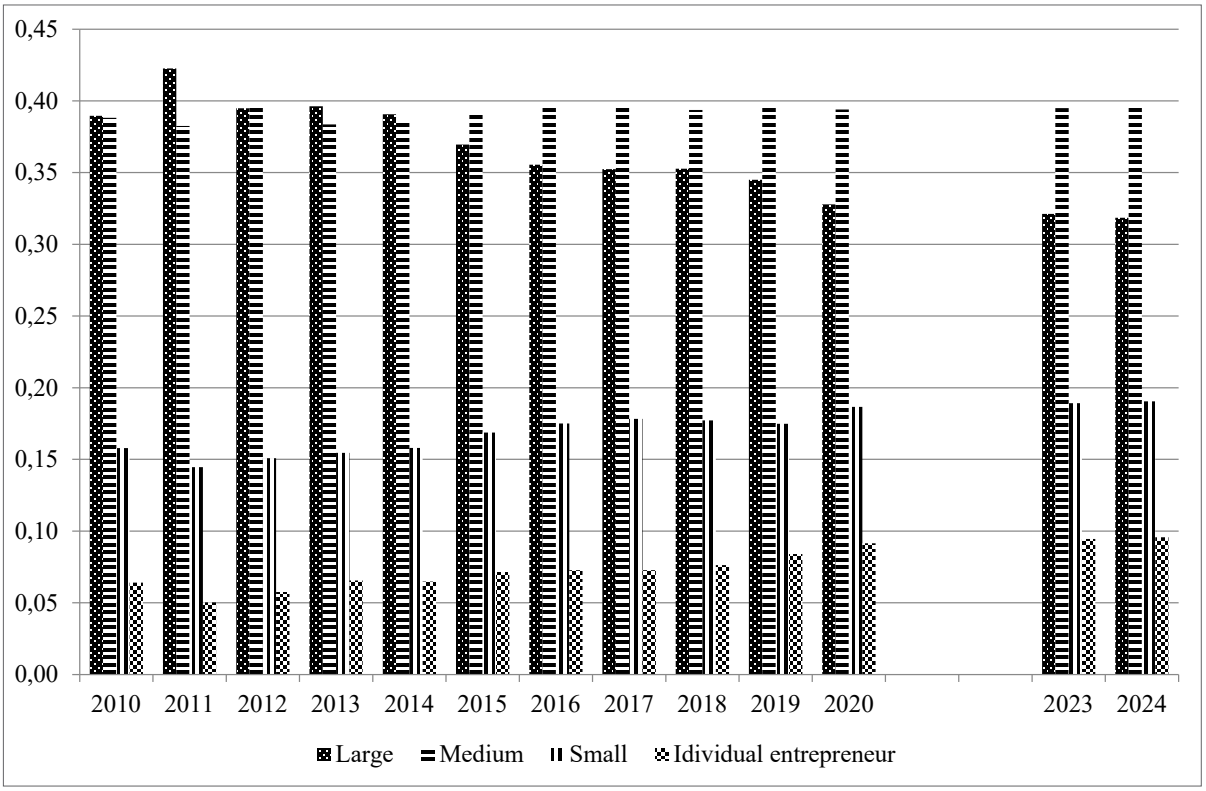

Figure 2. Distribution of sales by type of enterprise with forecast for 2023–2024
Source: calculated by the authors

This ratio, in accordance with the received forecasts, will be the same in the forecast period.

To estimate the impact of the number of employees and labour productivity on the volume of sales, we use the index method. Let us denote by $g_i(t)$ and $r_i(t)$ the labour productivity and the number of employees, respectively, for the enterprises of the i type in the t year of the retrospective period. For each year, starting from $t - 2$, we define the following indices:

1) index I_{gr} of output volume, defined by equality

$$I_{gr}(t) = \frac{\sum_{i=1}^{4} g_i(t) r_i(t)}{\sum_{i=1}^{4} g_i(t-1) r_i(t-1)};$$

2) index I_g of labour productivity, defined by equality

$$I_g(t) = \frac{\sum_{i=1}^{4} g_i(t) r_i(t)}{\sum_{i=1}^{4} g_i(t-1) r_i(t)}$$

3) index I_r of the number of employees, defined by equality

$$I_r(t) = \frac{\sum_{i=1}^{4} g_i(t-1) r_i(t)}{\sum_{i=1}^{4} g_i(t-1) r_i(t-1)}.$$

The I_{gr} index shows by how much the volume of products sold increases or decreases compared to the previous year, the I_g index shows by how much this volume would change if the number of employees in each type of enterprise remained unchanged, and the I_r index shows by how much this volume would change if labour productivity remained unchanged.

Let us also determine the absolute increases in sales volumes

$$A(t) = \sum_{i=1}^{4} g_i(t) r_i(t) - \sum_{i=1}^{4} g_i(t-1) r_i(t-1)$$

and the constituent parts of these increments:

$$A_g(t) = \sum_{i=1}^{4} g_i(t) r_i(t) - \sum_{i=1}^{4} g_i(t-1) r_i(t),$$

part of the growth obtained from the change in labour productivity at all kinds of enterprises and the part

$$A_r(t) = \sum_{i=1}^{4} g_i(t-1) r_i(t) - \sum_{i=1}^{4} g_i(t-1) r_i(t-1),$$

resulting from changes in the number of workers at these enterprises. The results of the calculations are given in Table 4.

The dynamics of the indices of the volume of products sold, labour productivity and the number of employees are shown in Figure 3.

Since the index I_{gr} of production volume for all years of the retrospective period, except for 2013, exceeds 100%, there is an increase in the volume of sold products in these years. The largest increase was recorded in 2015- by 24.6%, which in absolute terms amounts to 1096838 million UAH. The index I_r, of the number of employees in all years except 2018 and 2019 did not exceed 100%. This means that if labour productivity remained unchanged, the volume of products sold would decrease, while its real increase is determined by an increase in labour productivity in those years. The I_g labour productivity index shows by how much the volume of products sold would have increased with unchanged labour productivity. This index had the highest value of 1,341215 in 2015. The I_g and I_r indices were both greater than 100% only in 2018. This means that this year alone the increase in the volume of products sold was caused by both an increase in labour productivity and an increase in the number of employees, with higher labour productivity resulting in an increase in sales volumes on 1389720 million UAH and a 264812.5 million UAH increase in sales volumes caused by in the number of employees. Between 2011 and 2017, a reduction in the number of employees was accompanied by an increase in labour productivity, and in all years of

Table 4

Indices and absolute values of growth in sales volumes

Years	Indices			Absolute growths (million UAH)		
	I_{gr}	I_g	I_r	A_{gr}	A_g	A_r
2011	1,168437	1,196695	0,976387	605808,8	690737,1	-84928,3
2012	1,061241	1,073519	0,988563	257363,6	305426,8	-48063,2
2013	0,97189	1,006618	0,9655	-125366	28497,9	-153864
2014	1,028896	1,193649	0,861976	125249,1	723509,6	-598260
2015	1,245944	1,341215	0,928967	1096838	1413626	-316788
2016	1,210599	1,237208	0,978493	1170199	1289705	-119506
2017	1,235706	1,238434	0,997797	1585532	1600349	-14817,3
2018	1,199047	1,162027	1,031858	1654533	1389720	264812,5
2019	1,055916	0,992053	1,064375	557308,3	-84300,5	641608,8
2020	1,051138	1,060012	0,991628	538184,3	626289,9	-88105,6

Source: calculated by the authors

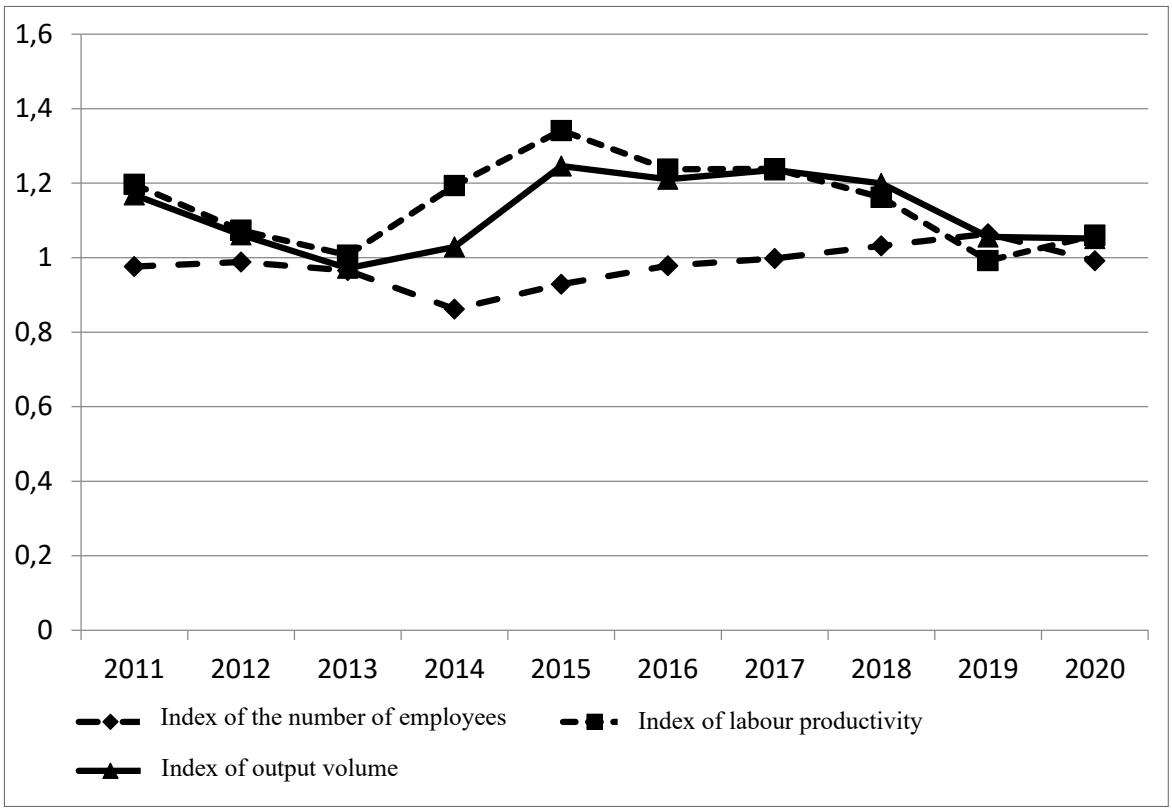

Figure 3. Evolution of indices of sales volumes, labour productivity and number of employees
Source: calculated by the authors

this period, except for 2013, the impact of labour productivity on sales was greater than that of the number of employees. In 2019, the opposite situation occurs, where the volume of products sold increased because of an increase in the number of employees. In 2020, as in 2011–2017, the growth in realised products was determined by an increase in labour productivity.

4. Conclusions

The results of modelling the estimation and forecasting of changes in entrepreneurship in the context of globalisation have been carried out using the Holt adaptive forecasting model. To assess the impact of the number of employees and labour productivity on the volume of products sold, the index method was used. The study was based on the reporting data on large, medium, small enterprises and individual entrepreneurs over the period of 2010–2020. It is determined that a significant feature of the dynamics of the distribution of employees by type of enterprise is a clear tendency to decrease the share of employees of large enterprises with a simultaneous increase in the share of employees of medium-sized enterprises and individual entrepreneurs, with no significant changes in the share of employees of small enterprises. A feature of the dynamics of the distribution of products sold by type of enterprise is a clear trend towards a decrease in the share of large enterprises' output with a simultaneous increase in the share of medium-sized enterprises, small enterprises, and individual entrepreneurs. At the same time, the shares of output of large and medium-sized enterprises significantly exceed the shares of small enterprises and individual entrepreneurs. This ratio, according to the forecasts, was also observed in the forecast period for 2023–2024. Thus, the proposed methodology for modelling changes in entrepreneurship in the context of globalisation allows for a convenient assessment of changes. Our further research will be aimed at expanding the number of indicators that can be used to assess changes in entrepreneurship and attracting other innovative forecasting methods.

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Бєлялов Талят
доктор економічних наук, професор,
Київський національний університет технологій та дизайну
Україна
ORCID: 0000-0003-4019-755X

Гечбая Бадрі
Доктор економічних наук, професор
Батумський державний університет імені Шота Руставелі
Грузія
ORCID: 0000-0003-2815-2228

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СТРУКТУРНІ ЗМІНИ У РОЗВИТКУ ПІДПРИЄМНИЦТВА В УМОВАХ ГЛОБАЛІЗАЦІЇ: ОЦІНЮВАННЯ ТА АДАПТИВНЕ ПРОГНОЗУВАННЯ

Анотація. *Ефективно функціонуюче підприємництво в усі часи вважалося важливою умовою розвитку ринкової економіки. Бізнес підвищує безпеку країни та її конкурентоспроможність на світовій арені в умовах глобалізації. Феномен підприємництва є багатоаспектним складним явищем. Розвиток бізнесу обумовлений багатьма чинниками, які стимулюють або навпаки стримують його функціонування. За таким умов актуальним питанням сучасної науки є розробка методології визначення структурних змін у підприємництві, а також прогнозування можливих варіантів його розвитку з урахуванням поточних змін у ринковому середовищі.*

Інформаційною базою нашого дослідження слугували звітні данні розвитку підприємництва за 2010–2020 роки, що офіційно оприлюднені на сайті Державної служби статистики України. При написанні статті нами використано систему методів, які у найліпший спосіб дозволяють визначити структурні зміни у підприємництві в умовах глобалізації, як приклад: наукове абстрагування, аналіз, гіпотетичний та логічний методи, методи абсолютних та порівняльних переваг. Для аналізу впливу кількості працюючих та продуктивності праці на обсяг реалізованої продукції використано індексний метод. Для дослідження динаміки структурних змін в підприємництві України та прогнозування відповідних показників на 2023–2024 роки використано адаптивну прогнозну модель Хольта.

Реалізація запропонованих методів та інструментаріїв моделювання, дозволила нам проаналізувати динаміку змін підприємництва в Україні та спрогнозувати його подальший розвиток. Визначено, що істотною особливістю динаміки розподілу працівників за видами підприємств є чітко виражена тенденція зменшення частки працівників великих підприємств із одночасним зростанням часток працівників середніх підприємств та ФОП при відсутності істотних змін в частці працівників малих підприємств. Особливістю динаміки розподілу реалізованої продукції за видами підприємств є чітко виражена тенденція зменшення частки продукції великих підприємств із одночасним зростанням часток середніх підприємств, малих підприємств та ФОП. В той же час частки продукції великих та середніх підприємств істотно перевищують частки малих підприємств та ФОП. Це співвідношення відповідно до одержаних прогнозів мало місце і в прогнозному періоді на 2023–2024 роки.

Аналіз структурних змін у підприємництві дозволяє зробити окремі висновки та пропозиції. Так, з метою підтримки розвитку підприємництва існує потреба формування критичної маси управлінців здатних вчасно реагувати на зміни у зовнішньому середовищі та приймати ефективні рішення. При формуванні державної політики щодо стимулювання розвитку бізнесу актуальним питанням є надання пільгових кредитів суб'єктам підприємницької діяльності для оновлення основних фондів, що значно поліпшить виробництво продукції та заощадить підприємницькі ресурси. Окрім того, важливим питанням є залучення трудових ресурсів до зайняття підприємництвом, особливо таких, що працюють на інноваційних засадах.

