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Analytical assessment of the interaction between components of the marketing complex of enterprise competitiveness

Abstract. The study aimed to develop theoretical and methodological foundations for analytical assessment of the comprehensive competitiveness of enterprises and the interaction of their marketing components, which should facilitate informed decision-making in competitive markets. The author's vision of competitiveness was presented from the perspective of a marketing approach to the formation of competitive results, functionality and potential of enterprises in key competitive markets, based on the recognition of the subject of competition as the target benchmark for rivalry between competitors. The objects of analysis were selected sectoral and status components of the complex: realised, functional and potential competitiveness in the commodity, labour and investment markets. A methodological toolkit for the analytical assessment of the marketing complex of enterprise competitiveness is proposed, which includes: a matrix analysis method with a sequential increase in competitiveness assessment indicators; analysis of the dynamics of indicators with the determination of its direction and nature of changes (accelerated, slowed down, predicted); analysis of configurations of differentiated values using static and dynamic indicators. The hypothesis regarding the need to achieve a balance of competitiveness levels in sectoral markets is substantiated, which should ensure the growing dynamics of enterprise profits through the means of marketing functional influence on marketing results and potential. An applied test of the developed analytical tool for assessing comprehensive competitiveness was conducted. The economic feasibility of balancing the components of the competitiveness complex of enterprises was confirmed by calculations – the coefficient of determination between the profit dynamics of the studied enterprises producing dry building mixtures and the level of balancing the realised sectoral competitiveness was 0.587, which corresponds to a high level of their correlation dependence. The practical value of the study is determined by the development of methodological tools for analysis of the competitiveness complex in the context of balancing its components, with which analytical services of enterprises can provide necessary information to justify the tasks of competitive development

Keywords: subject of competition; types of competitiveness; competitiveness indicators; balance of indicators; competitiveness analysis tools; marketing results; potential and functionality

INTRODUCTION

Competitive advantage is an indisputable prerequisite for the functioning of enterprises in a competitive environment. This requires the development of special analytical tools, given the complex nature of the competitive activity of enterprises in the markets of finished products and production resources. The development of such tools must be preceded by a well-founded understanding of the meaning of competitiveness, which will determine the evaluation indicators suitable for quantitative measurement and objective reflection of the competitive capabilities of enterprises.

In Ukrainian studies, the concept of competitiveness is often equated with efficiency. O.I. Kovtun (2021) believes that the main assessment characteristics of competitiveness are formed based on a representative set of generalised efficiency indicators. N.O. Yevtushenko &

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V.V. Varnitskyi (2021) adhere to a similar position, highlighting the complexity of the economic category of "competitiveness" and proposing a definition of it as the totality of an enterprise's opportunities to effectively use its resource potential to obtain the desired profits. This approach significantly narrows the scope of competitive opportunities for market participants and calls into question the advisability of using both concepts independently. Another interpretation of the concept of enterprise competitiveness is based on the market share indicator. It has been widely used by authors in analysing the results of market players' competitive activities, although it has not been combined with the concept of competitiveness, which, incidentally, was not modal. The market share of enterprises reflects the comparative nature of the competitiveness of competitive market players, but significantly limits the scope of research into the signs of competitive opportunities of enterprises and the formats of their manifestation.

Some scholars associate the competitiveness of enterprises with the competitiveness of their products. While some, in particular V.O. Herasymova & E.O. Rezanov (2020), reasonably believe that competitiveness is the result of following certain management decisions aimed at ensuring the ability of enterprises to develop, competing with their products with other market participants, others confuse these concepts. O. Vynogradova *et al*. (2021) argue that competitiveness reflects the ability of enterprises to produce competitive products by using their potential better than their competitors. It should be noted that the production of competitive products does not guarantee the competitive success of enterprises in the event of logistical, price, or territorial miscalculations. However, the most common interpretation of competitiveness is as a comprehensive result of the economic activity of enterprises. According to H. Datsenko *et al*. (2022), competitiveness should be assessed based on a broad list of performance indicators, differentiated by one or another classification criterion and level of aggregation. This shifts the focus from competitiveness as a comparative characteristic of the market activity of direct competitors to the entire complex of functional activities of the entities under study.

A comprehensive assessment of the characteristics of competitiveness indicates the complexity of evaluating its level due to the need to consider a significant list of its features. In particular, A. Sukhanova (2021) believes that the necessary comprehensiveness of competitiveness assessment is achieved using various methodological approaches based on the product life cycle, market share, effective competition theory, competitive advantage, product competitiveness assessment, etc. At the same time, the author does not address the ways and methods of implementing this approach. Most studies suggest that the issue of comprehensive assessment of enterprise competitiveness should be addressed using an integrated approach based on algorithms of varying complexity. V. Panchenko *et al*. (2024) propose using more complex calculation models based on the method of integrating integral assessment of dynamic series, considering the weighted significance of individual indicators, a fuzzy logic calculation apparatus combined with the method of hierarchy analysis, which can be used to build a multi-parameter model that reflects the integral level of competitiveness of market participants. It is worth noting that the integral assessment of any object has limited analytical application, since it forms the final result in the form of a cumulative numerical value, which has a rating meaning, but limits the evaluation of the components of the object under study with different levels of aggregation. This is relevant for such a complex object as competitiveness, the analysis of which may require assessment by functional components, sales markets, and time characteristics. This is also indicated by the proposal of V. Radko & S. Matsiura (2023) on the expediency of distinguishing strategic, tactical and operational characteristics of competitiveness, which capture a different format of its complexity and can differentiate assessment characteristics in time and by degree of significance for the development of enterprises. At the same time, the use of different indicators of competitiveness in assessing its strategic, tactical and operational formats seems justified.

One aspect that will contribute to the systematisation of approaches to understanding the meaning of competitiveness, and particularly the selection of its assessment characteristics, is the identification of direct and indirect influencing factors. Indirect factors include technical and technological conditions of production and methods of organising production processes. Their effective use creates the preconditions for increasing competitiveness but does not determine its level. Direct factors are means of marketing influence on the competitive capabilities of enterprises. They shape the level of their competitiveness based on adequate pricing policies, effective advertising campaigns, and reasonable product offerings in line with consumer needs in specific territorial segments, considering seasonality of consumption, etc. In this regard, M. Samofalova *et al*. (2024) noted the priority of assessing and analysing the competitiveness of enterprises based on marketing performance indicators, which accumulate the results of other areas of enterprise activity.

This indicates the theoretical and practical relevance of developing tools for analytically assessing the interaction of the components of the marketing complex of enterprise competitiveness, based on a conceptual understanding of the nature of market competitiveness and the formats for its implementation. The study aimed to develop analytical tools for assessing the competitive position of a company and the synergy of its marketing efforts. Static and dynamic analysis of the sectoral and status components of the competitiveness complex of enterprises provides an opportunity to obtain relevant analytical information about the problematic and strengthened links of the complex, which should be considered in the formation of the budget for their development. However, the adoption of appropriate decisions to support product, personnel and investment competitiveness must be coordinated. This justified the hypothesis that it is necessary to achieve a balance between their levels in sectoral markets, which should ensure the growing dynamics of enterprise profits through the means of marketing functional influence on marketing results and potential. The research novelty is determined by the proposed methodological tools for analytical assessment of enterprise competitiveness based on competitiveness as a set of interrelated components – sectoral and status – formed based on indicators – marketing results, functionality and potential, which in a comparative format characterise the level of implemented, functional and potential competitiveness of enterprises as sellers of products and buyers of resources.

MATERIALS AND METHODS

The selection of enterprises – for competitiveness analysis, which is a comparative category, met the following criteria:

- the same product focus and a similar product range, which made it possible to compare the cost indicators of their activities;
- emphasise consumer needs in a common area of competition, which is evidence of direct competitive relations between these companies;
- serving consumers with the same segment profile, which would indicate a common customer base as the main feature of competing market players;
- representativeness of competitive analysis results obtained based on specified objects.

The consideration of these criteria in the selection of the objects of analysis facilitated the accurate calculation of competitiveness based on relative indicators that were comparable. The objects of competitive analysis were identified as the largest enterprises producing dry building mixtures – Askona-Pivden LLC (n.d.), Baumit Ukraine LLC (n.d.), Fomalgaut-Polimin LLC (n.d.), Henkel Bautechnik LLC (Ukraine) (n.d.), Kreisel-Building Materials LLC (n.d.), PJSC Terminal-M (n.d.), and YouControl (n.d.). They have a similar range of products, and their assortment diversity does not exceed 25%. The wholesale consumers of these companies' products are large retail chains and construction organisations throughout Ukraine, and transport costs do not have a significant impact on the competitiveness of these goods in most regions. The production volume of the companies under study in 2024 amounted to 5,795.1 million UAH, which accounted for 87.8% of the total market volume of dry construction mixtures in Ukraine. This indicates the competitive comparability of the operating conditions of these companies and the high level of representativeness of the further analytical results obtained. The theoretical and methodological basis of the study was formed by the works of Ukrainian and foreign scientists, including those available on Internet resources, and the results of previous studies (Melnyk, 2025a; 2025b). The primary source of information on the economic activities of selected dry construction mix manufacturers was their websites, which contained information on the range of products manufactured and price dynamics. The information and analytical website YouControl (n.d.) was the source of data on the financial and economic indicators of the enterprises under study, information on the number of employees and their average salary. The retrospective analytical period was 4 years, 2020-2024, which identified trends in competitiveness dynamics necessary to justify the tasks of balancing its components.

The theoretical and scientific-methodological basis of the study was formed by methods of scientific cognition, general scientific principles and achievements in the field of competitive analysis. Comparative analysis was used to compare and study options for understanding the content of enterprise competitiveness and indicators for its assessment. Methods of scientific abstraction and logical generalisation were used to determine the subject of competition in the market for finished products and resources. Decomposition was used to identify the components of the competitiveness complex of enterprises, which are the consequences of the manifestation of marketing results, potential and functionality. Causal analysis was used to clarify the interdependence of the status components of competitiveness (realised, potential and functional). Coefficients were used to calculate the levels of sectoral and status components of the competitiveness complex. The index method was used to analyse the dynamics of competitiveness indicators, and its variant, the index of indices, was used to determine the indicator of accelerated or decelerated dynamics. The matrix analysis method with sequential accumulation of assessment indicators was used to perform a comprehensive analysis of the components of competitiveness. The configuration of competitiveness components was used for an applied comprehensive analysis of the competitiveness of the studied enterprises, which formed analytical conclusions suitable for determining the tasks of their competitive development. Variational analysis – to assess the level of balance of sectoral components of competitiveness. Rating assessment was used to determine the relationship between actual and potential competitiveness. Correlation analysis – to identify the dependence of the dynamics of enterprise profits on the balance of sectoral components of competitiveness.

The development and testing of methodological tools for analytical assessment of the interaction of components of enterprise competitiveness were based on materials from market participants who are in direct competitive relations. To assess the level of competitiveness balance, the standard deviation indicator was selected, calculated based on the arithmetic mean of the realised competitiveness of enterprises in the commodity, labour and investment markets. The net profit change index is a dependent variable. The use of static profit volume in the analysis is not correct, as it is influenced by more significant factors caused by the concentration of production, represented by the volume of products sold. To analyse the relationship between realised sectoral competitiveness and the balance between realised and potential competitiveness in individual markets, a rating assessment method was used, which, unlike the correlation method, can identify dependencies without quantifying their level. The aggregate indicator of the balance between actual and potential competitiveness in the markets was calculated as the arithmetic mean of the deviations of their ratings in the markets under study.

RESULTS

Methodological tools for analysing the comprehensive competitiveness of enterprises in static conditions

The development of methodological tools for analytical assessment of the interaction of components of the marketing complex of enterprise competitiveness was based on the author's approach to the content of market participants' competitiveness and its components, as well as the selection of appropriate assessment indicators. The basic concept of the content of enterprise competitiveness is the subject of competition, the acquisition of which serves as an evaluative characteristic of the level of competitiveness of entities in each competitive market. The sphere of economic competition among enterprises extends to commodity markets, where they are sellers of products, and resource markets, where enterprises compete as buyers of resources. Competitiveness reflects the ability of market participants to compete, which is shaped by many factors, including marketing, organisational, technical, technological, financial, and others. The substantive basis and level of this ability are manifested in the effectiveness of the complex of the listed factors, among which marketing factors accumulate the effects of all others, which suggests the marketing nature of the formation of enterprise competitiveness.

The competitiveness of enterprises as sellers of products and buyers of resources in various markets forms a sectoral format of competitiveness, which has a product-resource structure and corresponds to the number of types of competitive markets where these entities operate. The acquisition of the subject of competition occurs in a certain cyclical sequence, which manifests itself in a combination of status indicators of competitiveness – marketing results, potential and functionality, which are in constant interaction. The level of marketing results, potential and functionality is determined by the ratio of their basic assessment indicator for each enterprise to the average value of this indicator in the competitive market, which is a quantitative measure of the realised, potential and functional competitiveness of the enterprises under study (Table 1). The object of analytical attention is the marketing complex of enterprise competitiveness, as a set of their integrated competitive capabilities that manifest their effect on target competitive markets and are aimed at realising existing opportunities to gain control of relevant objects of competition that form the resource support for the reproduction process. The complex combines commodity, personnel and investment competitiveness represented in the status formats of the realised, functional and potential competitive capabilities of enterprises.

Table 1. Basic assessment indicators by type of competitiveness of enterprises in key markets of activity

Sectoral competitiveness	**Competitiveness status**		
	Implemented	**Functional**	**Potential**
Commodity	Volume of sales	Unit price	Profitability of sales
Labout	Estimated productive staff numbers*	Average salary	Personnel profitability
Investment	Equity capital	Return on equity	Level of entrepreneurial income

Source: compiled by the author based on S. Melnyk (2025a; 2025b)

The use of the integral method of competitiveness analysis, which is most common in scientific and applied research, does not produce accurate results due to the complex system of interdependence between the components of the complex and the impossibility of determining the target criteria for the dynamics of individual types of competitiveness, in particular, potential and functional competitiveness. The most suitable tool for analysing the competitiveness complex of an entity is matrix analysis with the sequential accumulation of assessment indicators and the formation of their possible configurations. The resulting configuration serves as a meaningful information resource for forming a comprehensive conclusion about the state and dynamics of the competitiveness of the entity under study by type in a particular market. The results of the analysis provide a conclusion about the overall level of competitiveness in the markets of activity and assess the balance of the entire competitiveness complex. The implementation of such a matrix analysis has a tabular form, where the values of the assessment indicators are displayed in a specific sequence, and their configurations are given an analytical characteristic (Table 2).