Ключові слова: *глобалізація, підприємництво, безпека, реалізація продукції, продуктивність праці, працівники, прогнозування.*

JEL: E20

Zolkover Andrii
Doctor of Science in Economics, Professor
Kyiv National University of Technologies and Design
Ukraine
ORCID: 0000-0002-8176-1850

Dimitrina Kamenova
Professor of Social Management
Varna University of Management
Bulgaria
ORCID: 0000-0003-4311-9709

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MACROECONOMIC ANALYSIS OF A COUNTRY'S DEVELOPMENT: SECURITY ASPECT

Abstract. *The global economy in the current period of evolutionary development is constantly changing and transforming due to the need to adapt it to the changing conditions of civilisational development. Every country in the world experiences global changes that put on the agenda the issues of ensuring an appropriate level of security in the financial, economic and food sectors. An important issue is the timely monitoring of economic security and forecasting of further social and economic development of the country.*

The panel data for our study consisted of 19 indicators of measuring the macroeconomic security of Ukraine, which we defined as stimulants, nominators and destimulants. The informational basis of forecasting is the reported data of the macroeconomic development of the country. With the usage of methods of statistical modelling, expert judgement, least squares, Fisher's criterion, correlation and regression analysis, the predicted values of macroeconomic security indicators and the level of shadowing of the economy were calculated. For an experimental purpose, it is proposed to compare the results of integral assessments and the predicted values of macroeconomic security of the country in two methods, namely: expert assessment and modified principal component.

The results of estimating the country's macroeconomic development obtained by the modified principal component method are significantly higher than those obtained from expert judgement. In 2013–2017, the difference between these estimates decreases, but the modified principal component estimate method remains higher. In 2018–2020, the estimate obtained by the expert valuation method becomes higher. The forecast for 2023–2024 assumes a stabilisation of the integral estimate. The modified principal component method predicts a certain increase compared to 2020, while the expert valuation method predicts a slight decrease. The results of modelling the further macroeconomic development of the country indicate the need for government managers to focus on the processes of attracting investment and stabilising the labour market, which would significantly increase the country's security.

The proposed logic of macroeconomic analysis of a country's functioning can be used in planning or strategising public policy for social and economic development. Taking into account the changes obtained in the process of such analysis will make it possible to increase the level of security of the country. Determination of forecast values of the level of shadowing of the economy will allow stakeholders to make adaptive managerial decisions in the direction of bringing the economy out of the shadow and stimulating security aspects of the country's development.

Keywords: *security, economic shadowing, labour productivity, wage, balance of payments, consumer price index, savings*

1. Introduction

Macroeconomic analysis of a country's development is an essential tool for ensuring the country's social and economic, financial, product and social security. The timeliness and usability of the security assessment procedure guarantees the effectiveness of management decisions and increase of the country's competitiveness. In addition, the volatility of the external environment and global trends undoubtedly influence the current development of Ukraine. In such case, timely diagnosis and determination of the cause-and-effect relations of changes in macroeconomic trends will enable the adjustment of the state development policy and forecasting of major trends. The level of shadowing of the national economy is of great importance for supporting the security of the country. The above-mentioned problems determine the importance of the study and its relevance in security science.

The aim of the article is to provide a logical macroeconomic analysis of a country's development in the context of a security aspect.

In the scientific findings of Sun *et al.,* [1], it is rightly noted that high-quality development of society and the economy as a whole is possible through a detailed analysis of economic and environmental security. That is why the authors proposed a methodology for determining the level and model of the dynamic development of environmental and economic security of different provinces and regions in the context of sustainable development. The resulting calculations have made it possible to determine the causes of natural resource depletion, which is necessary for the comprehensive, stable and quality social and economic development of individual provinces. The authors have determined the level of ecological and economic security in China, as well as the impact of the territorial location of the region on the ecologisation as a whole.

Su *et al.,* [2] have analysed food security as a necessary component of state economic development. The authors made an interstate comparison of food security in 25 countries for the period 1995–2019. Useful for our study is the system of indicators to assess food security and the inclusion to their group of secondary food security indicators that support food sustainability. The results obtained in the article show that economic policy uncertainty has a negative impact on food security, especially in developed and food-exporting countries. The mentioned modelling allowed the authors to propose a system of factors to increase food security: increasing of political support for grain production, increasing of capital investment, strengthening free trade, etc.

Song *et al.,* [3], investigated the relationship between natural resource assets, economic growth and economic security. The scientists proposed a mechanism of three methods to account for natural resource assets, as well as estimates of China's energy, minerals, water, land, and forests. What is important for our study is the combination of methods that the authors use to assess the linkage.

In their scientific researches Semenov *et al.,* [4], proposed an adaptive model for assessing the dynamics of financing measures for the development and implementation of innovative energy- and resource-saving projects in the agro-food sector. The combination of evaluation indicators and their statistical processing is of particular scientific interest for our study.

An article by Lee *et al.,* [5], focuses on modelling the impact of income on energy security and the economy as a whole. Using six indicators of energy security, the authors investigated their impact on income distribution. The strength of the scientific paper is the broad coverage of the information base of the study, where, using panel data from 68 countries for 2001–2018, the authors obtained an inverted U-shaped impact of energy security on income inequality. The findings have valuable advice for policymakers and academics who deal with the issues of assessing economic, energy or financial security at the macro level.

Tutak and Brodny, [6], using the functioning of the European Union as an example, diagnose the state of energy security in the "Three Seas Initiative" countries and determine how it has changed between 2009 and 2019. Interestingly, the article uses grey relational analysis (GRA) to analyse 17 indicators characterising security in the energy, economic, environmental and social aspects. The indicator weights were defined as the average by the methods: CRITIC, entropy and standard deviation. The results made it possible to segment security levels between the European Union countries, to identify leaders, outsiders and to formulate proposals.

Chi *et al.,* [7], who identified the causes of the energy dependence of Chinese regions, have conducted similar studies. Security was calculated in five segments: politics, economy, law, technology, and geography. Panel data covered the period from 2011 to 2018, and the application of the entropy method allowed for an objective assessment of the security of China and 22 countries in four regions of Northeast, Central, South and Southeast Asia.

The research of Semenov *et al.,* [4], Lee *et al.,* [5], Tutak and Brodny, [6] and Chi *et al.,* [7], is of particular scientific interest in the context of the resource-saving and greening of an industry that the entire global community is striving for.

Li *et al.,* [8], in the context of defining the triple attributes (i.e. equity, efficiency and security), proposed a methodology to assess sustainable water resources usage. Using the Ginny coefficient, method of data coverage analysis and water ecological footprint model, water resources equity, efficiency and environmental security indices were calculated. The resource usage assessment modelling was carried out for 2005–2019 with a diagnosis of 31 provinces and cities of China. The usage of the method of coverage data analysis, which allowed the authors to obtain important results for resource conservation and improvement of the environmental security of the country, is of interest to us.

The scientific views of Blihar *et al.*, [9], are of particular value within the subject matter of our study. Their article outlines a very important issue of our time — strengthening the financial and economic security of the country by developing a strong economic policy of Ukraine. The authors have analysed the financial and economic security of Ukraine and proposed directions for the reorientation of state regulation from the spontaneous development "financialisation mechanism" to the policy of supporting an appropriate level of financial security.

Bezverkhyi *et al.*, [10], proposed a very interesting model for assessing the integrated accounting of business entities. The authors carried out the selection of criteria to build an econometric model for assessing the quality of integrated accounting and analysed the results obtained. The logic of criteria selection and their statistical processing are of scientific interest in the framework of our study.

Important scientific findings have been obtained in the works of other scholars: Prievoznик *et al.*, [11], Conrad *et al.*, [12], Xue *et al.*, [13], Koshkina and Sharamko, [14], Breiding *et al.*, [15], Ereshko and Karanina, [16], Bricker and Bucks, [17], which are useful for our paper. The above works of researchers show an increased interest in the procedure for analysing macroeconomic security assessment. At the same time, there is a need to expand the logic of modelling integral indicators of macroeconomic security assessment and to revise the existing methodologies.

2. Materials and Methods

We propose to determine the macroeconomic security of the country's development using the methods of statistical modelling, expert estimation, least squares, Fisher criterion, correlation and regression analysis and Holt's method. Macroeconomic security is an important component of a country's economic security. Its level is determined by a set of indicators reflecting the balance of macroeconomic reproduction proportions. Let us denote the set of these indicators by X, and individual indicators included in this set by x_i. These indicators are divided into stimulants, whose increase contributes to better macroeconomic security, destimulants, whose increase diminishes macroeconomic security, and nominators, for which deviations in one direction or another from certain optimal values are undesirable. The characteristics selected for the study are shown in Table 1.

In order to make effective management decisions to improve the country's macroeconomic security, it is important to determine the expected future values of these indicators. The information basis for forecasting is statistical data for the retrospective period 2010–2020. Let us define by $x_i(t)$ the value of the indicator xi in t year of the period. These values are shown in Table 2.

Table 1

Macroeconomic security assessment indicators

Indicator	Content of the indicator	Type of the indicator
x_1	The difference between the growth rates of average monthly wages and labour productivity	Nominant, optimal value from −0.5 to 0.5
x_2	Level of the shadow economy as a percentage of GDP	Destimulant
x_3	Current account balance of Ukraine's balance of payments as a percentage of GDP	Nominant, the optimal value is from −1.5 to 1.5
x_4	Unemployment rate, i.e. the ratio of the number of unemployed registered in the state employment service to the number of employable people of working age (in percentage terms)	Destimulant
x_5	The long-term unemployment rate, i.e. the ratio of the number of unemployed for more than 12 months to the total number of unemployed (in percentage terms)	Destimulant
x_6	The difference between Ukraine's GDP growth rate and the growth rates of developing economies	Stimulant
x_7	Consumer price index	Nominant, the optimal value is from 2 to 3
x_8	Ratio of disposable income to GDP (percentage)	Nominant, the optimal value is from 53 to 55
x_9	Propensity of the population to save (in per cent)	Nominant, the optimal value is from 12 to 14
x_{10}	The ratio of wages volume to social benefits volume and other current transfers received, in the total structure of the population's income	Stimulant
x_{11}	Ratio of GDP per capita in Ukraine to the average value in the EU (in per cent)	Stimulant
x_{12}	Employment in the informal sector of the economy, as a percentage of the total number of employed people	Destimulant

Source: combination of indicators adapted by the authors from https://zakon.rada.gov.ua/rada/show/v1277731-13

Table 2

Values of macroeconomic security indicators of Ukraine

Indicator	Years										
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
x_1	6,5	3,6	14,4	8,5	-6,4	-19,4	5,5	15,9	10,4	7,9	7,4
x_2	36	31,8	30,3	30,4	35,7	35,1	32,6	31,8	29	28	30
x_3	-2,1	-6	-7,9	-8,7	-3,4	5,5	-2	-3,1	-4,9	-2,7	4
x_4	8,2	8	7,6	7,3	9,3	9,1	9,3	9,5	8,8	8,2	9,5
x_5	33,9	28,4	28	27,3	20,1	20,4	25,3	26,7	21,6	13,1	21,2
x_6	-3,3	-0,9	-5,1	-5,1	-11,5	-14,1	-2,2	-2,3	-1,1	-0,4	-1,8
x_7	9,1	4,6	-0,2	0,5	24,9	43,3	12,4	13,7	9,8	4,1	5
x_8	78,6	76,1	81,8	83	72,6	68,5	66,3	67,4	69,4	73,1	73,1
x_9	19,1	12,4	12,8	9,6	2,7	2,3	0,8	1,5	1,3	-0,4	-0,6
x_{10}	1,06	1,13	1,12	1,08	1,09	1,08	1,28	1,36	1,4	1,48	1,36
x_{11}	8,78	9,8	11,95	11,34	8,49	6,6	6,8	7,8	8,5	10,5	11
x_{12}	22,9	23,1	22,9	23,6	25,1	26,2	24,3	22,9	21,6	20,9	20,3

Source: compiled by the authors using https://www.ukrstat.gov.ua/

The adaptive Holt model is used to predict the dynamics of these indicators. A feature of this model is that it takes into account the presence of a trend. The model is applied when there is an upward or downward trend in the dynamics of its values. When examining the values of the following indicators xi during the retrospective period, revealed trends in the dynamics of the indicators x_2, x_4, x_5, x_8, x_{10}, x_{11}, x_{12}. Therefore, the Holt model can be used to determine the expected future values of these indicators. This model uses two coefficients, the row-smoothing coefficient α and the trend-smoothing coefficient β. The values of these coefficients are selected empirically. In our study of the dynamics of the selected indicators, a value of $\alpha = 0{,}9$ and $\beta = 0{,}05$, was adopted, which allowed us to obtain a high estimate of forecast accuracy.

When forecasting xi, using the Holt model, for each value of t from the retrospective period, the elements $g_i(t)$ of the exponentially-smoothed series and the trend value $r_i(t)$ are determined using the recurrent formulas

$$g_i(t) = \alpha x_i(t) + (1-\alpha)(g_i(t-1) + r_i(t-1))$$
$$r_i(t) = \beta(g_i(t) - g_i(t-1)) + (1-\beta) r_i(t-1)$$

For the first period, consider that

$$g_i(1) = x_i(1),\ r_i(1) = 0.$$

After determining the values of $g_i(t)$ and $r_i(t)$ for all years of the retrospective period, to make a forecast of x_i indicators use the formula

$$x_i(T+j) = g_i(T) + j r_i(T)$$

where T is the number of years in the retrospective period.

To assess the accuracy of the prediction, determine for each value of t from $t = 2$ to $t = T$ the values

$$q_i(t) = g_i(t) + r_i(t),\ \Delta_i(t) = x_i(t) - q_i(t)$$

та

$$\delta_i(t) = \frac{\Delta_i^2(t)}{x_i^2}.$$

The prediction accuracy is determined by the equality

$$\nu_i = 1 - \frac{\sum_{t=2}^{T} \delta_i(t)}{T-1}.$$

The definition of the projected values for indicator x_2 is shown in Table 3.

Similarly, forecast values are determined for the indicators x_4, x_5, x_8, x_{10}, x_{11} and x_{12}. The forecast results are presented in the Table 4.

For the other macroeconomic security indicators, Holt's model does not apply, as no trends in their dynamics have been identified. In some years of the retrospective period, the value of these indicators differs significantly from their level in other years. Such years are 2014 and 2015 for x1, x6 and x7, 2015 for x_3, and 2010, 2011, 2012 and 2013 for x9.

To forecast these indicators we use a multiple linear regression equation $x_i(t) = a_{i0} + a_{i1}t + a_{i2}w_i(t)$, where w_i, is an artificial variable equal to 1 for those t values that correspond to the years in which the variable x_i takes significantly different values and equal to 0 for other t values. The values of the variables w_i for the indicators x_1, x_3, x_6, x_7 and x_9 are given in Table 5.

The coefficients a_{i0}, a_{i1} and a_{i2} of the equations of multiple linear regression are determined by the least squares method. To check the adequacy of the obtained equations, we use Fisher's criterion. Determine the coefficient of determination R^2 by the formula

$$R^2 = 1 - \frac{\sum_{t=1}^{T} \left(x_i - a_{i0} - a_{i1}t - a_{i2}w_i(t)\right)^2}{\sum_{t=1}^{T} \left(x_i(t) - \bar{x}_i\right)^2}$$

Table 3

Determination of forecast values of the level of economic shadowing

Year	t	$x_2(t)$	$g_2(t)$	$r_2(t)$	j	$x_2(T+j)$	$q_2(t)$	$\Delta_2(t)$	$\delta_2(t)$	v_2
2010	1	36	36	0,000			36			99,32%
2011	2	31,8	32,22	-0,189			36	-4,2	0,017	
2012	3	30,3	30,47	-0,267			32,031	-1,731	0,003	
2013	4	30,4	30,38	-0,258			30,206	0,194	0,000	
2014	5	35,7	35,14	-0,007			30,122	5,578	0,024	
2015	6	35,1	35,10	-0,009			35,135	-0,035	0,000	
2016	7	32,6	32,85	-0,121			35,095	-2,495	0,006	
2017	8	31,8	31,89	-0,163			32,728	-0,928	0,001	
2018	9	29	29,27	-0,286			31,730	-2,730	0,009	
2019	10	28	28,10	-0,330			28,987	-0,987	0,001	
2020	11	30	29,78	-0,230			27,769	2,231	0,006	
2021					1	32,728				
2022					2	32,607				
2023					3	32,486				
2024					4	32,365				

Source: Calculated by the authors

where $\bar{x}_i$ is the mean value of the indicator xi during the retrospective period. Then we determine the actual value of Fisher's criterion by the following equation

$$F = \frac{R^2}{1-R^2}\frac{T-3}{2}.$$

Let us compare the obtained value with the table value of the Fisher criterion, which corresponds to probability 0.05 and degrees of freedom $k_1 = 2$, $k_2 = T - 3 - 8$. If the actual value is larger than the table value, the equation is adequate and can be used to predict the value of the indicator x_i. The values of

Table 4

Projected values of macroeconomic security indicators obtained by using Holt's model

Indicator	Content of the indicator	Forecast for 2023	Forecast for 2024	Accuracy of the forecast
x_2	Level of the shadow economy as a percentage of GDP	32,5	32,4	99,32%
x_4	Unemployment rate (in per cent)	9,4	9,5	99,16%
x_5	Long-term unemployment rate (in per cent)	23,9	23,3	91,74%
x_8	Ratio of population disposable income to GDP (in per cent)	64,8	64,2	99,61%
x_{10}	Ratio of the volume of wages to the volume of social benefits and other current transfers received	1,3	1,3	99,54%
x_{11}	Ratio of GDP per capita in Ukraine to the average value in the EU (in per cent)	6,5	6,4	96,42%
x_{12}	Employment in the informal sector of the economy as a percentage to the total employed population	24,7	24,8	99,75%

Source: calculated by the authors

Table 5

Value of artificial variables w_i

Variables	Years										
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
w_1	0	0	0	0	1	1	0	0	0	0	0
w_3	0	0	0	0		1	0	0	0	0	0
w_6	0	0	0	0	1	1	0	0	0	0	0
w_7	0	0	0	0	1	1	0	0	0	0	0
w_9	1	1	1	1	0	0	0	0	0	0	0

Source: calculated by the authors

Table 6

Parameters of multiple linear regression equations for macroeconomic security indicators

Indicator	a_{i0}	a_{i1}	a_{i2}	R^2	F
x_1	8,08436	0,13347	-21,71844	0,78552	14,64949
x_3	-7,24182	0,59364	9,18000	0,60039	6,00981
x_6	-3,92291	0,23829	-10,18771	0,89659	34,68174
x_7	3,82123	0,44744	27,81788	0,78591	14,68378
x_9	8,07965	-0,87424	7,58095	0,92758	51,23270

Source: calculated by the authors

Table 7

Projected values of macroeconomic security indicators, obtained from multiple linear regression equations

Indicator	Content of the indicator	Forecast for 2023	Forecast for 2024
x_1	The difference between the growth rates of average monthly wages and labour productivity	10,0	10,1
x_3	Current account balance of Ukraine's balance of payments as a percentage of GDP	1,1	1,7
x_6	The difference between Ukraine's GDP growth rate and the growth rates of developing economies	-0,6	-0,3
x_7	Consumer price index	10,1	10,5
x_9	Population's propensity to save (in per cent)	-4,2	-5,0

Source: calculated by the authors

regression coefficients, coefficients of determination and actual values of Fisher's criterion for indicators x_1, x_3, x_6, x_7 and x_9 are given in Table 6.

Since the tabulated value of the Fisher criterion F $F(0,05; 2; 8) = 4,45897$, the regression equation for all indicators is adequate. To determine the forecast values of these indicators we substitute the values $t = 14$ and $t = 15$, corresponding to 2023 and 2024, into the corresponding regression equations, and we take the value of artificial variables to be equal to 0. The resulting forecasting results are shown in Table 7.

3. Results and Discussion

The methodological recommendations for calculating the level of economic security of Ukraine, approved by the order of the Ministry of Economic Development and Trade of Ukraine № 1277 dated 29.10.2013, characteristic values for the indicators of the components of economic security of Ukraine were provided, which divide the set of their values into five areas: critical, dangerous, unsatisfactory, satisfactory and optimal. These areas for the indicators of the characteristics of macroeconomic security are shown in Table 8.

If the value of some indicator is not included in any of the listed areas, the value is considered to correspond to an absolutely dangerous level for which the safety level is 0.

By analysing the dynamics of the macroeconomic security indicators and the forecasts developed, the following conclusions can be drawn regarding these characteristics.

1. The difference between the growth rate of average monthly wages and labour productivity during the retrospective period reached an absolutely dangerous level in 2015 (exceeding the lower limit of acceptable values) and in 2012 and 2017 (exceeding the upper limit of acceptable values). In 2020, this indicator was in the critical area. For 2023–2024, it is projected to increase, which has a negative impact on macroeconomic security as the indicator moves away from the optimal area.

2. The level of shadowing of the economy was at an absolutely dangerous level by 2017. The situation improved slightly in 2019, although the indicator was in a critical area. The forecast assumes an increase of the shadowing level to 32.5%, which means a move to an absolutely dangerous level.

3. Ukraine's current account balance as a percentage of GDP has been in a satisfactory range during the retrospective period. The forecast assumes that it will increase and move into the optimal range.

4. The unemployment rate between 2014 and 2017 exceeded 9%, which is an absolutely dangerous level. The situation improved slightly in 2018–2019, although the value of this indicator remained critical. The forecast assumes an increase in the unemployment rate to 9.5%.

5. The long-term unemployment rate has been decreasing since 2014 and has been in the area of satisfactory values. In 2019, this indicator has moved to an optimal level. The forecast assumes an increase of this indicator to 23.3%, which means a transition to a satisfactory level.

Table 8

Areas of values of macroeconomic security indicators

Indicator	Value areas				
	critical	dangerous	unsatisfactory	satisfactory	optimal
x_1	[−15;-10)[8;12]	[−10;-6)[5;8)	[−6;-3)[2;5)	[−3;-0,5)(0,5;2)	[−0,5;0,5]
x_2	[25;30)	[22; 25)	[18; 22)	[13; 18]	< 13
x_3	[−7;-5)[7;10]	[−5;-4)[5;7)	[−4;-3)[3;5)	[−3;-1,5)(1,5;3)	[−1,5;1,5]
x_4	[8;9)	[7; 8)	[6; 7)	[5; 6]	< 5
x_5	[40;50)	[35; 40)	[30; 35)	[20; 30]	< 20
x_6	[−2;-1,5)	[−1,5; −1)	[−1; 1)	[1; 2]	> 2
x_7	[−2;-1)[8;12]	[−1;-0,5)[5;8)	[−0,5;1)[4;5)	[1;2)(3;4)	[2;3]
x_8	[40;43)[63;65]	[43;45)[60;63)	[45;50)[58;60)	[50;53)(55;58)	[53;55]
x_9	[3;5)[20;22]	[5;8)[18;20)	[8;10)[16;18)	[10;12)(14;16)	[12;14]
x_{10}	[1; 1,1)	[1,1; 1,2)	[1,2; 1,4)	[1,4; 1,6]	> 1,6
x_{11}	[10; 25)	[25; 50)	[50; 70)	[70; 90]	> 90
x_{12}	[20;25)	[15; 20)	[10; 15)	[5; 10]	< 5

Source: compiled by the authors using https://zakon.rada.gov.ua/rada/show/v1277731-13

6. The difference between Ukraine's GDP growth rate and the growth rate of developing economies was at an absolutely dangerous level between 2012 and 2017. In 2018–2019, this indicator is increasing and moving to an unsatisfactory level. The indicator is projected to rise to −0.35 percentage points by 2024, but remains in the unsatisfactory range.

7. The consumer price index was in an area of absolute danger between 2014 and 2017. From 2019 this index decreases and reaches 4.9% in 2020. The forecast for 2023–2024 assumes an increase of this index to 10.6%, which is included in the area of critical values.

8. The ratio of population disposable income to GDP has exceeded the maximum permissible level of 65% throughout the retrospective period. The forecast foresees a reduction to 64.2% by 2024.

9. The propensity of the population to save has been decreasing over the retrospective period and has fallen below the minimum value of 3% since 2015. It is forecasted that this indicator will continue to decrease and will reach a value of −5% in 2024.

10. The ratio of volumes of wages to social benefits and other current transfers received reached a satisfactory value of 1.47 in 2019. It is projected to decrease to 1.3 in 2024.

11. The ratio of GDP per person in Ukraine to the EU average is projected to fall from 10.9% in 2019 to 6.4% in 2024, which is below the minimum allowable value.

12. Employment in the informal economy has exceeded the maximum allowable value of 20% throughout the retrospective period. For 2023–2024, this indicator is projected to rise to 24.8%.

Let us define an integral assessment of the country's macroeconomic security that combines all the indicators x_i. For this purpose, it is necessary to normalise the initial indicators, as a result of which the obtained normalised values $y_i(t)$ will belong to the same interval.

For the stimulant-indicators x_i, we denote the lower boundaries of the areas of critical, dangerous, unsatisfactory, satisfactory and optimal values by x_{i1}^+, x_{i2}^+, x_{i3}^+, x_{i4}^+, x_{i5}^+ respectively. Similarly, for destimulant-indicators of x_i we denote the upper boundaries of the areas of critical, dangerous, unsatisfactory, satisfactory and optimal values, by x_{i1}^-, x_{i2}^-, x_{i3}^-, x_{i4}^-, x_{i5}^- respectively. For stimulants, normalisation is carried out according to the formula

$$y_i(t) = \begin{cases} 0,2e^{(x_i(t)-x_{i1}^+)} & if\ x_i(t) < 0 \text{ i } x_i(t) < x_{i1}^+ \\ 0,2\dfrac{x_i(t)x_i(t)}{x_{i1}^+} & if\ 0 \le x_i(t) < x_{i1}^+ \\ 0,2k + 0,2\dfrac{x_i(t) - x_{ik}^+}{x_{i(k+1)}^+ - x_{ik}^+} & if\ x_{ik}^+ \le x_i(t) < x_{i(k+1)}^+ \text{ i } k < 5 \\ 1 & if\ x_i(t) \ge x_{i5}^+ \end{cases}$$

For destimulants, normalisation is carried out using the formula

$$y_i(t) = \begin{cases} 0,2\dfrac{x_{i1}^-}{x_i(t)} & if\ x_i(t) \ge x_{i1}^- \\ 0,2k + 0,2\dfrac{x_{ik}^- - x_i(t)}{x_{ik}^- - x_{i(k+1)}^-} & if\ x_{i(k+1)}^- \le x_i(t) < x_{ik}^- \text{ i } k < 5 \\ 1 & if\ x_i(t) < x_{i5}^- \end{cases}$$

Nominators combine the characteristics of stimulators and destimulators. Before reaching the optimal value, the growth of the following indicators has a positive impact on macroeconomic security, and after going beyond the optimal value, it has a negative impact. Consequently, if the nominator value is less than the optimal value, normalisation

Table 9

Normalised values of the country's macroeconomic security indicators

Indicator	Years										
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
y_1	0,500	0,693	0,167	0,375	0,573	0,010	0,567	0,151	0,280	0,407	0,440
y_2	0,167	0,189	0,198	0,197	0,168	0,171	0,184	0,189	0,240	0,280	0,200
y_3	0,920	0,300	0,081	0,037	0,720	0,550	0,933	0,780	0,420	0,840	0,700
y_4	0,360	0,400	0,480	0,540	0,194	0,198	0,194	0,189	0,240	0,360	0,189
y_5	0,644	0,832	0,840	0,854	0,998	0,992	0,894	0,866	0,968	1,000	0,976
y_6	0,055	0,610	0,009	0,009	0,000	0,000	0,164	0,148	0,560	0,660	0,280
y_7	0,345	0,680	0,707	0,733	0,096	0,055	0,194	0,175	0,289	0,780	0,600
y_8	0,165	0,171	0,159	0,157	0,179	0,190	0,196	0,193	0,187	0,178	0,178
y_9	0,490	1,000	1,000	0,707	0,180	0,153	0,053	0,100	0,087	0,064	0,031
y_{10}	0,320	0,460	0,440	0,360	0,380	0,360	0,680	0,760	0,800	0,880	0,760
y_{11}	0,176	0,196	0,226	0,218	0,170	0,132	0,136	0,156	0,170	0,207	0,213
y_{12}	0,284	0,276	0,284	0,256	0,196	0,191	0,228	0,284	0,336	0,364	0,388

Source: calculated by the authors

is carried out as for stimulants, and if it is more than optimal value, as for destimulants.

The normalised values of $y_i(t)$ are shown in Table 9.

The Integral assessment of $W(t)$ of the macroeconomic security is obtained from the following equation

$$W(t) = \sum_{i=1}^{12} \gamma_i y_i(t),$$

where γ_i are the weighting coefficients of the indicators. These coefficients can be determined on the basis of expert judgement or the modified principal component method.

The coefficients determined by the expert assessment method are given in the methodological recommendations for calculating the level of economic security of Ukraine. This method allows the usage of the knowledge and experience of experts in the field of macroeconomics, but it also has some drawbacks, one of which is that in determining the weighting coefficients the existing correlations between the various indicators of macroeconomic security are not taken into account. The study of the dynamics of these indicators over a retrospective period showed that there are significant correlations between them. Thus, the correlation coefficients between the indicators x6 (difference in the growth rates of GDP of Ukraine and developing countries) and x1 (difference in the growth rates of average monthly wages and labour productivity), x5 (long-term unemployment rate) and x9 (propensity of population to save), x11 (ratio of GDP per person in Ukraine to average value in EU countries) and x8 (ratio of disposable income to GDP) exceeds 0.8.

The modified principal component method allows us to determine the weighting coefficients of the indicators in the integral assessment by taking into account the correlation between them. In applying this method, the weighting coefficients are taken to be proportional to the squares of the component of the eigenvector of the covariance matrix of the normalized indicators y_i, which corresponds to the maximum eigenvalue of this matrix.

The weighting coefficients of indicators in the integrated assessment of the country's macroeconomic security, determined by expert assessment and the modified principal component method, are shown in Table 10.

To predict the values of the integral assessment of the country's macroeconomic security for 2023 and 2024, let us determine the projected normalised values of $y_i(t)$ of y_i indicators at $t = 12$ and $t = 13$, corresponding to these years. Suitable values are given in Table 11.

The expected values of the integral assessment in 2023 and 2024 are determined from equality

$$W(t) = \sum_{i=1}^{12} \gamma_i y_i(t)$$

at $t = 12$ and $t = 13$. The dynamics of the integral assessment of the country's macroeconomic security in 2010–2020 and the forecast of this assessment for 2023–2024 are shown in Table 12.