Table 2. A schematic diagram of matrix analysis with sequential accumulation of evaluation indicators and formation of their possible configurations

Configurations of assessment indicators				**Analytical description of the configuration**
$M1_{ij}$	$M1_{ij}, M2_{ij}$	$M1_{ij}, M2_{ij}, M3_{ij}$	$M1_{ij}, M2_{ij}, M3_{ij}, \ldots Mn_{ij}$	
$M1_{ij}^{h}$	$M1_{ij}^{h}\ M2_{ij}^{h}$	$M1_{ij}^{h}\ M2_{ij}^{h}\ M3_{ij}^{h}$	$M1_{ij}^{h}\ M2_{ij}^{h}\ M3_{ij}^{h} \ldots Mn_{ij}^{h}$	
			$M1_{ij}^{h}\ M2_{ij}^{h}\ M3_{ij}^{h} \ldots Mn_{ij}^{l}$	
		$M1_{ij}^{h}\ M2_{ij}^{h}\ M3_{ij}^{l}$	$M1_{ij}^{h}\ M2_{ij}^{h}\ M3_{ij}^{l} \ldots Mn_{ij}^{h}$	
			$M1_{ij}^{h}\ M2_{ij}^{h}\ M3_{ij}^{l} \ldots Mn_{ij}^{l}$	
	$M1_{ij}^{h}\ M2_{ij}^{l}$	$M1_{ij}^{h}\ M2_{ij}^{l}\ M3_{ij}^{h}$	$M1_{ij}^{h}\ M2_{ij}^{l}\ M3_{ij}^{h} \ldots Mn_{ij}^{h}$	
			$M1_{ij}^{h}\ M2_{ij}^{l}\ M3_{ij}^{h} \ldots Mn_{ij}^{l}$	
		$M1_{ij}^{h}\ M2_{ij}^{l}\ M3_{ij}^{l}$	$M1_{ij}^{h}\ M2_{ij}^{l}\ M3_{ij}^{l} \ldots Mn_{ij}^{h}$	
			$M1_{ij}^{h}\ M2_{ij}^{l}\ M3_{ij}^{l} \ldots Mn_{ij}^{l}$	
$M1_{ij}^{l}$	$M1_{ij}^{l}\ M2_{ij}^{h}$	$M1_{ij}^{l}\ M2_{ij}^{h}\ M3_{ij}^{h}$	$M1_{ij}^{l}\ M2_{ij}^{h}\ M3_{ij}^{h} \ldots Mn_{ij}^{h}$	
			$M1_{ij}^{l}\ M2_{ij}^{h}\ M3_{ij}^{h} \ldots Mn_{ij}^{l}$	
		$M1_{ij}^{l}\ M2_{ij}^{h}\ M3_{ij}^{l}$	$M1_{ij}^{l}\ M2_{ij}^{h}\ M3_{ij}^{l} \ldots Mn_{ij}^{h}$	
			$M1_{ij}^{l}\ M2_{ij}^{h}\ M3_{ij}^{l} \ldots Mn_{ij}^{l}$	

Table 2. Continued

Configurations of assessment indicators				Analytical description of the configuration
$M1_{ij}$	$M1_{ij}, M2_{ij}$	$M1_{ij}, M2_{ij}, M3_{ij}$	$M1_{ij}, M2_{ij}, M3_{ij}, \ldots Mn_{ij}$	
$M1_{ij}^{l}$	$M1_{ij}^{l}\,M2_{ij}^{l}$	$M1_{ij}^{l}\,M2_{ij}^{l}\,M3_{ij}^{h}$	$M1_{ij}^{l}\,M2_{ij}^{l}\,M3_{ij}^{h} \ldots Mn_{ij}^{h}$	
			$M1_{ij}^{l}\,M2_{ij}^{l}\,M3_{ij}^{h} \ldots Mn_{ij}^{l}$	
		$M1_{ij}^{l}\,M2_{ij}^{l}\,M3_{ij}^{l}$	$M1_{ij}^{l}\,M2_{ij}^{l}\,M3_{ij}^{l} \ldots Mn_{ij}^{h}$	
			$M1_{ij}^{l}\,M2_{ij}^{l}\,M3_{ij}^{l} \ldots Mn_{ij}^{l}$	

Note: $M1, M2, \ldots Mn$ – assessment indicators characterising the components of competitiveness; i – type of competitiveness (implemented, potential, functional); j – the market under study (commodity, labour, investment); h, l – estimated level of the indicator value "high", "low" respectively

Source: compiled by the author as a result of the expansion of the application possibilities of matrix analysis

The number of indicators used in forming their configurations depends on the objectives and subject of analysis, as well as the available information base. The estimated levels of these indicators do not require deep differentiation due to their significant variability and the formation of analytical conclusions in the mode of diagnosing qualitative characteristics. If a more detailed assessment is required, the values obtained can be divided into the categories "high", "medium" and "low". However, this approach is only appropriate if a small number of assessment indicators are used, as otherwise the configurations obtained will be information-overloaded, which will complicate the formation of analytical conclusions. A comprehensive analysis of the competitiveness of enterprises in the main sectoral markets provides conclusions about the effectiveness of their actions when making decisions on the priority allocation of funds to finance the improvement/maintenance of product, personnel and investment competitiveness.

Methodological tools for analysis of the dynamics of enterprise competitiveness

The analysis of the marketing complex of enterprise competitiveness forms conclusions based on retrospective results. To determine the prospects for enterprise development, it is necessary to determine the existing dynamics of competitiveness indicators, which, in combination with static indicators, form the information base for forming sound analytical conclusions. The analysis toolkit has the following sections.

1. Identification of the direction of competitiveness indicators dynamics is based on the calculation of chain indices (I_i) and their average value (I_{aver}) for a specific retrospective period. When $I_{aver} > 1$, the dynamics are growing; when $I_{aver} < 1$, they are declining. I_{aver} is calculated using the geometric mean formula from the available chain indices I_i. According to the criterion of growth of this indicator, a decrease in dynamics is a basis for a thorough analysis of its causes; with an increase, it is a basis for management support of current decisions and actions.

2. Determining the nature of competitiveness indicators involves assessing their predictability and identifying signs of acceleration or deceleration.

2.1. The assessment of the predictability of dynamics is based on the calculation of the correlation coefficient (r) of the actual values of the indicator with the theoretical ones obtained based on the selection of an adequate trend model. When $r > 0.75$, the dynamics are considered predictable; when $r < 0.75$, they are considered unpredictable. The presence of predictable dynamics indicates an established trend and requires special management attention in terms of maintaining positive dynamics and changing negative ones.

2.2. Identification of signs of acceleration or deceleration in the dynamics under study involves calculating the corresponding index ($I_{n/y}$):

$$I_{n/y} = \sqrt[n]{I_1 : I_0 \cdot I_2 : I_1 \cdot \ldots I_n : I_{n-1}}, \qquad (1)$$

where I_0, I_1, I_2, I_n – chain indices of the indicator under study for specific periods. When $I_{n/y} > 1$, the dynamics are considered accelerated; when $I_{n/y} < 1$, they are considered slowed down. Growing dynamics with acceleration should be considered positive; growing dynamics with deceleration should be considered conditionally positive; decreasing dynamics with deceleration should be considered conditionally negative; decreasing dynamics with acceleration should be considered negative.

3. The formation and analysis of configurations of dynamic competitiveness assessment indicators can be used for an analytical interpretation of combinations of rising and falling indices of the indicators under study in different sequences, which will contribute to the objectification of differentiated assessment judgements and the adoption of adequate decisions (Table 3). A variety of configurations of dynamic assessment indicators arises in the absence of a trend in the change in their values (forecast or unforecast). The principles for evaluating these configurations are the greater significance of the next indicator compared to the previous one and the priority of the number of unidirectional indicator values over their sequence.

Table 3. Estimated threat level characteristics for different configuration options of the studied dynamic indicator with a target growth criterion (chain index) for a 3-year retrospective period

Period 1	Periods 1, 2	Periods 1, 2, 3	Risk level
$\uparrow_1$	$\uparrow_1; \uparrow_2$	$\uparrow_1; \uparrow_2; \uparrow_3$	No risk
		$\uparrow_1; \uparrow_2; \downarrow_3$	Level 3 risk
	$\uparrow_1; \downarrow_2$	$\uparrow_1; \downarrow_2; \uparrow_3$	Level 2 risk
		$\uparrow_1; \downarrow_2; \downarrow_3$	Level 6 risk
$\downarrow_1$	$\downarrow_1; \uparrow_2$	$\downarrow_1; \uparrow_2; \uparrow_3$	Level 1 risk
		$\downarrow_1; \uparrow_2; \downarrow_3$	Level 5 risk
	$\downarrow_1; \downarrow_2$	$\downarrow_1; \downarrow_2; \uparrow_3$	Level 4 risk
		$\downarrow_1; \downarrow_2; \downarrow_3$	Threat

Note: ↑ – increasing indicator; ↓ – reducing

Source: compiled by the author

There is no risk when the indicator shows an upward trend throughout all periods studied; the highest level of risk is observed when there is a systematic downward trend and is classified as dangerous. When the trend is mixed, the level of risk is presented in a differentiated manner in accordance with the specified criteria. Risks of levels 1-3 should be considered acceptable, while risks of levels 4-6 require a response from management, which is determined based on the capabilities and development strategies of each enterprise.

Approval of methodological tools for analysing the comprehensive competitiveness of enterprises in static and dynamic formats

A comprehensive analysis of the status components of competitiveness of the studied enterprises in a sectoral format is based on the calculation of their values (Table 4), presented in a differentiated dimension, which form the configuration of the components of the competitiveness complex of each market entity (Table 5).

Table 4. Sectoral and status indicators of competitiveness
of Ukrainian manufacturers of dry construction mixtures for 2024

Indicators	Enterprises					
	Henkel Bautechnik LLC	Kreisel-Building Materials LLC	PJSC Terminal-M	Fomalgaut-Polimin LLC	Askona-Pivden LLC	Baumit Ukraine LLC
Commodity competitiveness, *Ct*						
▪ realised, *Ctr*	2.52	0.86	0.75	0.72	0.59	0.57
▪ functional, *Ctf*	0.88	0.80	1.08	1.05	1.10	1.10
▪ potential, *Ctp*	2.31	1.38	0.35	0.86	-	0.11
Personnel competitiveness, *Pc*						
▪ realised, *Pcr*	2.66	2.01	0.65	0.39	0.21	0.09
▪ functional, *Pcf*	1.36	1.31	0.89	0.76	0.65	1.02
▪ potential, *Pcp*	2.32	1.67	0.25	0.73	-	0.03
Competitiveness investment, *Ci*						
▪ realised, *Cir*	3.06	0.28	0.21	0.42	1.52	0.50
▪ functional, *Cif*	1.25	1.23	0.74	1.10	-	0.68
▪ potential, *Cip*	3.26	1.14	0.11	0.45	-	0.04

Note: enterprise competitiveness calculated by the author based on the developed methodological tools
Source: compiled by the author based on Askona-Pivden LLC (n.d.), Baumit Ukraine LLC (n.d.), Fomalgaut-Polimin LLC (n.d.), Henkel Bautechnik LLC (Ukraine) (n.d.), Kreisel-Building Materials LLC (n.d.), PJSC Terminal-M (n.d.), YouControl (n.d.)

Table 5. Configurations of sectoral and status indicators
of the competitiveness complex of Ukrainian manufacturers of dry building mixtures for 2024

Enterprises	Configurations of competitiveness component values
Henkel Bautechnik LLC	$Ctr^h\ Ctf^l\ Ctp^h;\ Pcr^h\ Pcf^h\ Pcp^h;\ Cir^h\ Cif^h\ Cip^h$
Kreisel-Building Materials LLC	$Ctr^l\ Ctf^l\ Ctp^h;\ Pcr^h\ Pcf^h\ Pcp^h;\ Cir^l\ Cif^h\ Cip^h$
Fomalgaut-Polimin LLC	$Ctr^l\ Ctf^h\ Ctp^l;\ Pcr^l\ Pcf^l\ Pcp^l;\ Cir^l\ Cif^h\ Cip^l$
PJSC Terminal-M Askona-Pivden LLC Baumit Ukraine LLC	$Ctr^l\ Ctf^h\ Ctp^l;\ Pcr^l\ Pcf^l\ Pcp^l;\ Cir^h\ Cif^h\ Cip^l$

Source: compiled by the author based on Table 4 with the corresponding designation of configuration elements differentiated by levels: *h* – high; *l* – low

The configured values of the competitiveness complex components are used as an information base for characterising the state of competitive activity of enterprises in the main markets. Henkel Bautechnik LLC (Ukraine) has high relative indicators of marketing results, functionality and potential, which indicates the company's effective competitive policy. The only exception is the low level of marketing functionality in the commodity market. The reason for this is the leading position in the Ukrainian market for dry building materials mixtures and the justified use of relatively high prices for its products, which is a consequence of signs of partial monopolisation. At the same time, to maintain its competitive position, the company maintains high competitiveness in the labour and investment markets, which indicates an awareness of the importance of retaining productive personnel and attracting new investments. The opposite situation is observed in PJSC Terminal-M, Askona-Pivden LLC, and Baumit Ukraine LLC. Among the indicators of competitiveness, only the marketing function in the commodity market is distinguished by a high value.

Applied analysis of the dynamics of realised competitiveness of enterprises

An applied analysis of the dynamics of competitiveness indicators for the studied manufacturers of dry building material mixtures in Ukraine showed no evidence of their projected dynamics, especially in terms of significant acceleration. This is due to the high level of dependence of competitiveness indicators, which are relative in nature, on the significant influence of competitors' activities. As for the dynamics of the basic indicators for calculating competitiveness – marketing results, functionality and potential – their dynamics are less differentiated, but also have less analytical significance when studying changes in the competitive position of enterprises, which should have a relative assessment level. Meaningful analytical conclusions regarding the dynamics of competitiveness indicators can be obtained by comparing the indices of their annual changes, both for individual competitive markets and using a comprehensive approach. The analysis of the dynamics of the realised competitiveness of enterprises in the commodity market (Table 6) in the format of configurations of the composition of change indices – growth ↑ / decline ↓ (Table 7) is notable.