The values of the integral assessments of the macroeconomic security of the country in 2010–2020 and the projected values for 2023–2024 obtained by using expert evaluation and modified principal component methods are shown in Figure 1.

The results shown in Figure 1 show slight deviations — the integral assessments of the macroeconomic security of the country in 2010–2020 and the projected values for 2023–2024, based on the methods of expert evaluation and the modified principal component.

4. Conclusions

In 2010–2012, the integral assessment of the country's macroeconomic security obtained by the modified principal component method is significantly higher than that obtained by expert judgement. In 2013–2017, the difference between these estimates

Table 10

Weighting coefficients of indicators in the integral assessment of a country's macroeconomic security

Indicators	Weighting coefficients determined by the expert assessment method	Weighting coefficients determined by the modified principal component method
The difference between the growth rates of average monthly wages and labour productivity	0,0828000	0,0015210
Level of the shadow economy as a percentage of GDP	0,0950000	0,0000023
Current account balance of Ukraine's balance of payments as a percentage of GDP	0,0914000	0,3278708
Unemployment level	0,0914000	0,0406023
Long-term unemployment level	0,0894000	0,0053876
The difference between Ukraine's GDP growth rate and the growth rates of developing economies	0,0717000	0,0750212
Consumer price index	0,0854000	0,0707560
Ratio of population disposable income to GDP	0,0837000	0,0014823
The propensity of the population to save	0,0759000	0,4212010
The ratio of the volumes of wages to the volumes of social benefits and other current transfers received in the total structure of the population's income	0,0798000	0,0530842
Ratio of GDP per capita in Ukraine to the EU average	0,0711000	0,0026729
Population employment in the informal sector of the economy as a percentage of the total employed population	0,0824000	0,0004368

Source: calculated by the authors

decreases, but the modified principal component estimate remains higher. In 2018–2020, the estimate obtained by the expert valuation method becomes higher. The forecast for 2023–2024 assumes a stabilisation of the integral estimate. The modified principal component method predicts a certain increase compared to 2020, while the expert assessment method predicts a slight decrease. The difference between the estimates obtained by different methods can be explained by the fact that when calculating the modified principal component method, due to the identified correlation between the indicators, the weighting coefficients of the indicators differ significantly, while the expert assessment method assumes a small difference between these coefficients. The proposed logic of assessment and forecasting of the country's macroeconomic security

Table 11

Normalised y_i indicators values

Indicator	Year 2023	Year 2024
y_1	0,302	0,296
y_2	0,185	0,185
y_3	1,000	0,978
y_4	0,191	0,189
y_5	0,926	0,933
y_6	0,641	0,665
y_7	0,296	0,273
y_8	0,222	0,279
y_9	0,001	0,000
y_{10}	0,689	0,698
y_{11}	0,129	0,127
y_{12}	0,212	0,210

Source: calculated by the authors

Table 12

Evolution of the integral assessment of the country's macroeconomic security with a forecast for 2023–2024

Years	Integral assessment by the method of expert evaluation	Integral assessment using the modified principal component method
2010	0,37763	0,57320
2011	0,47909	0,66053
2012	0,38379	0,54713
2013	0,37417	0,40933
2014	0,33159	0,35379
2015	0,26019	0,28205
2016	0,37878	0,40484
2017	0,34091	0,37513
2018	0,38352	0,29538
2019	0,50797	0,47555
2020	0,42032	0,36096
2023 forecast	0,40225	0,44721
2024 forecast	0,40371	0,44771

Source: calculated by the authors

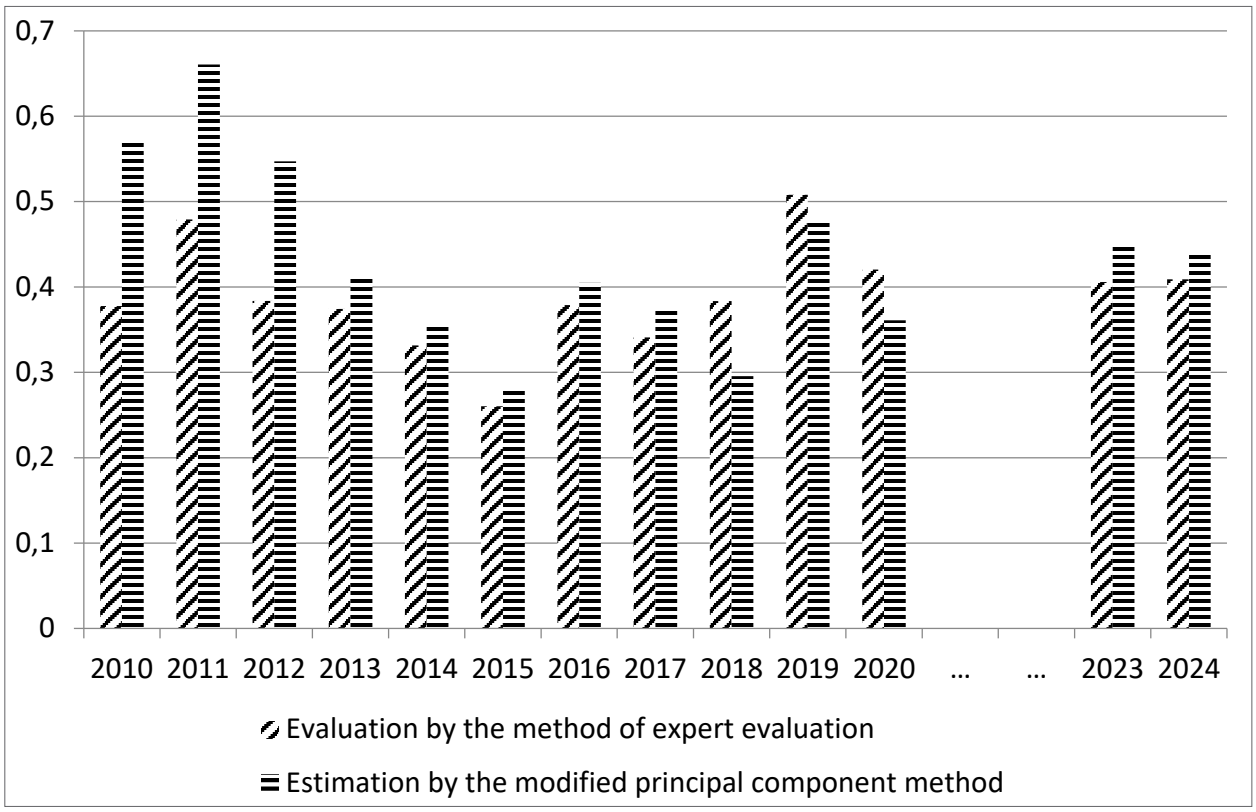

Figure 1. Integral estimates of the macroeconomic security of the country in 2010–2020 and projected values for 2023–2024

Source: calculated by the authors

assessment will be useful to managers of all levels, as well as Ukraine's foreign partners. The purpose of our further research will be to attract more methods and indicators to assess the macroeconomic security of the country, and to form proposals to maintain its proper level.

5. References

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Золковер Андрій
доктор економічних наук, професор
Київський національний університет технологій та дизайну
Україна
ORCID: 0000-0002-8176-1850

Дімітрина Каменова
професор соціального менеджменту
Варненський університет менеджменту
Болгарія
ORCID: 0000-0003-4311-9709

МАКРОЕКОНОМІЧНИЙ АНАЛІЗ РОЗВИТКУ КРАЇНИ: БЕЗПЕКОВИЙ АСПЕКТ

Анотація. *Глобальна економіка у сучасний період еволюційного розвитку знаходиться у постійній трансформації та зміні, що обумовлено необхідністю її пристосування до мінливих умов цивілізаційного розвитку. Кожна країна світу відчуває на собі глобальні зміни, що ставить на порядок денний питання забезпечення належного рівня безпеки у фінансовому, економічному, продовольчому секторах. Надважливим питанням є проведення вчасного моніторингу економічної безпеки та формування прогнозу подальшого соціально-економічного розвитку країни.*

Панельними даними в межах нашого дослідження слугували 19 показників вимірювання макроекономічної безпеки України, які визначалися нами як стимулятори, номінатори та дестимулятори. Інформаційною основою прогнозування є звітні данні макроекономічного розвитку країни. З використанням методів статистичного моделювання, експертного оцінювання, найменших квадратів, критерію Фішера, кореляційно-регресійного аналізу розраховані прогнозовані значення показників макроекономічної безпеки та рівень тінізації економіки. З експериментальною метою результати інтегральних оцінок та прогнозовані значення макроекономічної безпеки країни запропоновано порівнювати у два методи, а саме: експертного оцінювання та модифікованої головної компоненти.

Отримані результати оцінки макроекономічного розвитку країни, що одержані методом модифікованої головної компоненти, істотно перевищили оцінку, одержану за допомогою експертного оцінювання. В 2013–2017 роках різниця між цими оцінками зменшилася, але оцінка, одержана за допомогою методу модифікованої головної компоненти, залишається вищою. В 2018–2020 роках вищою стала оцінка, одержана методом експертного оцінювання. Прогноз на 2023–2024 роки передбачає стабілізацію інтегральної оцінки. Метод модифікованої головної компоненти прогнозує певне її зростання порівняно із 2020 роком, а метод експертного оцінювання — незначне зменшення. Результати моделювання подальшого макроекономічного розвитку країни засвідчують, на необхідності зосередження державних управлінців на процесах залучення інвестицій та стабілізації ринку праці, що значно підвищить безпеку країни.

Запропоновану логіку макроекономічного аналізу функціонування країни можливо використовувати при плануванні або стратегуванні державної політики соціально-економічного розвитку. Урахування змін, які будуть отримані в процесі такого аналізу, дозволять підвищити рівень безпеки країни. Визначення прогнозних значень рівня тінізації економіки дозволить зацікавленим стейкхолдерам приймати адаптивні управлінські рішення в напрямку детінізації та стимулювання безпекових аспектів розвитку країни.

Ключові слова: *безпека, тінізація економіки, продуктивність праці, заробітна плата, платіжний баланс, індекс споживчих цін, заощадження.*

JEL D81

Zubro Tetyana
Candidate of Economics Sciences (Phd in Economics)
University of Economics in Bratislava
Slovak Republic
ORCID: 0000-0002-6173-170X

Serhiienko Serhii
PhD student
Poltava State Agrarian University
Ukraine
ORCID: 0000-0003-0587-6039

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SCENARIO FORECASTING OF ENTERPRISE DEVELOPMENT UNDER CONDITIONS OF UNCERTAINTY

Abstract. *Today's institutional environment for large, medium-sized and small enterprises is dynamic and difficult to predict. The global crisis caused by fundamental changes in the business environment and financial markets has caused a structural breakdown in the logic of doing business, putting on the agenda the problem of choosing the most efficient way for companies to develop with the least expenditure of resources. Scenario forecasting can help managers to make the right decisions and thus reduce the negative impact of the external environment on the business.*

The information basis for our study was the results of the development of large, medium, small and micro-enterprises in Ukraine for the years 2011–2021. In order to implement scenario prediction, we used methods of mathematical modelling and forecasting, based on the study of the performance of economic systems over a certain retrospective period. Using the Farrar-Glober algorithm, we tested the multicollinearity or interdependence between the indicators. The forecasting of the development of enterprises under conditions of uncertainty is proposed to be carried out according to three scenarios.

Consequently, the implementation of the modelling logic has shown that for both entrepreneurship as a whole and for its individual types, the first scenario with a 10% increase in labour costs, while the amount of non-current assets remains unchanged, has the greatest effect. The highest rate of growth in the volume of output sold is provided by all scenarios considered for medium-sized enterprises, slightly less for large enterprises and the lowest for small and micro-enterprises.

The proposed scenario forecasting of enterprise development under uncertainty is easy enough to use and does not require a significant amount of labour or financial resources, which is especially important in the context of any business entity's desire to conserve resources. The value of our proposed modelling is in the fact that using the obtained equations of multiple linear regression, it is possible to estimate other possible scenarios of enterprise development and select the best one among them.

Keywords: *scenario forecasting, entrepreneurship, sold products, remuneration of labour, current and non-current assets, market, crisis*

1. Introduction

Domestic enterprises, regardless of their form of ownership, are constantly influenced by the external environment, which can affect their development in various ways. Market demands dictate the need to monitor current business activity to reduce risk, introduce innovations and strengthen innovative activity. Sometimes business owners do not have enough resources (material, informational or labour) to engage analysts to determine how to move forward. That is why there is a need to develop a methodology for forecasting the development of enterprises in conditions of uncertainty that meets the needs of modern business. The usage of scenario forecasting is the most appropriate in this case. With its help, it is possible to envisage different trajectories of business development and choose the best and most profitable scenario for a particular enterprise. The purpose of this article is to forecast the development of enterprises under conditions of uncertainty using a scenario approach.

In-depth research on enterprise and business development has been carried out in the scientific works of Engel *et al.*, [1], Weerawardena and Mort, [2], Giones and Brem, [3], Dodd, [4], who proposed innovative directions for modelling the activities of business entities. The authors have rightly emphasized the dynamism of the innovation process, the uncertainty of market conditions, the importance of social entrepreneurship development, the need for technological developments, and the adaptation of business culture to global transformation. At the same time, the above scholars proposed modelling tools for the study of business entities under conditions of uncertainty, crises and bifurcations. Haynie *et al.*, [5], developed a framework for "entrepreneurial thinking", which will allow businesses to sense, act and mobilise under uncertain conditions. This research is more of a psychological science, but it is the right psychological mind-set of the manager and the comfort of the team can guarantee increased profitability of the enterprise. McGrath *et al.,* [6], identify that for the effective development of enterprises, it is necessary to adapt the entrepreneurial culture to support the population and human values. Snihur *et al.,* [7], highlight the need for business model development in technology firms and especially in the aerospace industry. This study is quite relevant as the technologisation of the market economy and industry is key to the competitiveness of both the macroeconomic development of the country and the entrepreneurial units. Gregori and Holzmann, [8], have conducted a similar scientific study, in which they focuse on the prospects of business technology development and digitalisation. Important for our study is the research article by O'Brien and Meadows [9], where the authors proposed scenario strategy and technology planning of tools. The article extensively identifies the stages of a scenario to support business development, development and usage of innovative methods and technologies in knowledge economy conditions. De Brentani, [10], rightly focuses on the fact that managers in a complex external environment have to make complex decisions in a specific situation mode. Consequently, knowledge of the types of different situations or business scenarios that typically lead to success and failure is an important prerequisite for managerial decision-making. The researcher proposed five new service business development scenarios (three of which are related to success and two to failure) adapted to industrial service enterprises. In the conclusions, the scholar suggested a combination of factors that would lead to success under different conditions. The findings of Solodovnik *et al.*, [11], are important for our study. An interesting approach is to investigate the mutual influence of two essential factors for promoting economic development, such as innovation and foreign economic activity, which can be used for scenario forecasting. In particular, this applies to the algorithms for selecting directions of innovative development and methodology for determining the quality of planning work of the Department of foreign economic activity. Flores *et al.*, [12], focused attention on various management factors of microenterprises that influence management decisions. Researchers identified factors for constructing microenterprise management scenarios with emphasis on permanence, corporate social responsibility, knowledge management and microenterprise development. Scenario modelling was used in the work of Љkare *et al.*, [13], where the potential impact of the COVID-19 pandemic on the tourism industry was measured. Using panel vector autoregression of data from 1995 to 2019 in 185 countries, the authors performed systematic dynamic modelling of the impact of a pandemic crisis on tourism industries worldwide. Noteworthy works on scenario modelling are Picanэo-Castro *et al.*, [14], Cloete *et al.*, [15], Voinea *et al.*, [16], Kushnirenko *et al.*, [17], Bochulia and Sivitska, [18], Bui and Zenchenko, [19], Varnalii *et al.*, [20], Zahra, [21], etc.

The works of scientists show that scenario forecasting at both macro- and meso-, and micro-levels is a highly relevant phenomenon, especially in conditions of uncertainty and crisis situations. Taking into account the tools, methods and models developed by the authors, we will propose our own logic of scenario forecasting of enterprise development in conditions of uncertainty.

2. Materials and Methods

It is important for management decisions to be able to make a scientifically sound assessment of their expected consequences. For such an assessment, forecasting methods based on the study of the performance of economic systems over a certain retrospective period are used. One of such methods is factor forecasting based on multiple regression

equations, reflecting the dependence of performance on the main factors affecting it. A multiple regression equation has the form:

$$Y = f(X_1, X_2, \ldots, X_n)$$

where Y is the indicator reflecting the output of the economic system and X_i are the indicators reflecting the factors influencing this output.

Let us investigate the dependence of the performance of business entities in Ukraine on the amount of fixed assets, the amount of current assets and labour costs. For the study, we use a multiple linear regression equation:

$$Y = a_0 + a_1X_1 + a_2X_2 + a_3X_3$$

where Y is the volume of products sold, X_1 is labour costs, X_2 is the amount of current assets, X_3 is the amount of non-current assets.

The information base of the study is the data on the value of these indicators during 2011–2021. The value of the indicator X_i in the t year of this period is denoted by x_{it}.

Before using a multiple linear regression equation, make sure that there is no multicollinearity, i.e. the relationship between indicators X_1, X_2 and X_3. If multicollinearity is present, the regression equation cannot be used for forecasting. To check the presence of multicollinearity we use the Farrar-Glober algorithm. To do so, normalize the value of x_{it} of the indicators X_i, using the formula:

$$q_{it} = \frac{x_{it} - \overline{x}_i}{\sigma_{xi}\sqrt{n-1}}, \left(t = \overline{1,n}\right), \left(i = \overline{1,3}\right),$$

where q_{it} is the normalised value of indicator X_i in year t of the retrospective period;

n is the length of the retrospective period (n = 11);

$\overline{x}_i$ is the empirical mean value of indicator X_i;

σ_{xi} is the empirical standard deviation of indicator X_i;

The normalised values of the X_i indicators are shown in Table 1.

Let us denote by $Q^n = (q_{it})$ the matrix, the rows of which correspond to the years of the retrospective period, the columns to the indicators X_i, and the elements are the normalised values of q_{it} of these indicators. We denote by Q^{nT} the matrix transposed to Q^n. We define the correlation matrix $Kor = Q^{nT}Q^n$. It looks like this:

$$Kor = \begin{pmatrix} 1 & 0{,}97592 & 0{,}89764 \\ 0{,}97592 & 1 & 0{,}84563 \\ 0{,}89764 & 0{,}84563 & 1 \end{pmatrix}.$$

To check whether there is multicollinearity between the variables X_1, X_2 and X_3 we determine the actual and critical value of the criterion χ^2. The actual value is determined by the formula:

$$\chi^2_{actual} = \left[n - 1 - \frac{1}{6}(2m+5)\right]\ln(\det[Kor])$$

where n is the duration of the retrospective period (n = 11), m is the number of variables (m = 3), det[Kor] is the determinant of the matrix Kor.

We will get $\chi^2_{actual} = -39{,}112869$. The critical value is determined by the 0.95 confidence probability and the number of degrees of freedom $\frac{1}{2}m(m-1) = 3$. This value is 7.814728. Since the actual value of the criterion by modulo exceeds the table value, there is multicollinearity between the factors. Therefore, you should leave two factors in the regression equation. Determine which factor should be excluded from the model. To do this, let us define matrix W inverted to matrix Kor. This matrix has the form:

$$W = \begin{pmatrix} 34{,}25234 & -26{,}07016 & -8{,}70053 \\ -26{,}07016 & 23{,}35240 & 3{,}65411 \\ -8{,}70053 & 3{,}65411 & 5{,}71990 \end{pmatrix}$$

Then we define a matrix G, the elements g_{jr} of which are determined from the equality:

$$g_{jr} = \frac{-w_{jr}}{\sqrt{w_{jj}w_{rr}}}$$

Table 1

Normalised values of the Xi indicators

Years	Labour costs	Current assets	Non-current assets
2011	-0,34252	-0,31790	-0,45954
2012	-0,27467	-0,26198	-0,44134
2013	-0,24584	-0,20005	-0,37333
2014	-0,25988	-0,19538	-0,10199
2015	-0,24585	-0,21954	-0,07790
2016	-0,12300	-0,16972	0,02142
2017	0,00807	-0,07524	0,21898
2018	0,18565	0,08740	0,20450
2019	0,37097	0,27469	0,27979
2020	0,43339	0,48584	0,32196
2021	0,49367	0,59188	0,40747

Source: calculated by the authors

where w_{jr} denotes the element of the matrix W placed in the j row and r column. This matrix has the form:

$$G = \begin{pmatrix} -1 & 0{,}92179 & 0{,}62159 \\ 0{,}92179 & -1 & -0{,}01501 \\ 0{,}62159 & -0{,}01501 & -1 \end{pmatrix}$$

Based on matrix G, we create a matrix T, the elements t_{jr} of which are calculated using the formula:

$$t_{jr} = \frac{g_{jr}\sqrt{n-m-1}}{\sqrt{1-g_{jr}^2}}.$$

This matrix has the form:

$$T = \begin{pmatrix} N & 6{,}290756 & 2{,}099445 \\ 6{,}290756 & N & -0{,}88174 \\ 2{,}099445 & -0{,}88174 & N \end{pmatrix}$$

The elements of the main diagonal of this matrix are undefined because division by 0 is not possible. The maximum of the remaining elements is $t_{12} = 6{,}290756$. Let us compare it with the critical value of the Student's criterion, which corresponds to confidence probability 0.95 and the number of degrees of freedom n − m − 1 = 7. This critical value is 2.3646. Since the element t12 exceeds the critical value of Student's criterion, one of the indicators X_1 or X_2, i.e. labour costs or the volume of current assets, should be excluded from the model. Thus, two models are possible to estimate future output depending on the factors affecting it: a model that determines the dependence of output on labour costs and non-current assets and a model that determines the dependence of output on non-current assets and current assets.

3. Results and Discussion

In scenario forecasting of enterprise development under conditions of uncertainty, it should be taken into account that as long as there is a close correlation between the indicators of current and non-current assets (the correlation coefficient is 0.9875), it is appropriate to choose a model that includes factors of labour costs and non-current assets, i.e. it is determined by regression equation:

$$Y = a_0 + a_1X_1 + a_3X_3.$$

Let us introduce an additional variable X_0, taking the value 1 for all years of the retrospective period, i.e. $x_{0t} = 1$ for all values of t. Then the regression equation can be written as:

$$Y = a_0X_0 + a_1X_1 + a_3X_3.$$

Let us denote by a vector-column A, the elements of which are the coefficients a_0, a_1 and a_3. This vector can be defined from the equality:

$$A = (X^TX)^{-1}X^TP$$

where the matrices X and P are of the form:

$$X = \begin{pmatrix} x_{01} & x_{02} & x_{03} & \dots & x_{0n} \\ x_{1n} & x_{1n} & x_{1n} & \dots & x_{1n} \\ x_{3n} & x_{3n} & x_{3n} & \dots & x_{3n} \end{pmatrix}, \quad P = \begin{pmatrix} y_1 \\ y_2 \\ y_3 \\ \dots \\ y_n \end{pmatrix},$$

and X^T is a transposable matrix to matrix X.

By doing the calculations, we get:

$$A = \begin{pmatrix} 1400520756 \\ 10{,}64426 \\ 0{,}28486 \end{pmatrix}.$$

Consequently, the linear regression equation is as follows:

$Y = 1400520756 + 10{,}64426X_1 + 0{,}28486X_2$.

Check the adequacy of the resulting equation to the raw data. For this purpose, we determine the coefficient of determination R^2:

$$R^2 = 1 - \frac{\sum_{t=1}^{11}(y_t - a_0 - a_1x_{1t} - a_3x_{3t})^2}{\sum_{t=1}^{11}(y_t - \bar{Y})^2} = 0{,}96749.$$

With $\bar{Y}$ denotes the mean value of Y indicator for the retrospective period. We then determine the actual value of the Fisher criterion:

$$F = \frac{R^2}{1-R^2}\frac{n-m-1}{m} = 119{,}037.$$

The resulting value exceeds the critical value of this criterion, which for a confidence level of 0.95 being 4.459. Thus, the regression equation is adequate.

Check the significance of the coefficients a1 and a3 of the regression equation. For this purpose, let us determine the t-statistics of these coefficients equal to the moduli of values of these coefficients divided by the standard deviations of their estimates. For coefficient a_1 standard deviation of its estimate is 1.334 and t-statistics 7.9779, for coefficient a3 the mentioned values are 0.1479 and 1.9256 respectively. Comparing the value of t-statistics with a critical value of the Student's criterion, which at confidence probability 0.9 is 1.8595, we see that the t-statistics for the given coefficients exceed the critical value of criterion. Therefore, the coefficients a_1 and a_3 of the regression equation are significant. This means that the regression equation $Y = 1400\,520756 + 10{,}64426X_1 + 0{,}28486X_2$ can be used to determine the expected values of sales under possible changes in labour costs and non-current assets volumes.

Let the planned labour costs be δ_1, and the planned value of non-current assets is δ_3. Then the projected volume of products sold is determined by the following equation:

$\gamma = 1400520756 + 10{,}64426\ \delta_1 + 0{,}28486\ \delta_3$

Consider three possible scenarios for the development of entrepreneurship:

1) Labour costs increase by 10% compared to 2021, while non-current assets volume remains unchanged.

2) Labour costs remain unchanged, while non-current assets volume increase by 10% compared to 2021.

3) Labour costs and the volume of non-current assets increase by 5% compared to 2021.

Table 2

Forecasting sales volume under different entrepreneurship development scenarios

Change in labour costs compared to 2021	Change in the volume of non-current assets compared to 2021	Forecasted value of sales volume	The growth rate of the volume of products sold compared to 2021
Grow by 10 per cent	Does not change	12514428298	13,1%
Does not change	Grow by 10 per cent	11792970641	6,6%
Grow by 5 per cent	Grow by 5 per cent	12153699470	9,9%

Source: calculated by the authors

For each scenario, we determine the forecast value of the sales volume. The results are shown in Table 2.

A similar study was conducted separately for large, medium, small and micro enterprises. It was found that for all types of enterprises, there is a multicollinearity between the indicators of labour costs, the volume of non-current assets and the volume of current assets. A model based on a linear regression equation that includes two factors — labour costs (X1) and the value of non-current assets (X3) was developed for each type of enterprise. The resulting regression equations are presented in Table 3.

All equations obtained are adequate and their coefficients at X_1 and X_3 are significant.

Let us consider the three above-mentioned possible business development scenarios and apply them to large, medium, small and micro enterprises. The resulting forecast values of product sales volumes are presented in Table 4.

Consequently, for both entrepreneurship as a whole and for its individual types, the first

Table 3

Multiple linear regression equation for examining the dependence between products sold on labour costs and non-current assets

Type of enterprise	Multiple linear regression equation
Large	Y = 611426 + 0,00905X1 + 0,000202X3
Medium	Y = 711194 + 0,00928X1 + 0,00028X3
Small	Y = 141368 + 0,012756X1 + 0,000202X3
Micro	Y = 26418 + 0,0132089X1 + 0,000163X3

Source: calculated by the authors

Table 4

Projection of sales volume under different entrepreneurship development scenarios for different types of enterprises

Change in labour costs compared to 2021	Change in non-current assets volume compared to 2021	Forecasted value of sales volume	The growth rate of sales volume compared to 2021
Large enterprises			
Grow by 10 per cent	Does not change	12514428298	13,3%
Does not change	Grow by 10 per cent	11792970641	7,3%
Grow by 5 per cent	Grow by 5 per cent	12153699470	10,3%
Medium-sized enterprises			
Grow by 10 per cent	Does not change	5043705	15,7%
Does not change	Grow by 10 per cent	4729142	8,5%
Grow by 5 per cent	Grow by 5 per cent	4886424	12,1%
Small enterprises			
Grow by 10 per cent	Does not change	2313859	12,1%
Does not change	Grow by 10 per cent	2163755	4,8%
Grow by 5 per cent	Grow by 5 per cent	2238807	8,5%
Microenterprises			
Grow by 10 per cent	Does not change	790189	12,1%
Does not change	Grow by 10 per cent	741704	5,2%
Grow by 5 per cent	Grow by 5 per cent	765946	8,7%

Source: calculated by the authors

scenario has the greatest effect, assuming a 10% increase in labour costs with the same volume of non-current assets. The highest growth rate is provided by all the scenarios considered for medium-sized enterprises, somewhat lower for large enterprises, and the lowest for small and micro enterprises.

4. Conclusions

A guarantee of making effective managerial decisions is the availability of an analytical tool, the usage of which allows the manager to take into account all business development opportunities. Scenario modelling is such a tool, the usage of which helps and guides the entrepreneur in conditions of uncertainty. The uncertainty of the market environment is based on the fact that different directions of events are possible, which can positively or negatively affect the enterprise. It is the development of scenarios that makes it possible to analyse the consequences for an enterprise of a single phenomenon or several events, which will change the trend of business development by a different degree of influence. The value of our proposed modelling is in the fact that using the obtained equations of multiple linear regression, it is possible to estimate other possible scenarios of business development and choose the best one among them. Our adapted modelling is simple enough to use and does not require a significant amount of labour or financial resources, which is especially important in the context of any business entity's desire to conserve resources. Our further research will be aimed at expanding the possible scenarios of entrepreneurship development, which is a relevant issue considering the instability and rapid change of the entire institutional matrix of entrepreneurship and the growing competition between countries and businesses at the global level.

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Зубро Тетяна
кандидат економічних наук
Університет економіки в Братиславі
Словаччина
ORCID: 0000-0002-6173-170X

Сергієнко Сергій
аспірант
Полтавський державний аграрний університет
Україна
ORCID: 0000-0003-0587-6039

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СЦЕНАРНЕ ПРОГНОЗУВАННЯ РОЗВИТКУ ПІДПРИЄМСТВ В УМОВАХ НЕВИЗНАЧЕНОСТІ

Анотація. *Сучасне інституціональне середовище великих, середніх та малих підприємств є динамічним та важко передбачуваним. Загально світова криза, яка викликана докорінною зміною кон'юнктури та фінансових ринків спричинила структурний злам логіки ведення бізнесу, поставивши на порядок денний проблематику вибору найефективніших шляхів розвитку підприємств при мінімальних ресурсовитратах. Сценарне прогнозування спроможне допомогти управлінцям вірно прийняти необхідне рішення та таким чином зменшити негативний вплив зовнішнього середовища на бізнес.*

Інформаційним підґрунтям для нашого дослідження були результати розвитку великих, середніх, малих та мікропідприємств України за 2011–2021 роки. З метою реалізації сценарного передбачення нами були використані методи математичного моделювання та прогнозування, засновані на дослідженні показників діяльності економічних систем протягом певного ретроспективного періоду часу. З використанням алгоритму Фаррара-Глобера нами перевірялася мультиколінеарність або взаємозалежність між показниками. Прогнозування розвитку підприємств в умовах невизначеності запропоновано здійснювати за трьома сценаріями.