Table 6. Indices of realised commodity competitiveness of Ukrainian manufacturers of dry construction mixtures for 2024

Years	Enterprises					
	Henkel Bautechnik LLC	Kreisel-Building Materials LLC	PJSC Terminal-M	Fomalgaut-Polimin LLC	Askona-Pivden LLC	Baumit Ukraine LLC
2022	1.14	0.89	1.01	0.80	0.88	0.98
2023	0.99	1.05	1.12	0.99	0.79	1.02
2024	1.12	1.04	0.99	0.98	1.03	0.86
Average index value	1.08	0.99	1.04	0.92	0.90	0.95

Source: compiled by the author based on Askona-Pivden LLC (n.d.), Baumit Ukraine LLC (n.d.), Fomalgaut-Polimin LLC (n.d.), Henkel Bautechnik LLC (Ukraine) (n.d.), Kreisel-Building Materials LLC (n.d.), PJSC Terminal-M (n.d.), YouControl (n.d.)

Table 7. Configurations of indices of realised product competitiveness of Ukrainian manufacturers of dry construction mixtures and their assessment for 2024

Enterprises	Configutation of indices levels	Risk level
Henkel Bautechnik LLC	$\uparrow_1; \downarrow_2; \uparrow_3$	Level 2 risk
Kreisel-Building Materials LLC	$\downarrow_1; \uparrow_2; \uparrow_3$	Level 1 risk
PJSC Terminal-M	$\uparrow_1; \uparrow_2; \downarrow_3$	Level 3 risk
Fomalgaut-Polimin LLC	$\downarrow_1; \downarrow_2; \downarrow_3$	Threat
Askona-Pivden LLC	$\downarrow_1; \downarrow_2; \uparrow_3$	Level 4 risk
Baumit Ukraine LLC	$\downarrow_1; \uparrow_2; \downarrow_3$	Level 5 risk

Source: compiled by the author based on Table 6

The results of the analysis showed a predominantly positive trend in the realised product competitiveness of Henkel Bautechnik LLC (Ukraine), Kreisel-Building Materials LLC and PJSC Terminal-M and, accordingly, a low level of threat to their competitive position in the market. It is worth noting the further growth of the already high level of product competitiveness of Henkel Bautechnik LLC (Ukraine), which serves as an indicator of the emergence of signs of monopolisation of the dry construction mixtures market in Ukraine. Fomalgaut-Polimin LLC is most at risk, as it has a systematic decline in competitiveness at a relatively low baseline level. In addition, this company shows an average annual decline in product competitiveness of 8%, which indicates a negative outlook for overcoming its difficult competitive position.

The hypothesis of balance between the components of competitiveness and its analytical verification

Management balancing of competitiveness is a certain target ratio between the realised competitiveness of enterprises in key competitive markets and the realised and potential competitiveness in individual markets, which should contribute to permanent profit growth and the achievement of competitive development goals of enterprises. There is a certain contradiction between these goals due to the need to combine the interests of sustainable profit growth and the implementation of tasks that balance current marketing results with their potential and form the basis for the promising competitive development of enterprises.

Balancing competitive advantage in the commodity, labour, and investment markets is subordinate to the goal of increasing corporate profits through the rational use of competitive marketing potential. A sign of such balance is the equality of sectoral competitiveness of enterprises, which indicates a balanced distribution of funds and efforts to gain control over the objects of competition in the commodity, labour, and investment markets. It is worth noting that the quantitative balance of the realised sectoral competitiveness of enterprises is a target benchmark, which in real conditions can take the form of managerial balance, which takes into account the dynamics of the current competitiveness priorities of individual enterprises in each market.

The balance between the realised and potential competitiveness of enterprises in competitive markets is primarily managerial in nature and is subordinate to the task of ensuring the necessary dynamics of realised competitiveness to achieve its sectoral balance. This does not have fixed structural criteria. It is subordinated to the goal of achieving equality in the values of realised competitiveness in its segmental types by means of marketing functionality, taking into account the peculiarities of the procedure for forming the marketing results of enterprises' activities in these markets. The correctness of the assumptions made and the validity of the general hypothesis regarding the feasibility of forming a marketing complex of enterprise competitiveness based on the balance of its components requires applied verification. The primary object of such analysis is the level of dependence of the dynamics of enterprises' profits on the balance of their realised sectoral competitiveness.

An attempt to prove a significant dependence of the profit growth of the studied enterprises on the balance of their realised sectoral competitiveness in 2024 did not provide a fully correct result (Table 8). Their correlation coefficient is R_1 $(\sigma_{24} / In_{24}) = -0.323$. The existence of an inverse relationship between the profit index and the standard deviation of competitiveness indicators is a logical, practical consequence of the hypothesis justified above. However, the degree of this relationship is low. At $R = 0.323$, the coefficient of determination $D(R^2) = 0.104$. This means that the growth in profit for the year of only 10.4% depended on the level of balance of the studied competitiveness indicators. The reason for this was the objective dynamics of the profit indicator for 2024. Only in Fomalgaut-Polimin LLC did the profit index equal 68.6, which was a consequence of the low base value of the indicator in 2023.

Table 8. Indicators of profit dynamics and variations in the balance of realised sectoral competitiveness of Ukrainian dry construction mix manufacturers for 2021-2024

Indicators	Enterprises					
	Henkel Bautechnik LLC	Kreisel-Building Materials LLC	PJSC Terminal-M	Fomalgaut-Polimin LLC	Askona-Pivden LLC	Baumit Ukraine LLC
Variation in competitiveness for 2024, σ_{24}	0.229	0.670	0.235	0.187	0.550	0.212
Annual profit index for 2024, In_{24}	0.97	1.31	1.23	68.6	-	0.65
Average variation in competitiveness for 2021-2024, $\sigma_{21\text{-}24}$	0.318	0.270	0.338	0.197	0.670	0.302
Average net profit index for 2021-2024, $In_{21\text{-}24}$	1.15	1.18	1.12	1.32	1.08	1.18

Source: compiled by the author based on Askona-Pivden LLC (n.d.), Baumit Ukraine LLC (n.d.), Fomalgaut-Polimin LLC (n.d.), Henkel Bautechnik LLC (Ukraine) (n.d.), Kreisel-Building Materials LLC (n.d.), PJSC Terminal-M (n.d.), YouControl (n.d.)

In further calculations, the average annual values of the standard deviation of competitiveness and the profit index for 3 years were used, which was used to average their annual deviations. The result was more significant – R_2 $(\sigma_{21\text{-}24} / In_{21\text{-}24}) = -0.766$; $D(R^2) = 0.587$, which indicates a significant impact of the balance of realised sectoral competitiveness on the profit dynamics of the studied manufacturers of dry building mixtures in Ukraine. The balance of realised and potential competitiveness has no direct impact on profit dynamics. A certain imbalance is not a negative sign, as it indicates the functional activity of the enterprise in improving its marketing results through its existing potential. At the same time, when achieving a realised sectoral balance, a significant imbalance between realised and potential competitiveness in individual markets is not advisable, as it may disrupt sectoral balance. Table 9 presents the results of the analysis of the relationship between realised sectoral competitiveness and the balance between realised and potential competitiveness in individual markets.

Table 9. The relationship between the balance of realised sectoral competitiveness and the balance of realised and potential competitiveness of Ukrainian dry construction mix manufacturers for 2021-2024

Enterprises	Enterprise rating				
	by the balance of sectoral competitiveness achieved	The difference between the rating of realised and potential			Average difference
		commodity competition	labour competition	investment competition	
Fomalgaut-Polimin LLC	1	1	1	1	1.0
Kreisel-Building Materials LLC	2	0	0	3	1.0
Henkel Bautechnik LLC	3	0	0	0	0
Baumit Ukraine LLC	4	1	1	2	1.3
PJSC Terminal-M	5	1	1	2	1.3
Askona-Pivden LLC	6	1	1	4	2.0

Source: compiled by the author based on Table 4

The results of the analysis showed a direct correlation between the balance of realised and potential competitiveness and the overall balance of realised sectoral competitiveness of Ukrainian manufacturers of dry building mixtures, which has a significant impact on the positive profit dynamics of these companies. The approach proposed in this work is based on a recognition of the marketing nature of competitiveness, which is manifested in the commonality of the target orientation towards satisfying consumer needs (marketing result) and satisfying the needs of enterprises for resources to restore the production process (marketing potential). This significantly expands the scope of analytical assessment of the competitiveness of enterprises and makes it possible to study the effect of a greater number of factors on the growth of competitive opportunities for participants in competitive markets (Shapurova, 2018).

The article presents and analytically confirms the validity of the hypothesis regarding the economic feasibility of balancing the components of competitiveness, which contributes to positive dynamics of enterprise profits. This can be used for informed decisions regarding the priority dynamics of the realised, functional, and potential competitiveness of enterprises in the competitive markets under study, accounting for structural priorities. However, this balance is a target benchmark for the development of enterprise competitiveness, and in their practical activities, situations will inevitably arise when this balance will be of a managerial nature. This means that under certain external circumstances and current development goals, the quantitative ratio of individual types of competitiveness may be in a justified temporary imbalance. Such situations are mainly individual in nature, given the peculiarities of the competitive position and the specifics of the activities of a particular enterprise. The key question is whether it is feasible and, more notably, possible to develop methodological tools for determining the justified limits and duration of the imbalance between individual types of competitiveness. If the imbalance between actual and potential competitiveness is considered permanently justified, as it indicates a targeted adjustment of the marketing result, then a significant deviation in the indicators of actual competitiveness in individual markets may indicate insufficient resources and a loss of part of the financial result. This controversial issue requires further theoretical study and applied analytical assessment of the process of forming the results of the competitive activity of market participants.

The idea of balancing the system of performance indicators (BSC) was developed by R.S. Kaplan & D.P. Norton (1996). It is based on the implementation of cause-and-effect relationships between the strategic goals of enterprises, business units, their individual divisions, and the factors for achieving them based on the interests of employees, customers, and shareholders. It is a tool for implementing strategy at the operational level through a combination of tasks for the development of tangible and intangible assets of enterprises. The article proves the expediency of balancing the components of the competitiveness complex of enterprises, pursuing a less global goal of ensuring the current ratio between the levels of individual types of competitiveness, which contributes to the growing dynamics of profit. Incidentally, it should be noted that the separation of sectoral and status components of competitiveness as objects of balancing corresponds to the author's understanding of the meaning of competitiveness. In this regard, O.S. Shumilo *et al*. (2020) and K. Lukiewska & M. Juchniewicz (2021) noted that the existing variability in the interpretation of competitiveness, its components, indicators, and assessment methods depends on the interpretation of various economic theories that form the basis for understanding the essence and forms of competitive relations in the market.

The task of balancing competitiveness also involved resolving the contradiction between the marketing goals of satisfying consumer needs and the economic benefits that companies derive from this. According to A. Chikán *et al*. (2022), corporate competitiveness is the ability to consistently fulfil dual purpose: satisfying customer demand while making a profit. This corresponds to the content of the marketing concept in its applied format and is reflected in the defined status types of competitiveness – realised and potential. Their balance can be used to optimise the relationship between financing the growth of consumer demand and accumulating financial resources for the further competitive development of enterprises.

Building competitive development potential is a must for balanced business growth. This issue was addressed by researcher R. Yuleva-Chuchulayna (2025) in an analysis of the factors shaping the competitive development potential of players in a "saturated market". This circumstance was used to explore the difficulties of maintaining and increasing the achieved level of competitiveness of enterprises in conditions of intense competition. It is worth noting that the object of analysis was the finished products market, while competitive potential is also formed in other competitive markets, and its realisation is reflected in the competitiveness achieved in the commodity, labour and investment markets.

S. Afdallash & R. Trisnawati (2023) highlighted a notable direction for the balanced development of enterprises, combining the dynamics of financial indicators with the satisfaction of customer needs and the prospect of training and personal development of enterprise employees. The need to ensure consistency between the financial and non-financial components of enterprise development based on the concept of a balanced scorecard was also emphasised by C. Van Thuong & H. Singh (2023). In the context of the identified components of competitiveness, this balance is reflected in the dynamics of potential competitiveness in the commodity market, characterised by effective financial indicators, and the functionality of human resource competitiveness, which depends on the need to increase labour productivity based on the growth of employee qualifications and wage levels.

The balance of competitiveness must be future-oriented and consistent with the goal of sustainable competitive development of enterprises. It is worth noting that this refers not only to the need to ensure balance in the strategic period, but also to the formation of a regime for achieving it. Y. Zhang & H. Liu (2024) initiated the idea of maintaining a strategic rhythm in achieving enterprise development goals, the practical implementation of which is based on such dynamic characteristics as the speed and variability of strategic actions over time. The authors identified the conditions for developing strategic rhythm parameters in the following configurations: low speed – low variability, high speed – low variability, low speed – high variability, high speed – high variability, and analysed the reasons for the formation of strategic rhythm from the perspective of three groups of factors: managers, internal characteristics of the enterprise, and the external environment. This formed a research model of the relationship between strategic rhythm and the formation and preservation of a complex of competitive advantages of enterprises. The idea of forming a strategic rhythm has prospects for use in achieving a balance of competitiveness, and this mode should be differentiated, incorporating the achieved levels of competitiveness of the enterprise in the markets under study and the criterion of target balance of all components of this complex.

CONCLUSIONS

The development of methodological tools for analytical assessment of the interaction of components of the marketing complex of enterprise competitiveness was based on an understanding of competitiveness as the differentiated ability of competitive market entities to gain control over objects of competition. The acquisition of the object of competition occurs in a certain cyclical sequence, which is manifested in the combination of status characteristics of competitiveness – marketing results, potential and functionality, which are in constant interaction in competitive markets – commodity, labour and investment – where enterprises act as sellers of finished products and buyers of necessary resources. This forms commodity, personnel and investment competitiveness in realised, functional and potential formats. The diversity of types of competitiveness, the quantitative measurement of which involves the use of static and dynamic indicators, requires the development of special analytical tools suitable for obtaining the conclusions necessary to determine the appropriate actions.