Отже, реалізація логіки моделювання показала, що як для підприємництва в цілому, так і для його окремих видів, найбільший ефект має перший сценарій, що передбачає зростання на 10% витрат на оплату праці при незмінній величині необоротних засобів. Найвищий темп приросту обсягу реалізованої продукції забезпечують всі розглянуті сценарії для середніх підприємств, дещо менший для великих і найменший для малих та мікропідприємств.

Запропоноване сценарне прогнозування розвитку підприємств в умовах невизначеності є досить простим у використанні та не вимагає залучення значної кількості трудових або фінансових ресурсів, що особливо важливо в контексті прагнення будь-якого суб'єкту господарської діяльності до ресурсозбереження. Цінність запропонованого нами моделювання полягає у тому, що використовуючи одержані рівняння множинної лінійної регресії можна оцінити і інші можливі сценарії розвитку підприємництва та обрати серед них найкращий.

Ключові слова: *сценарне прогнозування, підприємництво, реалізована продукція, оплата праці, оборотні та необоротні активи, ринок, криза*

JEL: Q14

Hnatenko Iryna
Doctor of Science in Economics, Professor
Kyiv National University of Technologies and Design
Ukraine
ORCID: 0000-0002-0254-2466

Grzegorz Konieczny
Doctor of Social Science
Rector of WSHIU Academy of Applied Sciences,
Poland
ORCID: 0000-0002-6337-9738

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RANKING OF PROFITABILITY AND COSTS INDICATORS OF AGRIBUSINESSES

Abstract. *The microenvironment of agricultural enterprises is influenced by the external environment, which affects entrepreneurial activity in different ways. However, any response of managers to external changes must be justified, logical and in line with the needs of the current market. Timely diagnostics of profitability and costs indicators of agricultural enterprises and forecasting of their values are of great importance. Such actions will provide managers with reference points for making the necessary decisions and allow them to respond to any impulses affecting the development of the enterprise.*

To rank the profitability indicators of business entities we have chosen the activities of agricultural enterprises. Using methods of mathematical modelling, taxonomic analysis and ranking, we have analysed the dynamics of agricultural enterprises' performance indicators. The testing of some statistical functions made it possible to forecast the rating indicator of agrarian enterprises' activity in 2023–2024.

The result of the profitability and costs ranking of agri-businesses for the reporting year 2020 showed an increase compared to previous years. At the same time, it is possible to observe an increase in expenditures by enterprises, which indicates the need for stricter and deeper monitoring of the activities of agribusinesses by top managers. This monitoring will prevent bankruptcy or inefficient allocation of finances by the enterprises.

The profitability and costs ranking of agribusinesses described in the article is a universal method, applicable to any facility or industry. Ranking can be tested not only in studies of statistical units or their totality but also for determining dynamic changes in retrospective time series. The forecasting of the investigated indicators can serve as impulses for managers concerning the improvement of strategic orientation and making correct decisions by managers of agricultural enterprises with the purpose of forming the goals of further activity.

Keywords: *profitability, direct material costs, labour costs, general production costs, forecasting, ranking, agribusinesses*

1. Introduction

The profitability of any agricultural enterprise depends on well-chosen management guidelines, which include procedures of current and future costs estimation. Given that agricultural enterprises traditionally strive to save resources, including financial and labour, it is not always possible to estimate costs. There is a need to develop an estimation method that would allow managers of enterprises to carry out costs analysis quickly and easily. A relevant issue is the comparison of these analyses retrospectively. In view of the above, the aim of the article is to develop and test a methodology for ranking the profitability and costs indicators of agribusinesses.

Taxonomies, rating and indicative comparisons have been extensively researched in the works of many scholars. In particular, Ramnath *et al.,* [1], carried out a taxonomy of studies that examined the role of financial analysts in capital markets. The scholars classified some 250 articles published since 1992, describing the evolution of analysts' statistical forecasts, research incentives and decision-making processes, and suggested combinations of indicators used for analysis. Wolf *et al.,* [2] retrospectively evaluated the financial performance of a dairy farm by applying the scientific achievements of three university programmes in business analysis. Using indicators of profitability, solvency and liquidity, the researchers assessed the credit risk of the farm using the variance components method. These achievements are particularly important for shaping government programmes to protect pricing in the dairy market. Researchers Zakirova *et al.,* [3], proposed a model of comprehensive information and analytical support for strategic management. Among other things, the practical aspects of strategic management accounting in the enterprise, modern concepts of strategic management accounting, ways of alternative costs, directions for improving the modern practice of organisation and application of strategic management accounting are developed in the article. Of interest for our study is the development of the principles of selection of key performance indicators of enterprises, the algorithm for competitor rating analysis based on information support for strategic management, practical recommendations in the field of methodological support of strategic management accounting, aimed at improving the efficiency of processes of development and implementation of strategic management decisions. Davydenko and Skryphyk, [4], proposed a definition of the investment attractiveness of enterprises, which is based on various expert assessments of statistical information, as well as the combination of several techniques. The paper proposes criteria for deciding on the feasibility of investment and develops a rating assessment of investment attractiveness, taking into account the specifics of the industry. The proposed rating assessment can be adapted to the activities of agricultural enterprises in the formation of priority areas for investment, planning of operating costs, technology, etc. Significant scientific advances for our study are highlighted in the works of Crouhy *et al.,* [5]. Researchers have systematised the factors of effective implementation of digitalisation for innovative development of agriculture in Azerbaijan. The information base is the coverage of 1513 senior managers of agricultural enterprises. The article proposes levels of development of digitalisation of the agricultural sector of the country and empirically substantiates the qualitative nature of the impact of digitalisation factors on the innovative development of agricultural enterprises by regression modelling method. The results obtained can help develop a state strategy to strengthen the digitalisation of the country's agricultural sector in order to ensure its innovative development, food security and economic diversification. Innovative studies are the works of Kuncovб *et al.*, [6] in which an assessment of the impact of firm size on economic performance is defined. In particular, economic efficiency is proposed to be determined by means of multi-criteria evaluation of alternative methods, where profitability, labour productivity, etc. are used as indicators of economic efficiency. A linear regression model is used to model the relationship between company size and profitability. Multi-criteria estimation has determined that economies of scale play an important role in pig breeding firms. Kučera *et al.*, [7], who proposed a new methodology for calculating the optimal borrowing capacity of an enterprise under conditions of maintaining a positive financial leverage function, are important. The methodology was tested in agricultural enterprises between 2012 and 2018. The modelling made it possible to determine the optimal ratio of equity and loan capital. A credit risk rating system is proposed in works of Crouhy *et al.*, [8]. The authors propose to use a two-tier rating system, where the rating of the debtor and the rating of the institution (e.g. damage in case of default, lending with a view to default, etc.) are assessed. Corporate credit rating estimation is proposed by Wang and Ku, [9]. The paper uses innovative analytical neural network training methods to improve prediction accuracy, defines function space using new input variables, develops a new algorithm for financial data selection, and proposes a model assembly of parallel artificial neural networks. Note that artificial intelligence is quite often used for ranking, but requires specific professional skills and the involvement of a large data set for analysis. Poon *et al.,* [10], have proposed ranking financial data. Using bank accounting and financial data, the authors developed logistic regression models to explain or predict lending risks. This study helps to predict the onset of banking crises and determine how credit problems affect the financial sector in Asia and Latin America. Very important issues for the preservation of the natural environment have been touched upon by

Yu *et al.,* [11]. As scientists have rightly pointed out, supporting low-carbon energy processes is an important measure for reducing greenhouse gas emissions. However, such changes typically require investments that require continued access to finance. In such a case, the determination of credit ratings is a critical factor in the financing process. The paper assesses the feasibility of using different models to predict the credit ratings of environmentally friendly companies. The authors rank 355 companies in the euro area for the period 2010 to 2019. Given that green businesses face constant risk, the results obtained in the article are important in assessing the credit risk of pro-environmental firms. Modifying traditional credit rating models Moretto *et al.*, [12]. The paper investigated how financial ratings and supplier ratings can be combined into a credit rating model. The authors detailed the advantages and challenges of using the developed model for all stakeholders using prism theory. The results confirm the value of such a rating for strategic suppliers and other stakeholders. Svanberg *et al.,* [13], make an important contribution to the greening of production. Researchers have discussed a new direction for the development of corporate eco-efficiency ratings and proposed a solution to the problem of assessing the level of the greening of enterprises. Interesting for our paper is the usage of a new machine learning approach with an innovative set of algorithmic approaches that address the issues of non-linearity while the aggregation of indicators. Sun *et al.,* [14] make a significant scientific contribution to the theory of credit assessment of small enterprises. This scientific paper presents an innovative approach to assess the credit rating of small industrial enterprises using fuzzy decision-making methods. The simulation was validated using data on bank loans to 1,820 small industrial enterprises in China. The proposed ranking procedure was based on the usage of triangular fuzzy numbers, correlation and single factor analysis, the best-worst method in combination with the entropy weight method, fuzzy c-means algorithm, etc. What is important for our study is how the authors carry out the validation of the results obtained. Thus, the paper proposes a 10-fold cross-validation to assess the predictive efficiency of the proposed approach. Bhandari and Golden, [15], which assessed the impact of the CEO's personal political ideology, on the credit rating of the firm, conducted an unconventional study. The results confirmed the theory of consistency between the behaviour of top managers and social identity.

An in-depth review of the scientific literature regarding the rating of profitability and costs indicators of agribusinesses has shown a high interest of scientists in this issue. The extensive methodologies and models that scientists use for ranking are of interest. Innovative rating tools are the usage of neural networks and artificial intelligence, which are also in demand in today's market. Given the dynamism of the institutional environment, bifurcations in the life cycle of agribusinesses, changes in the management strategies of business entities, and transformations in the regulatory and legal support of the agribusiness sector, there is a need to review the rating system of profitability and costs indicators of agribusinesses.

2. Materials and Methods

Modern business entities are characterised by strategic orientation and purposefulness, which implies the formation of clear plans for their further development in the face of instability and change. One of the main attributes of an effectively operating agribusiness is the consideration by its managers of the conditions of the external environment and, on this basis, the adaptation of the enterprise's policy to changes in the external environment. In addition, agribusiness is a structural part of the market, cooperating with a large number of contractors (government, business, suppliers, customers, international partners, consumers, etc.), which belong to different sectors of economic activity. Therefore, it is very important to obtain timely and reliable information about the current development of both your own enterprise as well as that of other sectors to avoid production downtime, bankruptcy or unfair competition. Rating the profitability and costs indicators of agribusinesses in dynamics allows foreseeing possible difficulties in the activities of a business entity or industry, which will allow taking preventive measures in time to prevent the negative impact of the external environment on the business. There is a need to choose such a scientific method for solving this problem, which would allow for avoiding the multidimensionality and complexity of economic processes in the most effective way. It is necessary to select the tools for diagnosing the activities of enterprises, which would make it possible to construct a summary assessment of the performance of a complex object or process. This proves the importance of applying and extending multivariate statistical methods for rating profitability and costs indicators of agribusinesses or sectors of the economy as a whole. We propose to rank the profitability and costs of agricultural enterprises following a certain logic, shown in Figure 1.

At the initial stage of ranking the profitability and costs indicators of agricultural enterprises, we carry out the selection of indicators to be involved in the modelling. In this case, we should analyse the activity indicators of agricultural enterprises over the past eleven years, in particular: the level of profitability of agricultural production in the enterprises, direct material costs, direct labour costs, other direct costs and general production costs. The information base for obtaining these indicators was the data of the State Statistics Service of Ukraine for 2010–2020. The list of indicators of agricultural enterprises by areas of analytical research that

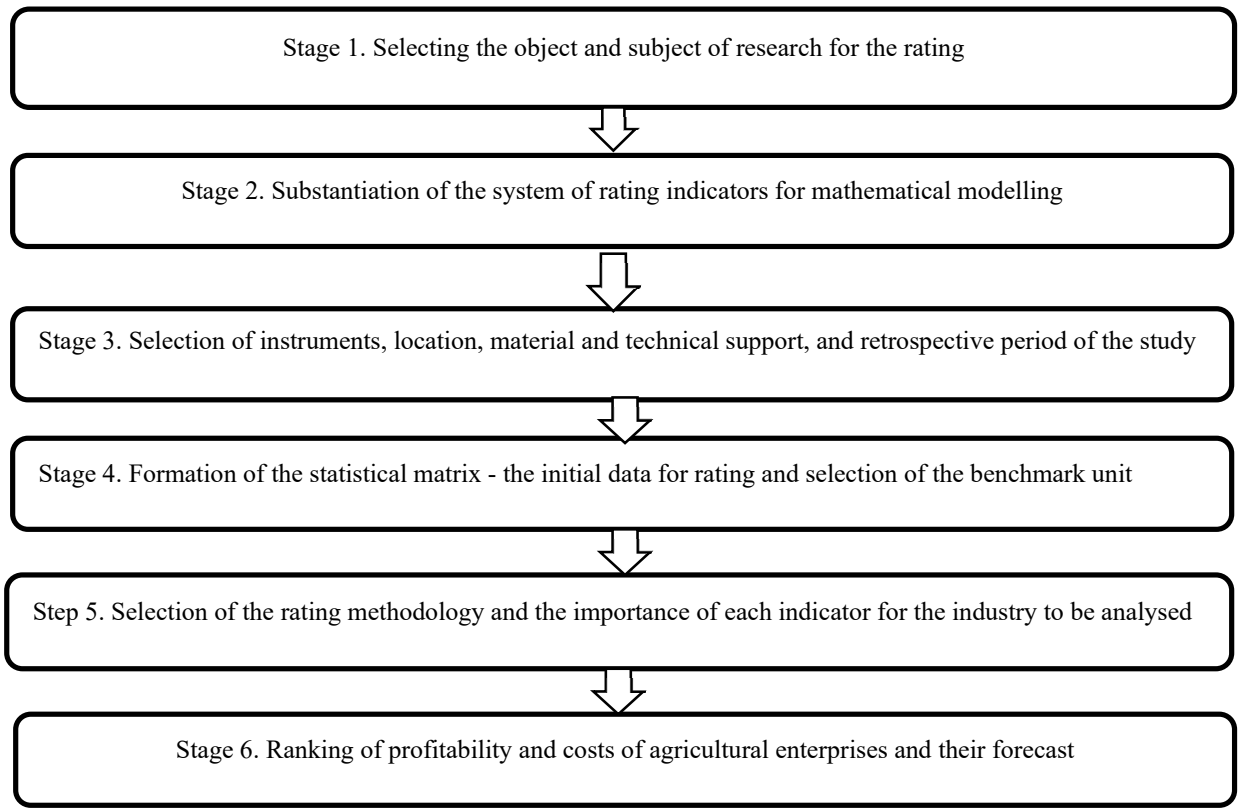


Figure 1. Algorithm for ranking indicators of profitability and costs indicators of agribusinesses

Source: Developed by the authors

form the information base for the last eleven years is presented in Table 1.