The developed competitiveness analysis tool combines the use of matrix analysis with the consistent accumulation of competitiveness assessment indicators and a comprehensive methodological approach to assessing the dynamics of indicators, determining their direction and nature of change (accelerated, slowed down, predicted). The results of this analysis formed configurations of differentiated values of the studied sectoral and status components of the competitiveness complex, suitable for meaningful comprehensive assessment and use in the practical activities of enterprises. The study analytically proved that the achievement of managerial balance of competitiveness levels in sectoral markets ensured the growing dynamics of enterprise profits through marketing functional influence on marketing results and potential. The determination index $D(R^2) = 0.587$, which indisputably indicates a significant impact of the balance of realised sectoral competitiveness on the profit dynamics of the studied enterprises producing dry building mixtures in Ukraine.

The analysis of the balance between the status indicators of actual and potential competitiveness in each competitive market confirmed its connection with the level of balance between sectoral components and proved the validity of the assumption about the interaction of these components with a focus on economically feasible comprehensive balance of actual competitiveness indicators. A promising direction for implementing the task of balancing the competitiveness complex of enterprises is to determine the mode of its achievement based on the concept of strategic rhythm. A problematic issue in the use of the proposed toolkit for assessing the marketing competitiveness of enterprises and balancing the components of this competitiveness is the processing of large amounts of numerical information and grouping it for qualitative analytical interpretation. A promising direction for solving this problem is the use of IT programmes, possibly with the use of data analytics technologies.

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REFERENCES

[1] Afdallash, S., & Trisnawati, R. (2023). Balanced scorecard and company performance. *American Journal of Economic and Management Business*, 2(7), 259-271. doi: 10.58631/ajemb.v2i7.49.

[2] Askona-Pivden LLC. (n.d.). *Catalogue*. Retrieved from https://anserglob.ua/ua/catalog/.

[3] Baumit Ukraine LLC. (n.d.). *Price*s. Retrieved from https://baumit.ua/files/ua/quicklink/2025/Price_Baumit_March25.pdf.

[4] Chikán, A., Czakó, E., Kiss-Dobronyi, B., & Losonci, D. (2022). Firm competitiveness: A general model and a manufacturing application. *International Journal of Production Economics*, 243, article number 108316. doi: 10.1016/j.ijpe.2021.108316.

[5] Datsenko, H., Koceruba, N., Krupelnytska, I., Kudirko, O., Lobacheva, I., & Otcalenko, O. (2022). Analytical toolkit for strengthening enterprise competitiveness in unstable economic conditions. *Financial and Credit Activity Problems of Theory and Practice*, 3(44), 216-223. doi: 10.55643/fcaptp.3.44.2022.3785.

[6] Fomalgaut-Polimin LLC. (n.d.). *Price*s. Retrieved from https://polimin.ua/wp-content/uploads/2024/04/PRAJS-Obiektnyj_RRTs_01.04.2024.pdf.

[7] Henkel Bautechnik LLC (Ukraine). (n.d.). *Catalogue*. Retrieved from https://www.ceresit.ua/catalog/vnutrisne-ozdoblennja.html.

[8] Herasymova, V.O., & Rezanov, E.O. (2020). Enterprise competitiveness: Essence and influencing factors in modern conditions. *Economic Space*, 154, 93-97. doi: 10.32782/2224-6282/154-17.

[9] Kaplan, R.S., & Norton, D.P. (1996). *The balanced scorecard: Translating strategy into action*. Boston: Harvard Business School Press.

[10] Kovtun, O.I. (2021). Assessment of the competitiveness of domestic enterprises of the agro-food sector in the context of strategy formation for their entry and activity in foreign markets. *Visnyk of Lviv University of Trade and Economics. Economic Sciences*, 63, 42-51. doi: 10.36477/2522-1205-2021-63-07.

[11] Kreisel-Building Materials LLC. (n.d.). Retrieved from https://cdnxit-holding.com/assets/api/914c5c56-91f5-4568-a591-a907f99eb554/original.

[12] Lukiewska, K., & Juchniewicz, M. (2021). Identification of the relationships between competitive potential and competitive position of the food industry in the European Union. *Sustainability*, 13(8), article number 4160. doi: 10.3390/su13084160.

[13] Melnyk, S. (2025a). Methodological framework for comprehensive assessment of enterprises' competitiveness. *Business Navigator*, 2(79), 198-204. doi: 10.32782/business-navigator.79-32.

[14] Melnyk, S. (2025b). Systematization and analysis of enterprise competitiveness assessment versions. *Strategy of Economic Development of Ukraine*, 56, 55-73. doi: 10.33111/sedu.2025.56.055.073.

[15] Panchenko, V., Biletska, I., Basii, N., Kogut, M., Vasyltsiv, T., & Mulska, O. (2024). Competitiveness vs financial-resource capabilities of business: Innovative marketing strategies. *Financial and Credit Activity Problems of Theory and Practice*, 2(55), 502-518. doi: 10.55643/fcaptp.2.55.2024.4351.

[16] PJSC Terminal-M. (n.d.). *Siltek catalogue*. Retrieved from https://siltek.ua/wp-content/uploads/2023/01/Siltek_catalogue_2022.pdf.

[17] Radko, V., & Matsiura, S. (2023). Methodological toolkit for evaluating enterprise competitiveness. *Scientific Innovations and Advanced Technologies*, 14(28), 759-767. doi: 10.52058/2786-5274-2023-14(28)-759-767.

[18] Samofalova, M., Horpynchenko, O., Molnar, O., Dorosh-Kizym, M., & Lytvyn, O. (2024). Financial provision of marketing activities of machine-building enterprises for strengthening competitiveness in the context of a new reality. *Financial and Credit Activity Problems of Theory and Practice*, 5(58), 264-276. doi: 10.55643/fcaptp.5.58.2024.4555.

[19] Shapurova, O.O. (2018). Methods of estimation of competitiveness of industrial enterprises. *Scientific Bulletin of Kherson State University. Series "Economic Sciences"*, 31, 152-155.

[20] Shumilo, O.S., Rudas, D.S., & Sukulsky, V.M. (2020) The principles and methods for assessing the competitiveness of enterprises. *Business Inform*, 6, 291-297. doi: 10.32983/2222-4459-2020-6-291-297.

[21] Sukhanova, A. (2021). Methodical approaches to assessing the competitiveness of the enterprise. *Economy and Society*, 26. doi: 10.32782/2524-0072/2021-26-62.

[22] Van Thuong, C., & Singh, H. (2023). The impact of a Balanced Scorecard on enterprise performance in Ho Chi Minh City. *International Journal of Organizational Leadership*, 12, 198-215. doi: 10.33844/ijol.2023.60359.

[23] Vynogradova, O., Asan, A., & Charna, O. (2021). Enterprise competitiveness as an economic category. *Economy. Management. Business*, 3(37), 4-11. doi: 10.31673/2415-8089.2021.030101.

[24] Yevtushenko, N.O., & Varnitskyi, V.V. (2021). Competitiveness of the enterprise: The concept, approaches and methods of evaluation. *Economy. Management. Business*, 3(37), 12-17. doi: 10.31673/2415-8089.2021.030202.

[25] YouControl. (n.d.). Retrieved from https://youcontrol.com.ua/.

[26] Yuleva-Chuchulayna, R. (2025). Formation of competitive advantages and competitiveness through the competitive potential of enterprises. *Journal "Pirinski Knizhovni Listi"*, 16, 98-111. doi: 10.5281/zenodo.14879220.

[27] Zhang, Y., & Liu, H. (2024). Enterprise strategic rhythm and competitive advantage. *Frontiers in Humanities and Social Sciences*, 4(2), 141-146. doi: 10.54691/y4k5x839.

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Аналітичне оцінювання взаємодії компонент маркетингового комплексу конкурентоспроможності підприємств

Анотація. Мета дослідження полягала у розробленні теоретико-методичних основ аналітичного оцінювання комплексної конкурентоспроможності підприємств та взаємодії її маркетингових компонент, що має сприяти прийняттю обґрунтованих рішень на конкурентних ринках діяльності. Представлено авторське бачення змісту конкурентоспроможності з позицій маркетингового підходу до формування конкурентного результату, функціоналу і потенціалу діяльності підприємств на основних конкурентних ринках, що ґрунтується на визнанні предмету конкуренції цільовим орієнтиром суперництва між конкурентами. Об'єктами аналізу було обрано секторальні і статусні компоненти комплексу – реалізована, функціональна і потенційна конкурентоспроможність на товарному, кадровому та інвестиційному ринках. Запропоновано методичний інструментарій аналітичного оцінювання маркетингового комплексу конкурентоспроможності підприємств, що включає у себе: метод матричного аналізу з послідовним нарощуванням оціночних показників конкурентоспроможності; аналіз динаміки показників з визначенням її напряму і характеру змін (прискореного, уповільненого, прогнозованого); аналіз конфігурацій диференційованих значень з використанням статичних та динамічних показників. Обґрунтовано гіпотезу щодо необхідності досягнення збалансування рівнів конкурентоспроможності на секторальних ринках, яке має забезпечити зростаючу динаміку прибутку підприємств засобами маркетингового функціонального впливу на маркетинговий результат і потенціал. Здійснено прикладну апробацію розробленого аналітичного інструментарію оцінювання комплексної конкурентоспроможності. Розрахунково підтверджена економічна доцільність збалансування компонент комплексу конкурентоспроможності підприємств – коефіцієнт детермінації, між динамікою прибутку досліджуваних підприємств з виробництва сухих будівельних сумішей і рівнем збалансування реалізованої секторальної конкурентоспроможності дорівнював 0,587, що відповідає високому рівню їх кореляційної залежності. Практична цінність дослідження полягає у розробленні методичного інструментарію аналізу комплексу конкурентоспроможності у контексті збалансування його компонент, що надає можливість аналітичним службам підприємств отримати інформацію, необхідну для обґрунтування завдань конкурентного розвитку

Ключові слова: предмет конкуренції; види конкурентоспроможності; показники конкурентоспроможності; збалансованість показників; інструментарій аналізу конкурентоспроможності; маркетинговий результат; потенціал і функціонал

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Growth hacking as a driver of innovative development of start-ups: Between marketing and product

Abstract. The aim of this study was to determine how tools of high-speed experimentation and data analysis can strengthen the innovative development of start-ups and increase the effectiveness of aligning marketing and product decisions. The methodology was based on a theoretical-empirical approach and included the systematisation of academic sources, the analysis of digital platforms, the comparison of technology companies and the study of practical cases that reflected the use of experimentation, recommendation models and optimisation of user experience. The results established that models with an emphasis on the product as the main growth tool ensured higher financial performance: companies that applied a product-led growth approach demonstrated an average annual increase in Annual Recurring Revenue of 35%, whereas companies with traditional approaches achieved only 26%, and customer acquisition costs in product-oriented businesses were 39% lower. The significance of experimentation cycles was confirmed by the high intensity of tests: the company Nebula conducted 612 experiments in 2024, which helped to increase conversions on average by 4-7%. Optimisation of user experience, researched on the example of Duolingo, provided an increase in user retention of 15-25%, while speeding up the process of first use of the product increased user activation by 10-30%. The most powerful viral mechanism proved to be recommendation models: the example of Dropbox demonstrated growth of 3,900%, and the number of users increased from 100 thousand to more than 4 million, which confirmed the effectiveness of viral dissemination cycles. The practical significance of this study lies in the fact that its results can be used by start-ups to build effective growth mechanisms, optimise product-marketing decisions and increase the effectiveness of experimentation

Keywords: rapid experiments; optimisation; viral mechanisms; scaling; business; conversion

INTRODUCTION

The rapid growth of the digital economy and the intensification of competition in the market for technology projects require start-ups to apply new approaches to product development and user strategies. Traditional marketing tools and linear product planning models are increasingly less likely to provide the desired results, especially at early stages, when speed, flexibility, and resource efficiency are critically important. This is precisely why the need is growing for approaches that combine work between marketing and product and provide dynamic hypothesis testing, risk minimisation and acceleration of development cycles.

Digital transformations show that enterprises face difficulties in choosing effective tools for rapid growth and increasing competitiveness, especially when traditional marketing approaches do not provide adequate development dynamics. In this context, the attention of researchers is drawn to the concept of growth hacking, which was considered by A. Yakivchenko (2025), who emphasised its ability to combine analytics, experiments, User Experience (UX) optimisation, gamification and digital automation to form innovative models of enterprise development. The author stressed that the use of data-driven solutions, A/B testing, behavioural analytics and viral mechanisms enables companies to scale the client base quickly, reduce acquisition costs and increase the effectiveness of strategic marketing in industry. Crisis economic conditions strengthen the need

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to search for effective approaches capable of ensuring the recovery and sustainable development of entrepreneurial initiatives. This issue was examined in the study by T. Zinchuk (2024), where the author analysed the factors that determine the dynamics of innovative entrepreneurship and outlined the key drivers of its strengthening. The results of the work highlighted the importance of financial support, institutional change, infrastructure modernisation and the development of an innovation culture as preconditions for the formation of a favourable environment capable of activating innovative initiatives and creating additional opportunities for the country's economic growth.

The growing uncertainty and intensification of market challenges complicate the choice of effective approaches to enterprise management, which increases interest in tools capable of ensuring organisational resilience and adaptability. This issue was considered by N. Rud (2021), who analysed innovative management methods in conditions of digital transformation and outlined the key factors influencing the effectiveness of managerial decisions. In N. Rud's work, the author emphasised the importance of modernising managerial approaches, integrating digital technologies, improving the quality of human resources and strategic flexibility of enterprises, which contributes to the creation of favourable conditions for development and reduces the impact of external risks. At the same time, V. Prokhorova & V. Chobitok (2023) analysed the strategic foundations of start-up development in an innovative environment and identified factors that influence the viability and market resilience. The authors emphasised that the creation of innovation infrastructure, the improvement of organisational mechanisms of interaction and investment support are key conditions for the successful transformation of start-ups and the entry into advanced technology markets. N. Mykytyuk & A. Chaykovsky (2025) focused on the role of creative management and defined it as a key driver of innovation in a company's marketing approaches, especially under conditions of active use of social networks. In the work, the authors showed that integrating creative ideas into digital communication channels makes it possible to create unique marketing campaigns and promotional tools that can adapt rapidly to dynamic changes and form a sustainable innovation effect in interaction with the audience.

The intensification of competition in the digital environment and the growth of consumer demands for speed, convenience, and personalisation of interaction stimulate the need to search for approaches that allow enterprises to develop effective marketing strategies and maintain stable development dynamics. This issue was examined by A. Tkachenko & D. Voronin (2024), who analysed digital tools and methods that determine the effectiveness of modern marketing. The authors showed that the use of internet marketing makes it possible to identify target segments, assess competitiveness and form an evaluation of strengths and weaknesses through the use of analytical methods, including Strengths, Weaknesses, Opportunities, Threats (SWOT) analysis, audience segmentation and competitive content analysis. At the same time, O. Dmytrieva (2022) drew attention to the growing role of innovation activity and start-up projects as a driving force for structural change and the modernisation of Ukraine's economic processes. The author summarised the approaches of different researchers to the interpretation of innovative entrepreneurship and showed that it can be considered as an activity aimed at creating new products and technologies, commercialising intellectual property or generating innovative ideas within entrepreneurial structures.

The growing uncertainty of the market environment and the need for enterprises to adapt internal management mechanisms to rapid changes create a demand for tools capable of ensuring stable innovation renewal and increasing the effectiveness of managerial decisions. M. Tymoshenko (2022) analysed the role of innovation as a key factor in the renewal of the economic system and emphasised that innovative development is based on the effective use of scientific achievements, institutional transformations and the high speed of dissemination of new ideas in the economy. The study also focused on the fact that innovation creates a foundation for increasing competitiveness and ensures an effective restructuring of economic processes through the use of scientific and technological achievements, new methods of organisation and economic mechanisms.

The mechanisms of operation of growth teams, product-led approaches, the formation of sustainable growth loops, tools for the implementation and evaluation of innovative solutions, the integration of creative and digital methods, as well as the dynamics of start-up development, the effectiveness of business incubators and the role of the start-up ecosystem in macroeconomic recovery remain insufficiently researched. The aim of this study was to substantiate approaches to the use of high-speed experimentation tools and data in start-ups to strengthen the innovation dynamics and increase the effectiveness of interaction between marketing and product decisions. On the basis of the stated aim, the following research tasks were formulated: to analyse the key tools and mechanisms of growth approaches that influence the processes of user acquisition, activation, and retention in start-ups; to investigate the role of the integration of marketing and product decisions in the formation of innovative development models and to determine the conditions under which such interaction ensures stable growth at early stages of the start-up life cycle.

MATERIALS AND METHODS

This study had a theoretical-empirical character and covered the period 2024-2025. The theoretical block was examined on the basis of the method of systematisation and critical analysis of academic sources, which made it possible to determine the essence of growth hacking, its differences from traditional growth models and to reconstruct the structural components of this concept. Within the framework of the theoretical analysis, the stages of the growth hacking cycle were reconstructed in accordance with the approach of the academic publications of R. Bohnsack & M. Liesner (2019), and the essence of the Acquisition – Activation – Retention – Revenue – Referral (AARRR) metric was also examined. The use of this method made it possible to form an analytical framework for the further study of start-up growth mechanisms.

The role of cross-functional growth teams, experimentation cycles and growth loops (Mahadik *et al.*, 2024) was analysed using content analysis, which made it possible to assess the importance of cross-functional interaction and high-speed iterations in shaping innovation dynamics. To illustrate the effectiveness of viral mechanisms, the case method was applied in the analysis of the DeepL referral programme, which made it possible to show how recommendation incentives ensure growth without additional traffic costs. The dissemination of content via TikTok, YouTube, and Instagram was studied using the method of comparative analysis, taking into account criteria that reflected real differences between platforms: the speed of initial reach, the length of the content life cycle, the intensity of organic scaling and the role of algorithmic recommendations. The use of the marketplaces Rozetka, OLX and Prom.ua to assess the role in accelerating the Acquisition and Activation stages was studied by an analogous method.

The impact of high-speed hypothesis testing on the innovation dynamics of start-ups was analysed by interpreting the results of empirical academic studies by V. Berg *et al*. (2020) and X. Zhang (2022). This approach made it possible to clarify how the frequency of experiments, the low cost of tests and the speed of feedback influenced the ability of start-ups to adapt the product quickly. The next stage was the study of the integration of marketing and product decisions, including Product-led growth (PLG), data-driven management and UX optimisation, carried out using the method of conceptual analysis. In this context, the role of the financial metrics Annual Recurring Revenue and Monthly Recurring Revenue was analysed, as well as the practical example of Nebula on the basis of the online publication by O. Lychak (2025) on the intensity of experimentation as an indicator of growth.

UX optimisation on the example of Duolingo was studied using the case analysis method to determine the impact of behavioural metrics on Retention. The dynamics of A/B testing in 2024-2025 and the example of Preply regarding statistically significant experiments were examined using content analysis in accordance with information from the online publication of Complex Agency (2025), which made it possible to assess the role of an evidence-based approach in product changes. The attribution tools Branch, AppsFlyer and Adjust were analysed using the method of functional comparison to determine the effectiveness in measuring growth channels. Within the final stage of the study, a comparative analysis of the cases of Dropbox, Airbnb and Gmail was carried out according to the criteria of the type of viral trigger, the speed of scaling and the level of user engagement. This made it possible to identify differences in the mechanisms of viral and product growth. Separately, the cases of HubSpot, Notion and Canva were examined using targeted case analysis in order to determine the approaches to product scaling. Additionally, Figma, Discord and Calendly were analysed using comparative analysis according to the criteria of the type of growth strategy, the main mechanism, the factor on which the scaling effect was based and the nature of the scale achieved. This made it possible to identify differences in the growth models in the context of the overall logic of the study.

RESULTS

Conceptual foundations of growth hacking in the context of start-up development

Growth hacking in the innovative environment of start-ups is regarded as an approach aimed at achieving sustainable growth through rapid experimentation, flexible use of data and the combination of marketing, product and technical solutions in a single system. Its essence lies in the fact that company growth is not a side effect of activity or the result of large-scale investment, but becomes the main goal around which all processes are built – from product development to communication with users. At the centre of the approach is the constant search for the most effective growth points, where even small changes can cause a significant effect thanks to the multiplicative impact on behavioural metrics. Growth hacking proceeds from the assumption that every stage of user interaction with the product hides potential for optimisation and therefore makes growth possible through a series of sequential, rapidly tested experiments (Bohnsack & Liesner, 2019). A key element of the essence of growth hacking is the cyclic nature of the process, which is based on the logic shown in Figure 1.

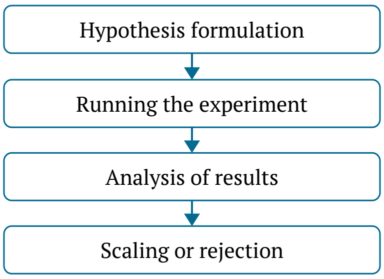

Figure 1. Stages of the growth hacking cycle
Source: compiled by the author based on R. Bohnsack & M. Liesner (2019)

This creates a continuous loop of improvement of the product and marketing techniques. Unlike approaches in which updates are planned in advance and implemented within long cycles, growth hacking presupposes constant readiness for change, a high work tempo and the ability to translate analysis results into practical actions quickly. Such an approach shortens the time between an idea and its verification (from several months to days), which is critically important for start-ups with limited resources and high market uncertainty. The essence of growth hacking is also closely linked to the use of behavioural and product-marketing metrics, which make it possible to evaluate not the overall result but specific elements of user interaction with the product. At the centre of such a system are AARRR metrics, which cover acquisition, activation, retention, monetisation and virality. These metrics make it possible to see the entire user journey as a sequence of points at each of which changes can be tested, the strength of impact analysed and those that can become a source of long-term growth identified. The use of product-behavioural indicators makes the approach as targeted as possible, since decisions are based not on assumptions but on real data (Rizvanović *et al.*, 2023).

Another aspect of the essence of growth hacking is the close integration of cross-functional teams that combine the competences of marketing, product management, analytics, UX design and engineering. Unlike a division of roles in which each team works autonomously, growth teams operate as a single organism aimed at creating rapid innovations. Such teams focus not on extensive plans or large-scale projects, but on micro-solutions that form a cumulative effect. Such an organisation of work strengthens the ability of start-ups to adapt to user feedback, quickly remove barriers and develop solutions that increase product efficiency (Mahadik *et al.*, 2024). An important part of the essence of growth hacking is the construction of self-reinforcing cycles, or so-called growth loops, which create mechanisms for autonomous product growth. A growth loop is not a one-off marketing action, but a structured process in which the result of one user's interaction automatically creates conditions for the emergence of new users or for strengthening the activity of existing ones. In other words, it is a closed loop in which each subsequent cycle becomes stronger thanks to the accumulated effect of previous actions. In such loops, growth ceases to depend on external advertising or financial investment and begins to be generated by the internal logic of the product.

Referral programmes are the most common type of growth loop. The mechanism of operation lies in the fact that the user receives an incentive to share the product with friends or acquaintances – this may be a bonus, a free period of use or another benefit. A striking example is the DeepL referral programme, in which the user receives additional free translations or an increased feature limit after the person the user invited registers on the platform and starts using the service. New users who join via a recommendation, in turn, can repeat this cycle, creating a constant inflow of traffic. The importance of referral growth loops lies in the fact that every new user becomes a "growth agent", and thus scaling takes place naturally rather than through paid channels. Content loops are another type of growth loop, based on the creation of valuable content by users or on the interaction with content. These include reviews, social media posts, user photos or videos, comments and ratings. When content created by users is disseminated externally, it attracts other people who become new users, create the own content and repeat the cycle. The effectiveness of this mechanism depends largely on the characteristics of the platform, primarily on the speed of reach and the potential for organic scaling.

On TikTok, virality is formed by the algorithmic recommendation model of the For You Page, which is capable of showing new videos to thousands of users within the first minutes after publication. This makes TikTok one of the most dynamic platforms in the context of rapid organic growth, where even a small volume of interaction (a few likes or views) can cause swift dissemination of content. On YouTube, the scaling mechanism has a different nature: a video gains reach gradually but maintains a longer life cycle, since the search and recommendation algorithm continues to show it to new audiences over weeks or months. This ensures stable organic growth through the accumulation of views and increases the chances of long-term virality. On Instagram, the speed of reach is determined by the content format: Reels receive the highest potential for organic spread because the platform promotes short videos as a competitor to TikTok, whereas posts and stories provide more limited but targeted access to audiences. Similar mechanisms operate on marketplaces such as Rozetka, OLX and Prom.ua, where organic growth is conditioned by user interaction with products, reviews, and ratings. Recommendation algorithms rank content based on user behaviour – clicks, search queries, viewing time and interactions – which allows popular products and listings to rise rapidly in search results without additional advertising expenditure. As a result, such platforms create conditions for accelerated virality based on a combination of user content, social signals and algorithmic promotion, which significantly increases the pace of organic scaling.

A separate class of growth loops consists of collaborative or joint user actions that amplify the effect of network interaction. For example, in collaboration services or gamified products, inviting colleagues, friends or team members is an integral part of functionality. In such cases, the growth cycle not only generates new users but also increases the value of the product with each new participant, forming a network effect. This makes the product more attractive, as users receive a better experience only when others are involved. The essence of growth loops lies in the fact that such loops create a long-term, reproducible scaling mechanism that does not depend on temporary marketing campaigns. Instead of repeatedly attracting new waves of users through paid advertising, the product itself begins to form an inflow of new users thanks to its internal architecture of interactions. As a result, the start-up achieves a stable growth dynamic that accumulates effect with each new iteration of the loop. This turns growth into a systemic process in which every element of the product is aimed at reproducing and strengthening the previous cycle, giving the product the ability to scale faster, more economically and more sustainably (van Gasteren, 2025).

High-speed hypothesis testing is one of the key elements of the innovation dynamics of start-ups, as it provides the ability of a company to test assumptions about user behaviour, product potential and the effectiveness of individual solutions promptly. In an environment where start-ups operate under conditions of high uncertainty – when market reaction, user needs, monetisation speed and product viability cannot be predicted, and technological trends change too quickly – hypothesis iteration becomes the key foundation of data-driven decision-making. This is typical for technology start-ups at early stages of development, in particular mobile applications, Software as a Service (SaaS) solutions, platforms and Artificial Intelligence products that operate with minimal budgets, a lack of historical analytics and intense competition. Under such conditions, intuitive judgements and long planning cycles are unreliable, whereas short experimental cycles allow ideas to be tested quickly, behavioural data to be obtained and product logic to be adjusted. The essence of this approach lies in the fact that instead of launching large-scale features or costly marketing campaigns, teams create small changes that can be tested over a short period of time and on this basis draw conclusions about further actions. This significantly accelerates the innovation cycle, as each test conducted becomes a source of knowledge that is immediately integrated into the product and influences subsequent decisions (Scheuenstuhl *et al.*, 2021).

A critical consequence of high-speed testing is that it enables start-ups to reduce the risks of erroneous investment. In traditional approaches, teams spend resources on developing major features or conducting large-scale marketing activities before it becomes clear whether such initiatives will actually have an effect. In contrast, rapid hypothesis testing makes it possible to confirm or refute key assumptions at an early stage. If a feature does not deliver the expected result, the start-up avoids significant losses of time and budget; if the experiment shows potential, the team can scale the solution confidently and on a sound basis. Rapid experiments also have a positive impact on the ability of start-ups to respond to market changes. Since each hypothesis is tested over a short period, the company receives up-to-date data on user needs, changes in the behaviour and reactions to new features or mechanics. This provides flexibility and allows the product strategy to be adjusted quickly to new conditions. The dynamic nature of the start-up market presupposes the need for constant product updates, and it is high-speed testing that makes it possible to maintain such a pace without losing quality and without disrupting system integrity (Berg *et al.*, 2020).