The data shown in Table 1 form the observation matrix using which we will evaluate the ranking of profitability and costs indicators of agribusinesses. A fairly convenient way of ranking is to use certain mathematical tools and methods that have been thoroughly researched in the scientific world. A ranking is a rating, the methodology of which is purposeful, systematic, comprehensive and adaptive in nature, based on the analytical approaches of segmenting the object of research. We chose the rating method, which has advantages relative to cluster or matrix analysis or the scoring method. In particular, the ranking does not require a wide range of statistical data, nor does it require significant financial or

Table 1

Dynamics of the performance of agricultural enterprises for rating implementation, 2010–2020

Years	Initial data				
	The level of profitability of agricultural production in enterprises, %	Direct material costs — total, UAH million	Direct labour costs, UAH million	Other direct costs — total, UAH million	General operating costs — total, UAH million
2010	21,10	52528,20	6806,80	9276,90	10023,40
2011	27,00	70732,20	9028,90	11610,10	13947,50
2012	20,50	84855,70	11610,40	16496,30	16621,60
2013	11,20	88541,70	9719,40	18392,30	18656,40
2014	25,80	108700,90	11044,10	22110,50	26391,40
2015	45,60	168505,0	12425,50	33021,50	38131,80
2016	37,30	207870,2	15638,40	47357,10	50240,00
2017	22,70	242313,70	20326,70	79262,10	63067,70
2018	22,80	247997,20	25234,40	95016,80	74745,00
2019	11,80	228980,50	25228,90	83493,30	58686,30
2020	18,40	205418,50	25850,30	85807,10	52237,70

Source: https://www.ukrstat.gov.ua/

human resources. Therefore, any stakeholder interested in the development of the agribusiness sector can use it. It should be noted that the main purpose of using the ranking method is to construct a final indicator, which will fully characterise the activity of the complex object or process to be observed and serve as a reason to forecast the main performance indicators of agricultural enterprises. We adapt the taxonomic analysis of our study by extending its tools and modelling logic. Consequently, after selecting the information base for observing the profitability and costs of agricultural enterprises, there is a need to standardise the "dispersed" statistical data having different units of measurement. For this purpose, we will carry out a standardisation process of the observation matrix, which includes the performance indicators of agricultural enterprises. These actions will allow us to identify the reference vector, determine the distances between the indicators and the specified vector, and calculate the integral indicator of profitability and costs of agricultural enterprises. An important development in forecasting the integral indicator of the performance of agricultural enterprises for the next period. We use Microsoft Excel spreadsheets and its built-in functions to calculate using the method of ranking the performance of agricultural enterprises. In the first stage, we form a matrix of standardised performance indicators of agricultural enterprises (Z_{st}), 2010–2020.

3. Results and Discussion

The next step in ranking the profitability and costs indicators of agribusinesses should take into account that all variables assigned to the observation matrix have different effects on enterprises. They should be divided into stimulants and destimulants. Factors contributing to the development of enterprises are stimulants and vice versa are destimulants. Then we select the vectors-etalons — the maximum value of the standardised indicator-stimulant and the minimum value for the destimulants. In this case, we can conventionally divide the performance indicators of agricultural enterprises that directly or indirectly affect the financial results of economic entities as follows: the level of profitability of agricultural production in the enterprises — a stimulant;

direct material costs — a stimulant;

direct labour costs — a stimulant;

other direct costs — destimulant;

general production costs — destimulant.

However, it should be noted that this division is arbitrary and is based solely for calculating the profitability and costs characteristics of agribusinesses (Figure 3).

The next step involves selecting between individual observations and an etalon vector metric using the Euclidean distance. This distance is calculated using Pythagoras' theorem and allows us to calculate the smallest distance between the indicators referred to Euclidean space. The Euclidean distance or metric in space is calculated using formula (1):

$$U_{so} = \sqrt{\sum_{n=1}^{m}(Z_{st} - Z_{0t})^2} \ .$$

The calculation of the Euclidean distance or metric is shown in Figure 4.

Next, we calculate the values taken from the matrix of standardised indicators used to calculate the ranking of profitability and costs of agribusinesses, 2010–2020:

1. The average distance between the stimulant (destimulant) values and the etalon vector is calculated according to the formula:

$$\bar{U}_0 = \frac{1}{m}\sum_{n=1}^{m} U_{so} \ .$$

G4 =(B4-B15)/B16

	A	B	C	D	E	F	G	H	I	J	K
2		Initial data					Interim calculations (Z st)				
3	Years	The level of profitability of agricultural production in enterprises, %.	Direct material costs - total, UAH million	Direct labour costs, UAH million	Other direct costs, UAH million - total	General operating expenses - total, UAH million	The level of profitability of agricultural production in enterprises	Direct material costs total	Direct labour costs	Other direct costs	General operating expenses - total
4	2010	21.10	52528.20	6806.80	9276.90	10023.40	-0.29	-1.17	-1.24	-1.08	-1.26
5	2011	27.00	70732.20	9028.90	11610.10	13947.50	0.29	-0.95	-0.93	-1.01	-1.09
6	2012	20.50	84855.70	11610.40	16496.30	16621.60	-0.35	-0.77	-0.57	-0.86	-0.97
7	2013	11.20	88541.70	9719.40	18392.30	18656.40	-1.27	-0.73	-0.84	-0.81	-0.88
8	2014[2]	25.80	108700.90	11044.10	22110.50	26391.40	0.18	-0.48	-0.65	-0.70	-0.53
9	2015[2]	45.60	168505,0	12425.50	33021.50	38131.80	2.13	0.25	-0.46	-0.37	-0.01
10	2016[2]	37.30	207870,2	15638.40	47357.10	50240.00	1.31	0.74	-0.01	0.05	0.52
11	2017[2]	22.70	242313.70	20326.70	79262.10	63067.70	-0.13	1.16	0.64	1.00	1.09
12	2018[2]	22.80	247997.20	25234.40	95016.80	74745.00	-0.12	1.23	1.33	1.46	1.61
13	2019[2]	11.80	228980.50	25228.90	83493.30	58686.30	-1.21	1.00	1.33	1.12	0.90
14	2020[2]	18.40	205418.50	25850.30	85807.10	52237.70	-0.56	0.71	1.41	1.19	0.61
15	Average value of a feature built-in mathematical function AVERAGE	24.02	147785.40	15719.44	45622.18	38431.71					
16	Standard deviation built-in statistical function STDEV.P	10.12	81317.98	7173.73	33767.87	22548.14					
17											

Figure 2. Dynamics and matrix of standardised performance indicators of agricultural enterprises, 2010–2020 (List of calculations)

Source: calculated by the authors

B31 =MAKC(B20:B30)

	A	B	C	D	E	F
19	Years	The level of profitability of agricultural production in enterprises, % / Stimulant	Direct material costs - total, UAH million / Stimulant	Direct labour costs, UAH million / Stimulant	Other direct costs, UAH million - total / Destimulant	General operating expenses - total, UAH million / Destimulant
20	2010	21.10	52528.20	6806.80	9276.90	10023.40
21	2011	27.00	70732.20	9028.90	11610.10	13947.50
22	2012	20.50	84855.70	11610.40	16496.30	16621.60
23	2013	11.20	88541.70	9719.40	18392.30	18656.40
24	2014^2	25.80	108700.90	11044.10	22110.50	26391.40
25	2015^2	45.60	168505,0	12425.50	33021.50	38131.80
26	2016^2	37.30	207870,2	15638.40	47357.10	50240.00
27	2017^2	22.70	242313.70	20326.70	79262.10	63067.70
28	2018^2	22.80	247997.20	25234.40	95016.80	74745.00
29	2019^2	11.80	228980.50	25228.90	83493.30	58686.30
30	2020^2	18.40	205418.50	25850.30	85807.10	52237.70
31	Etalon (Z_0t) (stimulant – max)	45.60	247997.20	25850.30	X	X
32	Etalon (Z_0t) (destimulant – min)	X	X	X	9276.90	10023.40

Figure 3. Determination of the etalon vector to be calculated by taxonomic analysis of business entities, 2010–2020 (List of calculations)

Source: calculated by the authors

2. Then the standard deviation is equal to:

$$D_o = \sqrt{\frac{1}{m}}\text{y}\left(U_{so} - \bar{U}_0\right)^2$$

3. To calculate the overall distance between the stimulants (destimulants) and the etalon, given the existence of large differences in the input standardised values of profitability and costs, it is

B38 =КОРЕНЬ((G4-B31)^2)

	A	B	C	D	E	F
34	Determination of the distance between individual observations and the etalon vector using the formula: $u_{so} = \sqrt{\sum_{n=1}^{m}(z_{st} - z_{0t})^2}$					
35						
36		Built-in mathematical function SQRT				
37	Years	The level of profitability of agricultural production in enterprises	Direct material costs - total	Direct labour costs	Other direct costs	General operating expenses - total
38	2010	45.89	247998.37	25851.54	9277.98	10024.66
39	2011	45.31	247998.15	25851.23	9277.91	10024.49
40	2012	45.95	247997.97	25850.87	9277.76	10024.37
41	2013	46.87	247997.93	25851.14	9277.71	10024.28
42	2014^2	45.42	247997.68	25850.95	9277.60	10023.93
43	2015^2	43.47	247996.95	25850.76	9277.27	10023.41
44	2016^2	44.29	247996.46	25850.31	9276.85	10022.88
45	2017^2	45.73	247996.04	25849.66	9275.90	10022.31
46	2018^2	45.72	247995.97	25848.97	9275.44	10021.79
47	2019^2	46.81	247996.20	25848.97	9275.78	10022.50
48	2020^2	46.16	247996.49	25848.89	9275.71	10022.79
49						

Figure 4. Calculation of distances between selected performance indicators of agricultural enterprises and the etalon vector (List of calculations)

Source: calculated by the authors

Results of the ranking of profitability and costs indicators of agribusinesses, 2010-2020

Years	$\bar{U}_0 = \frac{1}{m}\sum_{n=1}^{m} U_{so}$					$D_o = \sqrt{\frac{1}{m}\Sigma(U_{so} - \bar{U}_0)^2}$					$\bar{U}_0 = \bar{U}_0 + 2.4D_o$				
	The level of profitability of agricultural production in enterprises	Direct material costs - total	Direct labour costs	Other direct costs	General operating expenses - total	The level of profitability of agricultural production in enterprises	Direct material costs - total	Direct labour costs	Other direct costs	General operating expenses - total	The level of profitability of agricultural production in enterprises	Direct material costs total	Direct labour costs	Other direct costs	General operating expenses - total
2010	9.18	49599.67	5170.31	1855.60	2004.93	16.42	88726.59	9248.93	3319.39	3586.53	42.01	227052.86	23668.17	8494.37	9177.99
2011	9.06	49599.63	5170.25	1855.58	2004.90	16.21	88726.51	9248.82	3319.37	3586.47	41.48	227052.66	23667.88	8494.31	9177.84
2012	9.19	49599.59	5170.17	1855.55	2004.87	16.44	88726.45	9248.69	3319.31	3586.43	42.07	227052.50	23667.55	8494.18	9177.73
2013	9.37	49599.59	5170.23	1855.54	2004.86	16.77	88726.44	9248.78	3319.29	3586.39	42.91	227052.46	23667.79	8494.13	9177.64
2014[2]	9.08	49599.54	5170.19	1855.52	2004.79	16.25	88726.35	9248.72	3319.25	3586.27	41.59	227052.23	23667.63	8494.03	9177.33
2015[2]	8.69	49599.39	5170.15	1855.45	2004.68	15.55	88726.08	9248.65	3319.14	3586.09	39.80	227051.56	23667.45	8493.73	9176.85
2016[2]	8.86	49599.29	5170.06	1855.37	2004.58	15.84	88725.91	9248.49	3318.99	3585.89	40.55	227051.11	23667.04	8493.34	9176.36
2017[2]	9.15	49599.21	5169.93	1855.18	2004.46	16.36	88725.76	9248.25	3318.65	3585.69	41.87	227050.73	23666.44	8492.48	9175.84
2018[2]	9.14	49599.19	5169.79	1855.09	2004.36	16.36	88725.73	9248.01	3318.48	3585.50	41.86	227050.66	23665.81	8492.05	9175.37
2019[2]	9.36	49599.24	5169.79	1855.16	2004.50	16.75	88725.82	9248.01	3318.60	3585.76	42.85	227050.88	23665.82	8492.36	9176.02
2020[2]	9.23	49599.30	5169.78	1855.14	2004.56	16.51	88725.92	9247.98	3318.58	3585.86	42.26	227051.14	23665.74	8492.30	9176.28

Years	$dr_i = \frac{U_{so}}{U_0}$					$MK_n = 1 - dr_i$				
	The level of profitability of agricultural production in enterprises	Direct material costs - total	Direct labour costs	Other direct costs	General operating expenses - total	The level of profitability of agricultural production in enterprises	Direct material costs total	Direct labour costs	Other direct costs	General operating expenses - total
2010	0.28	0.44	0.54	0.52	0.48	0.718	0.558	0.458	0.480	0.519
2011	0.26	0.41	0.50	0.49	0.48	0.738	0.588	0.498	0.507	0.523
2012	0.24	0.38	0.46	0.47	0.47	0.758	0.618	0.538	0.534	0.527
2013	0.22	0.35	0.42	0.44	0.47	0.778	0.648	0.578	0.561	0.531
2014	0.20	0.32	0.38	0.41	0.47	0.798	0.678	0.618	0.588	0.535
2015	0.18	0.29	0.34	0.39	0.46	0.818	0.708	0.658	0.615	0.539
2016	0.16	0.26	0.30	0.36	0.46	0.838	0.738	0.698	0.642	0.543
2017	0.14	0.23	0.26	0.33	0.45	0.858	0.768	0.738	0.669	0.547
2018	0.12	0.20	0.22	0.30	0.45	0.878	0.798	0.778	0.696	0.551
2019	0.10	0.17	0.18	0.28	0.45	0.898	0.828	0.818	0.723	0.555
2020	0.08	0.14	0.14	0.25	0.44	0.918	0.858	0.858	0.750	0.559

Figure 5. Block for the step-by-step calculation of the rating of profitability and costs of agricultural enterprises, 2010–2020 *(List of calculations)*