The impact of high-speed hypothesis testing on the formation of an innovation culture within the team is particularly notable. Continuous experimentation creates an environment in which mistakes become not failures but sources of knowledge. This approach motivates employees to put forward new ideas boldly, as the risks of testing these ideas are minimal and the lessons valuable. A culture of rapid testing encourages the team to act proactively, seek new growth mechanisms, work on improving functionality and analyse user behaviour from the perspective of constructive experimentation. Ultimately, this increases the overall innovation capacity of the start-up. In addition, rapid hypothesis testing contributes to the creation of effective growth loops – self-reinforcing cycles that ensure product scaling through repeated user actions. Since experiments make it possible to identify quickly the mechanics that have the greatest impact on acquisition, virality or monetisation, start-ups can build systems in which successful actions by one user create conditions for the emergence of new ones. This turns the innovation process from a rare event into a constant, self-renewing mechanism (Zhang, 2022). Overall, high-speed hypothesis testing plays a key role in the development of start-ups, as it ensures accelerated decision-making, increases innovation activity, reduces risks, shapes a flexible culture and creates conditions for stable product growth. It is not merely a method, but a strategy that determines the pace and logic of the development of innovative companies.

Integration of marketing and product decisions as the basis of an innovative growth model

PLG, data-driven management and UX optimisation form the conceptual basis of innovative strategies for start-ups in which the product acts as the main scaling mechanism. Since 2022, around 58% of SaaS companies and technology start-ups have already applied PLG as a key growth model, with 91% of these firms planning to increase investment and 47% intending to double spending in this area (Kluz, 2025). PLG is becoming a basic strategy, especially in the fast-growing DevTools and Cloud Infra segments, where 40-70% of start-ups use this approach already at early stages of development. The effectiveness of PLG is confirmed by financial results: companies with this model show an average annual increase in Annual Recurring Revenue of 35%, whereas non-PLG firms achieve about 26%, reach the USD 100 million Annual Recurring Revenue mark more quickly (in 83% of cases) and spend 39% less on customer acquisition owing to higher levels of activation and retention (SaaS Writing Team, 2025).

The essence of PLG lies in providing value to the user from the first minutes of interaction, which shortens the decision-making cycle and stimulates the organic spread of the product. In this logic, performance is defined by indicators such as Monthly Recurring Revenue, Annual Recurring Revenue, activation rate and retention. In PLG products, the average time-to-value ranges from a few minutes to 1-2 days, and in some cases less than 30 minutes. In traditional sales-led models, this indicator may stretch over weeks or months. It is precisely the ability to bring the user quickly to the “aha moment” that gives PLG companies an advantage in the speed of scaling. It is not accidental that about 40-45% of start-ups that achieve high valuations and investment use PLG already in the first year (SaaS Writing Team, 2025).

A fundamental pillar of PLG is a system of data-driven management based on analytics. In 2025, 60-65% of technology start-ups make business decisions on the basis of data, using key metrics such as activation rate, retention rate, Lifetime Value, Customer Acquisition Cost, Monthly Recurring Revenue, Annual Recurring Revenue, churn and the virality coefficient. Serial testing is actively applied in growth teams: successful start-ups carry out 10-50 experiments per month, and at Nebula this figure in 2024 reached 612 experiments per year. A/B testing provides an average conversion increase of 4-7%, and in some cases up to 20% and more. The regularity and speed of experiments allow start-ups to assess the impact of even small changes and to determine precisely the direction of further optimisations (Lychak, 2025).

The third strategic component of PLG is UX optimisation, which directly affects activation and retention. Data show that reducing the number of steps in onboarding, speeding up loading or simplifying core actions increases the activation rate by 10-30%, and in products such as Duolingo UX improvements increase retention by 15-25% (Raj, 2023; Gangurde, 2025). Loading speed is also critically important: every second of delay reduces conversion by approximately 2.5-3%, whereas speeding up a page by 1 second increases it by 2.7%. Virality within UX mechanisms is also supported by referral programmes, where the average k-factor is 0.1-0.5, which ensures organic user growth even without an exponential effect (Moiseeva, 2025). High-quality UX also has a significant impact on the long-term value of the customer. Optimised onboarding can increase Lifetime Value by 20-30%, as satisfied users have a lower churn rate and more often switch to paid features. An increase in retention of just 5% can raise company profit by 25-95%, which demonstrates the direct link between UX and financial results (Krisko, 2025).

Effective growth of start-ups in the modern, highly competitive environment increasingly depends on the ability to combine marketing and product data into a single analytical system. Traditionally, these two areas operated separately, which created gaps between user acquisition and the subsequent behaviour in the product. In PLG models, this approach is considered outdated, since the user journey is a holistic process in which marketing stimuli directly determine the quality of activation, and the product experience influences the effectiveness of marketing investment. Therefore, the integration of analytical tools capable of synchronising behavioural, product and marketing data becomes critical. One of the key components of such integrated analytics is A/B testing, which has become a standard in 2024-2025: around 77% of companies worldwide regularly conduct A/B experiments on the web platforms. At the same time, launching 1-5 tests per week, typical for flexible technology teams, remains characteristic mainly of strong product-led start-ups. The experience of companies such as Preply shows that such a testing pace ensures a stable flow of data for decision-making, although for most companies it is more an exception than the rule. It is important that only 10-30% of experiments become statistically significant, which is linked to requirements for correct design, sufficient sample size and maintaining a significance level of 93-95%. Despite this, even such a share of "successful" tests provide substantial practical benefits in scaling the product (Complex Agency, 2025).

The second group consists of CDP platforms (Customer Data Platforms), which act as a single centre for storing customer data. CDPs aggregate data from dozens of sources – marketing channels, mobile applications, desktop platforms, Customer Relationship Management (CRM) systems, billing services and email communications. Platforms such as mParticle or RudderStack make it possible to create holistic user profiles and link events occurring in different environments. This provides start-ups with the opportunity to analyse the full life cycle of interaction – from the first advertising click to the formation of recurring revenue (Thorenberg, 2025). Attribution tools occupy a special place, as these tools determine the contribution of each channel to the final conversion. For PLG companies, where part of growth is formed organically or through referral cycles, attribution tools are critically important because these tools make it possible to assess the contribution of each channel to user acquisition and activation. Branch, AppsFlyer and Adjust are used to determine the traffic source, track transitions via referral links and analyse the quality of users coming from different channels. Branch makes it possible to record the effectiveness of referral mechanics and identify which types of invitations work best. AppsFlyer allows comparison of organic and paid channels, measuring the impact on activation, retention, and Lifetime Value. Adjust is used to assess how changes in UX affect conversions across channels, helping to determine where the most valuable users come from. Taken together, these tools provide a comprehensive view of the effectiveness of growth channels. This is particularly relevant given that the average proportion of significant A/B experiments in technology companies is only 10-30% (Complex Agency, 2025). Thus, integrated analytics becomes a key tool in building an effective PLG strategy and provides stable innovative growth of products.

PLG, data-driven management and UX optimisation form a coherent strategic model in which the product becomes the main factor of scaling, and data the key to precise management decisions. Current statistical data indicate that the PLG model is being implemented ever more actively in technology companies, ensuring a faster pace of revenue growth, higher levels of activation and more efficient use of resources. The combination of product and marketing analysis creates an end-to-end system for understanding the user, in which every stage – from acquisition to monetisation – is measured and optimised on the basis of experiments. At the same time, UX optimisation acts as a critical component that directly shapes activation, retention and Lifetime Value, ensuring stability and scalability of the product. As a result, the interaction of these three elements creates a resilient model of innovative growth that allows start-ups to adapt rapidly to market conditions and form competitive advantages.

Assessment of the impact of growth hacking on the innovation dynamics of start-ups

Classical examples of growth hacking in technology companies have formed the foundation of scaling approaches that thousands of start-ups actually use. The most well-known cases – Dropbox, Airbnb, Gmail – show that growth can be based not on large budgets, but on the ability to identify the key points of user interaction and to create self-reinforcing mechanisms. These cases became the basis for the PLG concept, as the cases demonstrated that the product can be not only the final result of development, but also the key channel for acquisition, retention and viral dissemination. One of the most iconic examples is the Dropbox referral programme. The company offered users an additional 500 MB of storage space for each new friend invited. This scheme created a direct incentive to spread the service and turned users into a channel of organic growth. As a result, the user base grew from 100,000 to 4 million, and later to 15 million in just a few months, ensuring 3,900% growth. The key element of this approach was the so-called growth loop: the attracted user generates new users, reinforcing the growth effect (Loukas, 2025).

Another illustrative case is Airbnb, which at an early stage integrated the ability to publish listings simultaneously on Airbnb and Craigslist. Craigslist already had a huge base of active users, and exploiting this resource allowed Airbnb quickly to increase the visibility of its listings among the target audience. This tactic enabled the company to "borrow" traffic from a large platform without advertising costs and to obtain a critical mass of users for accelerated growth. The integration strategy was based on understanding the behaviour of hosts and guests, which made it possible to reduce entry barriers and increase trust in the service. The launch of Gmail also demonstrates the effectiveness of growth hacking through psychological mechanisms. Access to the service was available only by invitation, which created artificial scarcity, heightened the sense of exclusivity and increased the perceived importance of the product. Invitations were sold on eBay, generated information noise and ensured exceptionally high demand even before the full functionality of the service had been formed. Gmail used a principle of behavioural economics: limited access strengthens perceived value for the user. The HubSpot case shows how free value can become a source of scaling. The company created a number of free tools – an SEO analysis service, a website speed test, content generators – which provided real value from the first contact. In return, HubSpot received contact details of potential clients and moved these contacts into its sales funnel. This approach combined content marketing, analytics and product thinking, creating a unique system of organic lead-generation growth (Dois, 2025).

A common feature of all these cases is the identification of "points of maximum impact" – behavioural triggers that determine the product's value for the user. Companies did not invest large budgets in advertising; instead, the companies-built mechanisms in which the user became the driver of scaling. Such examples formed the basis for PLG models, in which the product integrates marketing functions, ensuring sustainable growth, virality and innovativeness. The experience of leading technology companies shows that effective growth hacking strategies are formed on the basis of deep behavioural analytics, optimisation of the product experience and the creation of self-propagating mechanisms. New-generation start-ups demonstrate that scaling can be almost entirely organic if the product is designed as a user acquisition channel. As shown in Table 1, it is precisely the combination of viral features, collaboration, and a low entry threshold that has become the foundation of the exponential growth.

Table 1. Examples of growth hacking strategies in technology companies

Company	Type of growth strategy	Main mechanism	Basis of the effect	Scale result
Notion	Collaboration-driven growth	Public templates, shared documents	Rapid spread through templates and open workflows	20+ million active users
Canva	User-generated virality	Content with watermark	Natural virality through sharing designs on social media	185 million users (2024)
Figma	Product-as-a-network	Real-time collaborative work	Users attract the team through collaboration	Accelerated Scaling, acquired by Adobe for USD 20 billion
Discord	Community-led growth	Servers as separate "ecosystems"	Self-scaling through communities	Transition from gaming focus to mass market
Calendly	Workflow-embedded virality	Sending booking links	Every interaction creates a viral cycle with new users	20 million+ users in 2024

Source: compiled by the author

The examples given show that successful growth hacking strategies are based not on isolated tactics, but on a deep understanding of how the user interacts with the product and what mechanisms can turn this interaction into a self-reinforcing growth cycle. Each of the analysed companies forms its own system of virality, which naturally scales its audience without a proportional increase in marketing expenditure. Notion demonstrates that user-created content can form an entire ecosystem of templates that itself attracts new users. Canva confirms the power of "virality through outcome": when a design is shared with a watermark, the product advertises itself without additional spending. In the case of Figma, it is worth mentioning that collaboration becomes the key driver of scaling – every new project brings in additional participants, and every team becomes a separate growth centre. Discord proves the effectiveness of the community-led approach, in which users create an environment for further engagement, forming unique communities that ensure long-term retention. Calendly demonstrates the power of workflow virality: every link sent is an embedded marketing action that automatically brings in new users.

What these strategies have in common is that growth arises not thanks to external campaigns, but through internal product characteristics that create stable cycles of dissemination, retention and repeated interaction. This confirms the central thesis of growth hacking: scaling becomes the result of properly designed product-marketing mechanisms rather than separate tactical activities. All the companies analysed have built growth on deep analysis of behavioural data, rapid hypothesis testing and continuous removal of friction along the user journey. These companies not only attracted users, but also minimised time to value, which is critically important for the PLG model. Thus, the examples in the table confirm that the ability to integrate viral mechanisms into the very structure of the product is a key success factor for start-ups in the modern market, where speed, flexibility and experimental activity determine competitive advantages.

DISCUSSION

Growth hacking is one of the key mechanisms of innovative development for start-ups, as it combines product and marketing approaches in a joint process of accelerated scaling. It is based on rapid experiments, behavioural data analysis and short hypothesis-testing cycles, which make it possible to react quickly to market changes and adjust user-interaction strategies. At the intersection of product and marketing, an integrated system is formed, in which growth depends on coordinated team actions and the ability to adapt the product rapidly in line with audience reactions. This study and the work of M. Cristofaro *et al*. (2025) converged in the view that growth hacking was based on data, high-speed experiments, cross-functional interaction and constant iteration of solutions. In both approaches, experimental activity was seen as a key tool for reducing uncertainty, while analytics and metrics were treated as the basis for decision-making. At the same time, the study by M. Cristofaro *et al.* interpreted growth hacking as a formalised scientific approach to data-driven decision-making with clear preconditions and a standardised analyse-ideate-prioritise-test cycle, whereas this study focused on its applied role in start-ups, where growth was ensured through AARRR metrics, product-led models, viral mechanisms and the construction of growth loops. This difference between strategic and tactical dimensions also appeared in the comparison with A. Cavallo *et al.* (2024). Both this study and the current one started from the premise that modern companies grew thanks to innovativeness, adaptability, and work with data. However, authors moved towards entrepreneurial resilience – the restoration of business models, the use of social capital and shock management. In contrast, this study showed how companies could act even before negative scenarios occurred –

through constant experiments, UX optimisation and behavioural hypothesis cycles that created an "accelerator" effect for growth. Whereas in authors' the scale of analysis was macro-level, in this study it was micro-processual, focused on the daily work of growth teams.

In comparison with A. Rezazadeh *et al.* (2025), the centre of gravity of both works was again innovativeness, but its interpretation differed. Authors interpreted it through organisational ambidexterity – the ability simultaneously to exploit existing competences and explore new directions. In this study, innovativeness had a different configuration: it was defined by the intensity of experiments, AARRR analytics, product-led development and viral interaction cycles. Whereas in the aforementioned study innovativeness was a strategic construct, here it took on an applied dimension and immediately influenced conversions, activation, and user retention. The work of C. Gerlich *et al.* (2025) continued this logic of differentiation. It explained growth hacking through the concept of dynamic capabilities, emphasising the processes of sensing, seizing and reconfiguring as the basis of organisational adaptability. This study revealed a shared reliance with aforementioned one on data and experimental activity, but interpreted these data in a much more operational way: as tools for rapidly influencing user behaviour, optimising the funnel and building growth loops. Whereas authors discussed strategic reconfiguration of the company, this study focused on the day-to-day tactical work of growth teams. Comparison with L. Zhou *et al.* (2025) showed that both studies considered growth hacking a cyclical, data-oriented and experimental approach. However, researchers interpreted it as an organisational capability within the Resource-Based View and Dynamic Capabilities Theory, which shaped the performance of small and medium-sized enterprises. This study, by contrast, interpreted growth hacking as a set of practical actions – AARRR metrics, PLG, UX optimisation and serial tests – aimed at attracting, activating and retaining users. Thus, the common element was the logic of iterativity, while the difference lay in the depth and level of strategicity at which these iterations were analysed.

This study and the work of C. Foggetti *et al.* (2025) converged in the view that growth hacking was an effective tool for accelerated growth in the digital economy and depended on experimental activity, analytics, and a rapid hypothesis-testing cycle. Both studies recognised the central role of behavioural data, testing, optimisation of acquisition channels and close interaction between marketing and product teams. These studies also shared an understanding of growth hacking as a dynamic process that integrated technology, creativity, and adaptability. At the same time, the differences were substantial. This study focused on start-ups and the operational mechanisms of rapid scaling – AARRR metrics, growth loops, PLG, UX optimisation and experiments aimed at influencing user behaviour. Here, growth hacking was interpreted as an applied toolkit that shaped the short-term dynamics of growth through product-marketing actions. The study by C. Foggetti *et al.* (2025) on the contrary, analysed growth hacking in the context of broad digital marketing ecosystems, emphasising the role of technological platforms, algorithmic personalisation, advanced marketing analytics and environments that combined SEO, content strategies, social media and automation.

This difference in perspectives became a logical basis for the distinctions observed in comparison with the work of N. Petersen (2024). Author went beyond the product level, but did so towards the strategic analysis of business models of Born Digital and Born Global companies. Both studies recognised experimental activity and digitalisation as the foundation for growth, but this study worked with micro-processes – behavioural analytics, tactical experiments and the AARRR model – whereas the reasercher described how growth hacking shaped the trajectories of internationalisation and the strategic architectures of firms. Thus, in the first case, it was an instrument of rapid scaling, while in the aforementioned study it became a tool of strategic positioning. A similar logic appeared in comparison with the work of Y. Joshi (2025), although the emphasis shifted significantly towards the market. Both approaches recognised the importance of A/B testing, behavioural analytics and digital experiments, but this study interpreted these practices as mechanisms of internal growth for the start-up. In author's research, by contrast, growth hacking was embedded in the external competitive environment, where the key roles were played by demand dynamics, platform algorithms and the intensity of digital competition. In other words, this study explained how start-ups grew, while reasercher clarified in what market environment these mechanisms operated or were destroyed.

Comparison of this study with the work of J. Jung *et al.* (2025) showed that both approaches treated growth hacking as an innovative model of accelerated development built on data, rapid experiments and short decision-making cycles. Both studies stressed the importance of iterativity, hypothesis testing and the integration of marketing and product functions in order to increase user activation and retention. At the same time, the differences lay in the focus: this study analysed the practical mechanisms of scaling start-ups, whereas authors devoted primary attention to organisational conditions – in particular digital culture, team coordination and management processes – that determined companies' ability to apply experimental strategies effectively. In the study by O. De Almeida Andrade *et al.* (2020), growth hacking was viewed as a tool of exponential scaling using the example of Uber, where the main drivers were marketing accelerators, viral promotions, dynamic pricing and word-of-mouth effects. The authors analysed growth hacking at the macro level – through the interaction of the platform with the market, the behaviour of drivers and users, and the influence of the sharing economy on the traditional transport industry. In this study, growth hacking was interpreted differently – as a micro-processual system based on rapid experiments, UX optimisation, AARRR analytics and viral interaction cycles that formed the product's internal growth mechanisms. Unlike the Uber model, where virality was created mainly by marketing activities, in this study it arose from user behaviour and product design. The two works shared recognition of the importance of digital experiments and rapid iterations. The difference lay in the level of analysis: authors described market dynamics and platform scaling, whereas this study focused on the product's internal processes and analytics that directly influenced user activation and retention.

The comparison showed that different scholarly approaches treated growth hacking as an iterative, experimental and data-oriented process in which the combination of product and marketing decisions ensured innovative development of start-ups. The common elements were an emphasis on rapid hypotheses, behavioural analytics and optimisation of user interaction. At the same time, the differences related to the level of analysis: some works considered growth hacking in a strategic dimension, others in an operational-applied one. In this context, this study occupied an applied position, detailing the mechanisms of tactical scaling through digital experiments.

CONCLUSIONS

The study showed that growth hacking is emerging as a key tool for the innovative development of start-ups, capable of ensuring growth speed, high flexibility and resource efficiency in an environment of intensified digital competition. The results obtained confirmed that the basis of this model is data-driven management, serial experiments, integration of marketing and product decisions, and the construction of cyclical growth mechanisms. Current market trends show that technology companies are actively moving towards PLG: already in 2022-2025, around 58% of SaaS start-ups used PLG, and 91% planned to increase investment in this approach, which indicates its strategic significance. The effectiveness of PLG is confirmed by financial metrics: companies with this model show an average annual increase in Annual Recurring Revenue of 35%, whereas non-PLG firms reach only 26%, and 83% of such companies attain USD 100 million in Annual Recurring Revenue, while spending 39% less on customer acquisition.

Experiments occupy a central place in growth hacking: in leading technology companies, the number of tests reaches dozens per month – for example, Nebula conducted 612 experiments in 2024, ensuring a continuous flow of behavioural data. Although only 10-30% of tests become statistically significant, these form the basis of targeted product and marketing improvements. Such experiments ensure an average conversion increase of 4-7%, and in some cases more than 20%. UX optimisation proved to be no less important: improving onboarding can increase activation by 10-30%, raise retention by 15-25%, and shortening time-to-value provides rapid achievement of the "aha moment". It is indicative that improving retention by 5% can increase company profit by 25-95%, which is why UX becomes the foundation of long-term growth.

Growth loops and viral mechanisms play a distinct role, enabling autonomous scaling without rising costs. The clearest example is Dropbox, which increased its user base from 100,000 to 4 million, and later to 15 million, thanks to a referral programme, achieving 3,900% growth. Similar dynamics are demonstrated by Canva (185 million users), Notion (20+ million), Calendly (20 million+) and Figma, where collaboration has become a source of exponential scaling. A limitation of this study is that it focuses mainly on theoretical approaches and open statistical data, which naturally narrows the depth of analysis of practical cases. The prospects for further research lie in forming an empirical sample of start-ups in order to compare the effectiveness of growth approaches across different sectors and at different stages of development.

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REFERENCES

[1] Berg, V., Birkeland, J., Nguyen-Duc, A., Pappas, I.O., & Jaccheri, L. (2020). Achieving agility and quality in product development: An empirical study of hardware startups. *Journal of Systems and Software*, 167, article number 110599. doi: 10.1016/j.jss.2020.110599.

[2] Bohnsack, R., & Liesner, M.M. (2019). What the hack? A growth hacking taxonomy and practical implications of growth hacking for firms. *Business Horizons*, 62(6), 799-818. doi: 10.1016/j.bushor.2019.09.001.

[3] Cavallo, A., Cosenz, F., & Notoc, G. (2024). Business model scaling and growth hacking in digital entrepreneurship. *Journal of Small Business Management*, 62(4), 2058-2085. doi: 10.1080/00472778.2023.2195463.

[4] Complex Agency. (2025). *A/B testing in design: Scientific methods to increase conversion*. Retrieved from https://the-complex.agency/blog/a-b-testuvannya-v-dizajni-naukovi-metodi-pidvishennya-konversiyi/.

[5] Cristofaro, M., Giardino, P.L., & Barboni, L. (2025). Growth hacking: A scientific approach for data-driven decision making. *Journal of Business Research*, 186, article number 115030. doi: 10.1016/j.jbusres.2024.115030.

[6] De Almeida Andrade, O., Rainatto, G.C., Lima, F., & Silva Neto, G.R. (2020). The power of growth hacking strategies and the exponential growth of Uber. *International Journal of Research in Marketing Management and Sales*, 2(1), 16-24. doi: 10.33545/26633329.2020.v2.i1a.40.

[7] Dmytrieva, O. (2022). Trends in the development of innovative entrepreneurship and startup projects in Ukraine. *Problems and Prospects of Entrepreneurship Development*, 28, 104-118. doi: 10.30977/PPB.2226-8820.2022.28.104.

[8] Dois, Z. (2025). *Growth hacking in real life: Cases that went very well (and very badly)*. Retrieved from https://uk.doisz.com/blog/exemplos-de-growth-hacking/.

[9] Foggetti, C., Natalicchio, A., Ardito, L., & Albino, V. (2025). Opening the black box of growth hacking: Insights into the microfoundations of lean startup capabilities. *Journal of Business Research*, 191, article number 115272. doi: 10.1016/j.jbusres.2025.115272.

[10] Gangurde, B. (2025). *What duolingo taught me about retention (and how i'd build it into my own apps)*. Retrieved from https://surli.cc/hjfvhs.

[11] Gerlich, C., Brenk, K., Antonio, J.L., Kanbach, D.K., & Kraus, S. (2025). Wielding a double-edged sword: Unravelling the development of dynamic capabilities through growth hacking. *Journal of Business Research*, 189, article number 115172. doi: 10.1016/j.jbusres.2024.115172.

[12] Joshi, Y., Bodhi, R., Chatterjee, S., & Mariani, M. (2025). The impact of growth hacking on firm performance under environmental turbulence: A moderated-mediation analysis. *Journal of Business Research*, 191, article number 115271. doi: 10.1016/j.jbusres.2025.115271.

[13] Jung, J., Ko, H., & Kim, Y.J. (2025). How do startups drive innovations towards sustainability? *Sustainability*, 17(4), article number 1693. doi: 10.3390/su17041693.

[14] Kluz, L. (2025). *Product-led growth benchmarks: Key SaaS findings and trends*. Retrieved from https://productled.com/blog/product-led-growth-benchmarks.

[15] Krisko, Y. (2025). *Onboarding*. Retrieved from https://snov.io/glossary/onboarding/.

[16] Loukas, D. (2025). *Dropbox marketing success: 3900% growth with a simple referral program*. Retrieved from https://viral-loops.com/blog/dropbox-grew-3900-simple-referral-program/.

[17] Lychak, O. (2025). *Five lessons on how to increase conversion fivefold, or why do we need 18 product managers*. Retrieved from https://dou.ua/forums/topic/55326/.

[18] Mahadik, S., Pakanati, D., Cherukuri, H., & Jain, S. (2024). Cross-functional team management in product development. *Modern Dynamics Mathematical Progressions*, 1(2), 270-294. doi: 10.36676/mdmp.v1.i2.24.

[19] Moiseeva, A. (2025). *How website loading speed affects conversion and how to improve it*. Retrieved from https://procamp.ua/blog/yak-shvydkist-zavantazhennya-sajtu-vplyvaye-na-konversiyu-ta-yak-yiyi-pokrashhyty/.

[20] Mykytyuk, N.E., & Chaykovsky, A.M. (2025). Creative management as a driver of effective innovations in marketing strategies of enterprises using social networks. *Current Issues of Economic Sciences*, 11. doi: 10.5281/zenodo.15348345.

[21] Petersen, N. (2024). Digital and international growth hacking business models: Born globals, born digitals, and synergies. *Digital Technologies Research and Applications*, 3(2), 81-91. doi: 10.54963/dtra.v3i2.247.

[22] Prokhorova, V.V., & Chobitok, V.I. (2023). Strategic development of startups in an innovative environment. *Business Inform*, 9, 325-330. doi: 10.32983/2222-4459-2023-9-325-330.

[23] Raj, P. (2023). *How Slack, Duolingo, Instagram & Calm are using internal triggers to improve their engagement & retention*. Retrieved from https://uxplanet.org/how-slack-duolingo-instagram-calm-are-using-internal-triggers-to-improve-their-engagement-a867d31c1ff4.

[24] Rezazadeh, A., Kohns, M., Bohnsack, R., António, N., & Rita, P. (2025). Generative AI for growth hacking: How startups use generative AI in their growth strategies. *Journal of Business Research*, 192, article number 115320. doi: 10.1016/j.jbusres.2025.115320.

[25] Rizvanović, B., Zutshi, A., Grilo, A., & Nodehi, T. (2023). Linking the potentials of extended digital marketing impact and start-up growth: Developing a macro-dynamic framework of start-up growth drivers supported by digital marketing. *Technological Forecasting and Social Change*, 186, article number 122128. doi: 10.1016/j.techfore.2022.122128.

[26] Rud, N.T. (2021). Startups: Development trends and risks. *Economic Forum*, 2(2), 46-54. doi: 10.36910/6775-2308-8559-2021-2-6.

[27] SaaS Writing Team. (2025). *Product-led growth vs. sales-led growth*. Retrieved from https://winsomemarketing.com/saas-marketing/product-led-growth-vs.-sales-led-growth.

[28] Scheuenstuhl, F., Bican, P.M., & Brem, A. (2021). How can the lean startup approach improve the innovation process of established companies? An experimental approach. *International Journal of Innovation Management*, 25(3), article number 2150029. doi: 10.1142/S1363919621500298.

[29] Thorenberg, L. (2025). *First vs. second vs. third-party data: What are they and why they matter*. Retrieved from https://www.northbeam.io/blog/first-vs-second-vs-third-party-data-what-are-they-and-why-they-matter.

[30] Tkachenko, A., & Voronin, D. (2024). Innovative potential of startups: Assessment criteria and diagnostics. *Economic Analysis*, 34(2), 301-316. doi: 10.35774/econa2024.02.301.