Source: calculated by the authors

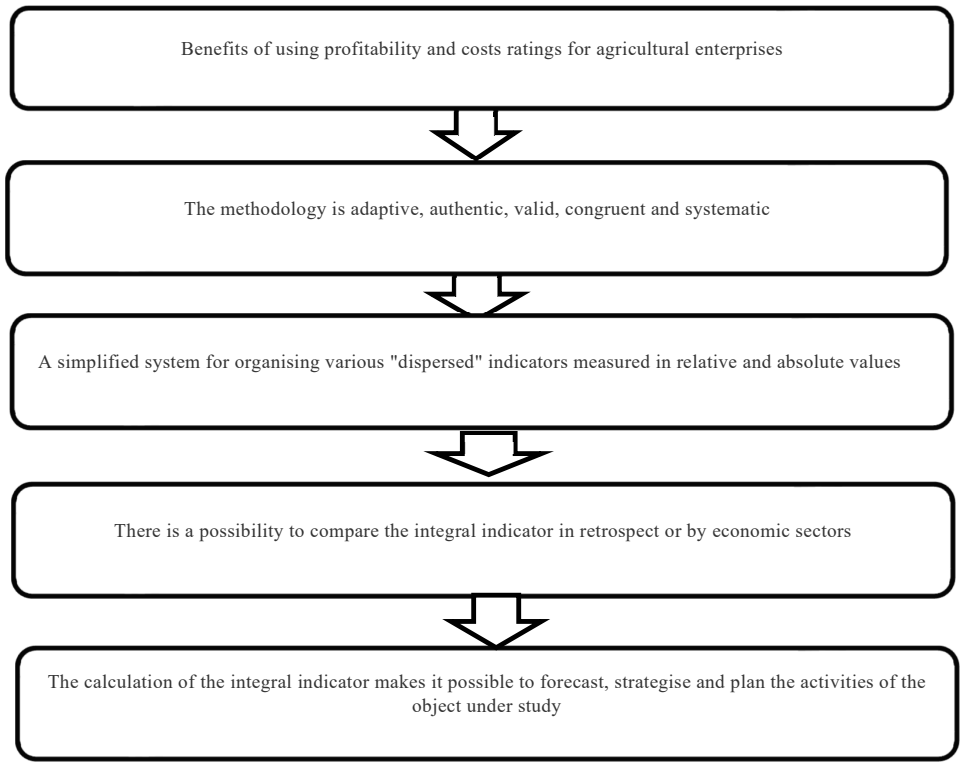
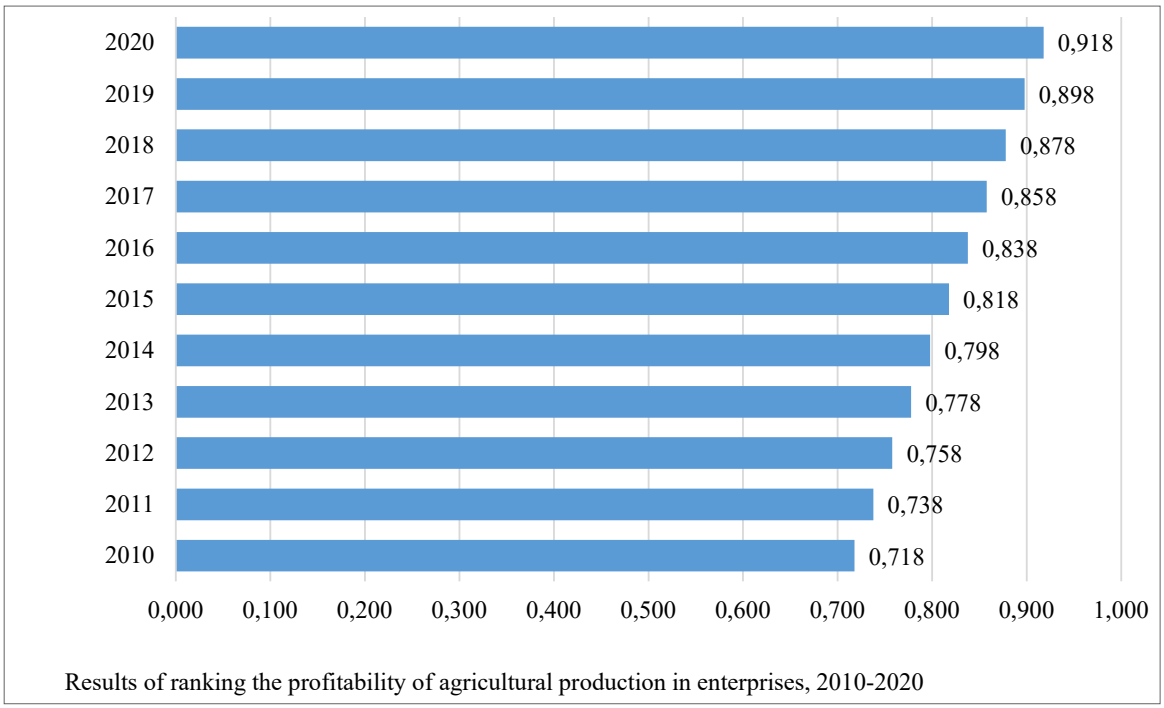


Figure 6. Benefits of applying profitability and costs ranking of agribusinesses in scientific researches

Source: Suggested by the authors



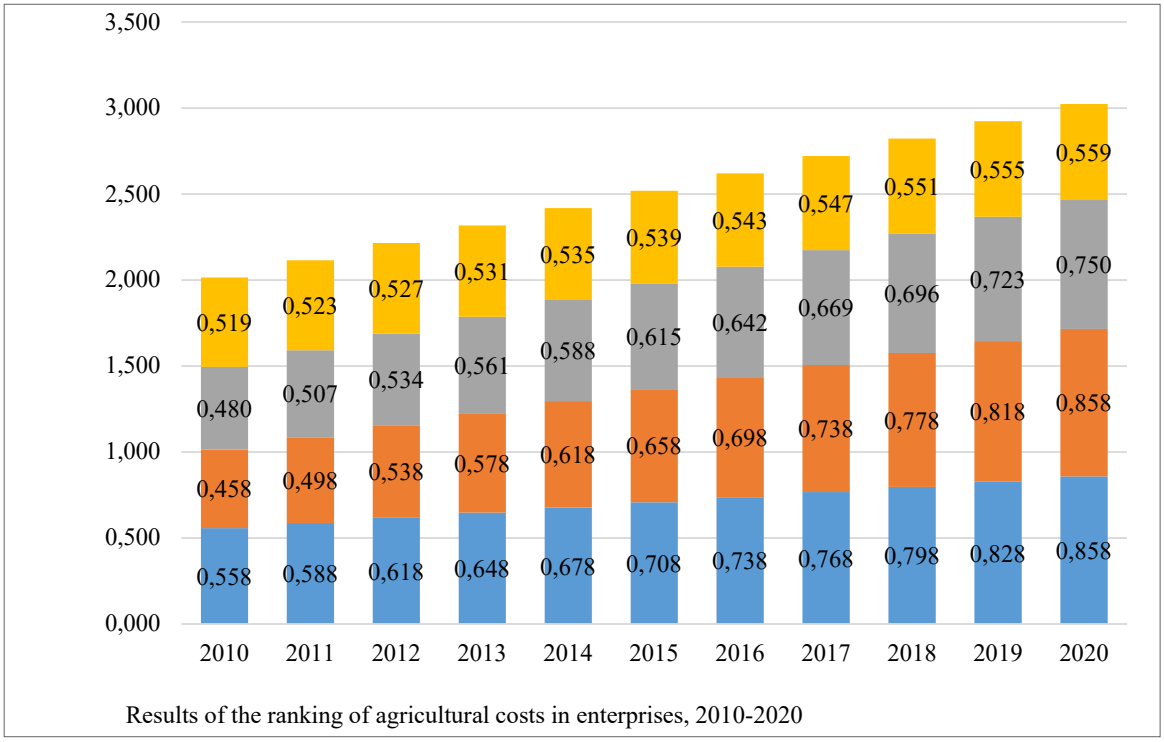


Figure 7. Dynamics of the ranking indicator of the level of profitability of production and costs of agricultural production in enterprises, 2010–2020.

Source: calculated by the authors

Table 2

Forecasting the taxonomic performance of agricultural enterprises activities, 2023–2024

Years	Forecasting indicators using the built-in statistical function FORECAST				
	The level of profitability of agricultural production in enterprises	Direct material costs — total	Direct labour costs	Other direct costs	General operating expenses — total
2023	0.978	0.948	0.938	0.831	0.571
2024	0.998	0.978	0.978	0.858	0.575

Source: calculated by the authors

proposed to increase the distance to 2.4 standard deviations:

$$\bar{U}_0 = \bar{U}_0 + 2.4D_o .$$

4. The deviation of the profitability of the i year from the etalon is calculated as:

$$dr_i = \frac{U_{so}}{U_0} .$$

Finally, to determine the ranking of profitability and costs of agricultural enterprises for 2010–2020, let us calculate the formula:

$$MK_n = 1 - dr_i .$$

As a result of the above calculations, an interpretation of the profitability and costs ranking of agribusinesses can be made. Consequently, the closer the value of the indicator is to one, the more efficient an agricultural enterprise is. Thus, the step-by-step calculation of profitability and costs ranking of agribusinesses allows us to determine the advantages of applying this method in scientific research (fig. 6).

It should be noted that based on the information given in Figure 7, the ranking of profitability and costs of agricultural enterprises is a universal method that can be applied to any object or industry (this method is derived from the classical taxonomic analysis). The rating can be adapted in not only for studies of statistical units or their totality but also for determining the dynamics of changes in an individual unit. In particular, the dynamics of changes in an individual unit according to the ranking methodology is investigated by means of a retrospective time series. Our study uses the performance of agricultural enterprises by means of time series.

Analysing the result of the profitability and costs ranking of agricultural enterprises for the last year 2020, we can observe its growth compared to previous years. In particular, there has been an increase in:

the level of profitability of agricultural production in the enterprises from 0.898 to 0.918 units;

direct material costs from 0.828 to 0.858 units;

direct labour costs from 0.858 to 0.818 units;

other direct costs from 0.723 to 0.750 units;

general production costs from 0.555 to 0.555 units.

Graphically, the dynamics of profitability and costs ranking of agricultural enterprises, 2010–2020, is shown in Figure 7. This figure also shows the dynamics of agricultural production costs, 2010–2020.

At the final stage, we will make a forecast of the rating of a performance indicator of agricultural enterprises and their graphical representation for the next two years. The forecasting of these indicators has been made by the authors and is a proposal for improving the strategic orientation and making the right managerial decisions by the managers of agricultural enterprises in order to formulate goals for the comprehensive activities of business entities.

So, the conducted forecasting of the rating indicator of agricultural enterprises activity using the built-in statistical function FORECAST shows that the indicators of the level of profitability of agricultural production in enterprises, direct material costs, direct labour costs, other direct costs and general production costs are increasing and are approaching the normalised value of 1, which may be a positive phenomenon (table 2).

Graphically depicts the projection of the rating indicator of agricultural enterprises, 2023–2024 in Figure 8.

The obtained forecast results of profitability and costs ranking of agricultural enterprises in 2023–2024 showed the increase in profitability of agricultural production from 0.978 to 0.998 units, direct material costs from 0.948 to 0.978 units, direct labour costs from 0.938 to 0.978 units, other direct costs from 0.831 to 0.858 units, general production

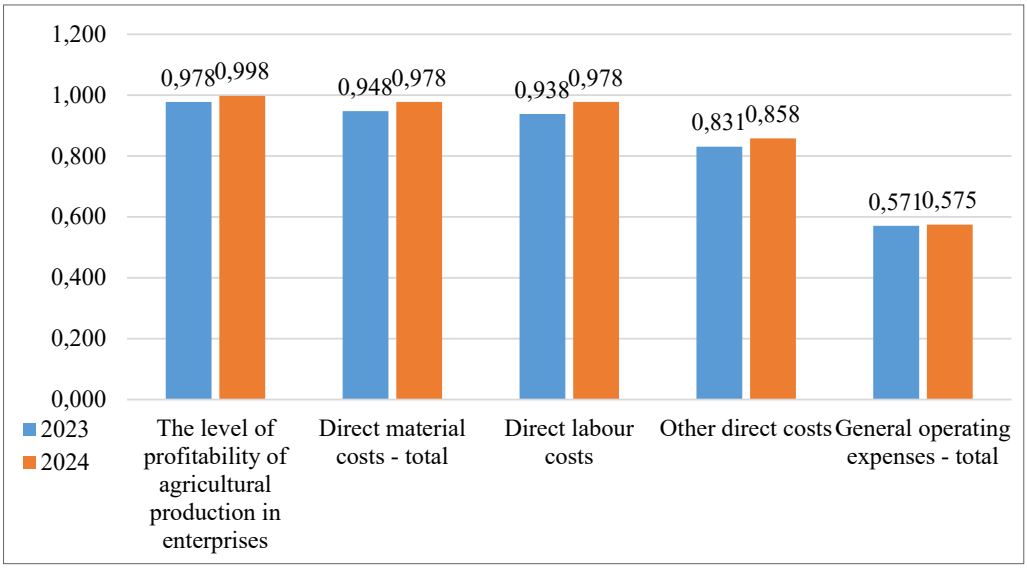


Figure 8. Forecasting the performance rating indicator of the agricultural enterprises' activity, 2003–2004

Source: calculated by the authors

expenses from 0,571 to 0,575 units. Thus, we can see an increase in all indicators during the study period. This indicates that profitability in the agricultural sector is simultaneously increasing with costs. This phenomenon can be explained by the fact that by increasing costs companies expand their production activities, and effective business management contributes to increasing profitability and timely coverage of current costs.

4. Conclusions

Consequently, the results of this study allow us to conclude that the ranking method can be used in the study of the dynamics of the activities of enterprises engaged in agriculture. The proposed ranking method is based on taxonomic analysis and makes it possible for a manager or other interested person to summarise the totality of the activity results of enterprises engaged in various sectors and obtain an integral ranking indicator. In future studies, we will involve more performance indicators of agricultural enterprises and their comparison at the inter-industry level will be carried out, which will allow for a deeper analysis and forecasting of the further development of enterprises, taking into account the competition in the market.

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Гнатенко Ірина
доктор економічних наук, професор
Київський національний університет технологій та дизайну
Україна
ORCID: 0000-0002-0254-2466

Гжегож Конєчний
доктор соціальних наук,
ректор WSHIU Академії прикладних наук
Польща
ORCID: 0000-0002-6337-9738

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РЕЙТИНГУВАННЯ ПОКАЗНИКІВ РЕНТАБЕЛЬНОСТІ ТА ВИТРАТ АГРОПІДПРИЄМСТВ

Анотація. *Мікросередовище аграрних підприємств знаходиться під впливом зовнішнього середовища, яке по-різному відбивається на підприємницькій діяльності. При цьому будь-яка реакція менеджерів на зовнішні зміни повинна буди обґрунтованою, логічною та відповідати потребам сучасного ринку. Важливе значення набуває вчасна діагностика показників рентабельності та витрат агропідприємств, а також прогнозування їх значень. Такі дії нададуть управлінцям орієнтири для прийняття потрібних рішень та дозволять реагувати на будь-які імпульси, які впливають на розвиток підприємства.*

Для рейтингування показників рентабельності витрат суб'єктів підприємництва нами обрано діяльність агропідприємств. З використанням методів математичного моделювання, таксономічного аналізу, рейтингування нами проаналізовано динаміку показників діяльності сільськогосподарських підприємств. Апробація окремих статистичних функцій дозволила провести прогнозування рейтингового показника діяльності аграрних підприємств на 2023–2024 рр.

Отриманий результат рейтингування рентабельності та витрат агропідприємств за звітній 2020 рік, засвідчив його зростання в порівнянні з попередніми роками. Одночасно можна спостерігати збільшення витрат підприємствами, що говорить про необхідність більш жорсткого та глибокого моніторингу діяльності агропідприємств менеджерами вищої ланки. Зазначений моніторинг надасть змогу запобігти банкрутства або неефективності розподілу фінансів підприємств.

Описане у статті рейтингування рентабельності та витрат агропідприємств є універсальним методом, який можна застосувати для будь-якого об'єкту або галузі. Рейтингування може бути апробованим не тільки в дослідженнях статистичних одиниць або їх сукупності, але й для визначення динамічних змін за часовими ретроспективними рядами. Прогнозування досліджуваних показників може слугувати імпульсами для управлінців, щодо вдосконалення стратегічної орієнтації та ухвалення вірних рішень менеджерами сільськогосподарських підприємств з метою формування цілей подальшої діяльності.

Ключові слова: *рентабельність, прямі матеріальні витрати, витрати на оплату праці, загальновиробничі витрати, прогнозування, рейтингування, агропідприємства*

НАУКОВИЙ ЖУРНАЛ

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Контактний телефон: +38 (044) 333-4556
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