[31] Tymoshenko, M. (2022). Innovative startups as a factor of economic development: Best world practice and experience of Ukraine. *Scientific Notes of the Lviv University of Business and Law. Economic Series. Legal Series*, 33, 13-20. doi: 10.5281/zenodo.6618998.

[32] van Gasteren, W. (2025). *Growth loops: Right for you? + 5 steps to design yours*. Retrieved from https://growwithward.com/growth-loops/.

[33] Yakivchenko, A. (2025). Hacking as a tool for ensuring the development model of innovative marketing in an industrial enterprise. *Herald of Khmelnytskyi National University. Economic Sciences*, 338(1), 343-353. doi: 10.31891/2307-5740-2025-338-51.

[34] Zhang, X. (2022). Incremental innovation: Long-term impetus for design business creativity. *Sustainability*, 14(22), article number 14697. doi: 10.3390/su142214697.

[35] Zhou, L., Li, L., & Cheng, J. (2025). The growth code of SMEs in the digital wave: How innovation, initiative, and management ability drive growth hacking capabilities. *Asia Pacific Journal of Innovation and Entrepreneurship*, 19(4), 352-377. doi: 10.1108/APJIE-04-2025-0045.

[36] Zinchuk, T. (2024). Modern drivers of innovative entrepreneurship development: Ukrainian realities and European experience. *Economy and Society*, 66. doi: 10.32782/2524-0072/2024-66-125.

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Growth hacking як драйвер інноваційного розвитку стартапів: між маркетингом і продуктом

Анотація. Метою даного дослідження було визначити, як інструменти швидкісного експериментування та аналіз даних можуть підсилювати інноваційний розвиток стартапів і підвищувати ефективність узгодження маркетингових та продуктових рішень. Методологія ґрунтувалася на теоретико-емпіричному підході та включала систематизацію наукових джерел, аналіз цифрових платформ, порівняння технологічних компаній і дослідження практичних кейсів, що відображали застосування експериментування, рекомендаційних моделей і оптимізації користувацького досвіду. У результатах було встановлено, що моделі з акцентом на продукт як основний інструмент зростання забезпечували вищі фінансові показники: компанії, які застосовували підхід product-led growth, демонстрували середньорічне зростання регулярного річного доходу на рівні 35 %, тоді як компанії з традиційними підходами – лише 26 %, а витрати на залучення клієнтів у бізнесів, що орієнтувалися на продукт, були на 39 % нижчими. Значущість циклів експериментування підтверджувалася високою інтенсивністю тестів: компанія Nebula проводила 612 експериментів у 2024 році, що сприяло підвищенню конверсій у середньому на 4-7 %. Оптимізація користувацького досвіду, досліджена на прикладі Duolingo, забезпечувала приріст рівня утримання користувачів на 15-25 %, тоді як пришвидшення процесу першого використання продукту підвищувало активацію користувачів на 10-30 %. Найпотужнішим віральним механізмом виявилися рекомендаційні моделі: приклад Dropbox продемонстрував зростання на 3 900 %, а кількість користувачів збільшилася від 100 тис. до понад 4 млн, що підтвердило ефективність циклів вірального поширення. Практичне значення даного дослідження полягає в тому, що його результати можуть бути використані стартапами для побудови ефективних механізмів зростання, оптимізації продуктово-маркетингових рішень та підвищення результативності експериментування

Ключові слова: швидкі експерименти; оптимізація; віральні механізми; масштабування; бізнес; конверсія

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Economic potential of natural healing assets: International market trends, business models, and prospects for Ukraine

Abstract. The economic recovery of nations following extensive conflict requires the strategic capitalisation of high-value, domestic assets capable of generating robust revenue and restoring depleted human capital. Ukraine's globally significant Natural Healing Assets (NHA) represent such a strategic priority. The study aimed to conduct a comprehensive analysis of international business experience in using NHA to develop practical recommendations for their effective use in Ukraine. The methodology involved systematic analysis, generalisation, and synthesis of data from numerous international reports and academic articles, utilising comparative analysis to assess global market criteria and business models. The concept of NHA was defined as resources recorded in state registers and utilised for profit or social benefit. A detailed analysis of global entrepreneurial markets utilising NHA was conducted. It was identified that the largest markets by volume by 2028 will be wellness tourism (1,359.3 billion USD), bottled water production (438.5 billion USD), and ecotourism (422.3 billion USD). Key criteria (stability, investment attractiveness, sustainability) for nine market segments were systematised, confirming that the growth rates of all NHA markets exceed the CAGR of World GDP. The three main international models for NHA integration (Public, Private, and Public-Private Partnership) were analysed, establishing that the optimal model depends on the specific asset and strategic goals. Comprehensive practical recommendations for Ukraine were developed, identifying medical rehabilitation as a key priority. The research findings provide entrepreneurs, investors, and government authorities in Ukraine with an evidence-based framework for selecting optimal business models and priority investment directions for NHA use

Keywords: resort economy; investments; tourism; rehabilitation; wellness; recreation; public-private partnership

INTRODUCTION

The economic recovery of nations following extensive conflict requires the strategic capitalisation of high-value domestic assets capable of generating robust revenues and restoring depleted human capital. Ukraine possesses globally significant Natural Healing Assets (NHA) that represent a powerful, nature-based foundation for national economic revitalisation. The primary challenge lies in the effective transition of the historically state-centric sanatorium and resort infrastructure into competitive, market-driven business models capable of attracting substantial international investment and integrating into high-margin global value chains. Failure to modernise this resource potential would represent a substantial lost opportunity for economic growth, foreign-exchange earnings and, importantly, for addressing the pervasive national crisis of health, disability and population recovery resulting from military operations. Therefore, defining viable, resilient commercial frameworks for NHA utilisation is a strategic economic priority.

The academic literature has confirmed the strategic importance of this sector while delineating significant systemic barriers to its economic realisation. N. Horozhankina *et al.* (2025) identified key economic issues, specifically reduced state funding due to political instability and the widespread deterioration of facilities built in the 1980s and 1990s. They concluded that sustainable restoration

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fundamentally depends on external investment, modernisation, adaptation to strict European medical tourism standards and active integration into the global market. Similarly, V. Yavorska *et al.* (2022) highlighted resort recreation as a priority area capable of generating significant foreign-exchange earnings and creating jobs. However, their work identified the main obstacle as the lack of a comprehensive state and regional strategy designed to actively influence the sector's investment attractiveness.

W. Zhang *et al.* (2022) focused on the economic benefits of the medical tourism industry and proposed an improved Markov chain method to analyse and predict market scale and development trends. They concluded that healthcare tourism is a new, high-potential product capable of generating significant economic and social benefits, with its value growing at twice the rate of traditional tourism. N. Khumarova & K. Kostetska (2025) analysed the financial sustainability of the Ukrainian sanatorium and resort sector, demonstrating uneven regional development (growth in western regions vs. losses in central and southern areas). Crucially, their study demonstrated a direct interrelation between profitability and the extraction and sale of natural therapeutic resources, identifying mineral water and non-alcoholic beverage producers as having the best financial results. This research underscores that resource capitalisation, rather than solely medical services, is the key driver of financial resilience in the sector. Further defining the sector, A. Shashero *et al.* (2025) examined the modern resort business of Ukraine as a complex socio-economic system, emphasising that isolated improvements are insufficient and that systemic economic and structural reforms are necessary to leverage therapeutic natural resources effectively. I. Kudinova & O. Grishchenko (2021) reinforced the economic potential, noting that medical tourism in Ukraine attracts foreign investment due to competitive price parameters, yet they explicitly identified underdeveloped infrastructure and low levels of certification in medical institutions as key barriers to achieving global competitiveness.

Beyond the direct resort business, analysis of related international markets demonstrates substantial economic opportunity. C. Brancu & O. Turcu (2025), in a study of the cosmetics industry, reported robust global growth driven by premiumisation and demand for high-quality, sustainable products. This confirms the strong economic viability of utilising NHA components (such as therapeutic muds or mineral compounds) as high-value inputs for natural cosmetics and specialised APIs. Concurrently, international research using financial clustering for the SPA sector (Vašaničová *et al.*, 2025) identified management models characterised by high profitability and resilient financial structures. This demonstrates that successful NHA enterprises can be segmented based on distinct, successful financial performance criteria, providing a framework for benchmarking resilience. B. Mayor *et al.* (2021) concluded that financing Nature-Based Solutions (NBS) business models is problematic due to the multiple stakeholders and diverse benefits involved. This complexity hinders a clear, single argument for both public and private investment, underscoring the necessity of innovative financing structures capable of monetising diverse value streams.

Despite the consensus on Ukraine's high NHA potential and the identified constraints (e.g., suboptimal planning and infrastructure decay), the existing economic literature lacks an integrated strategic analysis. Previous studies have not provided a comprehensive comparative techno-economic analysis of the three primary international business models (Public, Private, and Public-Private Partnership) across the full spectrum of NHA-utilising industries (SPA, natural cosmetics, specialised APIs, and bottled water). This deficit leaves policymakers and investors without a data-driven framework to select optimal governance and financial structures. Furthermore, while financing complex natural solutions is acknowledged internationally, the specific mechanisms required to translate the socio-economic benefits of Ukrainian NHA (particularly mass medical rehabilitation) into bankable and commercially viable post-war investment projects remain inadequately explored, limiting rapid economic restoration. The aim of the study was to conduct a comprehensive analysis of international business experience in the utilisation of natural healing assets and to develop practical recommendations for their effective use in Ukraine.

MATERIALS AND METHODS

A comprehensive approach combining theoretical and empirical methods was used in this study. The research was based on the systematic analysis, generalisation and systematisation of data obtained from numerous global economic reports, the business press and online media, and scientific articles. In particular, global reports covered the market sizes of activities using NHA across five regions: North America (U.S., Canada, Mexico); Europe (Germany, UK, France, Italy, Spain, Switzerland, Netherlands, Belgium, Sweden, Austria); Asia Pacific (China, Japan, India, Australia and New Zealand, South Korea, Thailand, Indonesia, Malaysia, Vietnam, Singapore); Latin America (Brazil, Mexico, Argentina, Chile, Colombia); Middle East and Africa (Gulf Cooperation Council (GCC) countries, Israel, Turkey, South Africa, Egypt, Nigeria). Comparative analysis of global market criteria and international models of entrepreneurial activity in the field of NHA utilisation was the key method. This enabled the identification of their advantages, disadvantages and development trends. Based on the results obtained, and by applying induction and logical generalisation, practical recommendations for Ukraine were formulated.

Where numerical values of key indicators were absent from the available sources, the respective indicators were calculated during the research when the necessary initial data were provided. For example, the growth rates of the analysed activity markets were characterised using the compound annual growth rate (CAGR). The CAGR was calculated according to formula (1), with results expressed as a percentage (Ahmed, 2023; Fernando, 2025):

$$CAGR = \left(\left(\frac{EV}{BV}\right)^{\frac{1}{n}} - 1\right) \times 100, \tag{1}$$

where $CAGR$ – the Compound Annual Growth Rate, (%); EV – ending value, (USD); BV – beginning value, (USD); n – the number of years between the beginning and ending values, (years). The transformed formula (1) was used to determine the monetary equivalent based on the CAGR of the relevant year in the period for which the average annual growth rate was calculated, namely:

$$FV_k = BV \times (1 + CAGR)^n, \qquad (2)$$

where FV_k – the future or intermediate value in year k; BV – beginning value, (USD); $CAGR$ – the Compound Annual Growth Rate, expressed in decimal format; n – the number of years that have passed from the beginning of the period to year k, (years). To evaluate the intensity of the projected growth of global markets for entrepreneurial activities utilising NHA, comparative analysis of market data against world gross domestic product (GDP) figures was performed. The initial data for world GDP dynamics were sourced from the statistical records of the International Monetary Fund (IMF) (2025) for the 2023-2030 period. For enhanced clarity and precise communication of complex market data, all foundational quantitative evidence (Market Size and CAGR) and analytical results were synthesised and presented using tables and figures (charts).

RESULTS

Definition of general concepts regarding natural healing assets

Research into the economic essence of natural healing assets required a clear delineation of basic terms. First, it was necessary to define the initial concept of natural healing resources (NHR), which is enshrined at the legislative level. Based on the Law of Ukraine No. 2026-III (2000), natural healing resources are defined as elements of the natural environment that had demonstrated medicinal properties, as established through medical-biological assessment of the quality and value of the NHR, and that were used for the prevention and treatment of diseases and for medical rehabilitation. The main types of natural healing resources include:

1. Mineral and thermal waters are underground waters with an increased content of certain chemical elements, gases, salts, or specific physical properties (temperature), which are used for drinking therapy, baths, irrigation pools, and other procedures.
2. Healing muds (peloids) and ozokerite are natural formations consisting of organic and mineral substances that have high heat capacity and thermal conductivity, as well as chemical activity. They are generally used in the form of applications and baths.
3. Brine from estuaries and lakes, and seawater, are concentrated salt solutions of natural origin that have a therapeutic effect due to their chemical composition and physical properties.
4. Natural objects and complexes with favourable climatic conditions, such as mountainous areas, forested areas, and sea coasts, create a special microclimate that promotes health (aerotherapy, heliotherapy, thalassotherapy) (Law of Ukraine No. 2026-III, 2000; Babov *et al.,* 2021).

There is no clear definition of the concept of "natural healing assets" at the legislative level in Ukraine. The transition from NHR to NHA was considered to occur on the basis of the implementation of Article 16 of the Law of Ukraine No. 2026-III (2000), namely, the key point of this transition was the inclusion of NHR in the State Fund of Mineral Deposits of Ukraine and the State Cadastre of Natural Healing Resources of Ukraine. Following the inclusion of NHR in state registers, the "resource" acquired the status of an "asset" and fell under legal regulation regarding its further use by legal entities and individuals for the purposes of treatment, medical rehabilitation and disease prevention, as well as for industrial use (bottling mineral water, packaging healing mud, manufacturing cosmetic and pre-formed products based on mud, etc.). Thus, the definition of the concept of NHA (tangible assets) was formulated as follows. NHA are natural healing resources that have been identified through comprehensive medical-biological, climatological, geological-hydrological, balneological and other research, have a proven medical-biological assessment of the quality and value of the NHR, are recorded in the State Fund of Mineral Deposits of Ukraine and the State Cadastre of Natural Healing Resources of Ukraine, and are used or will be used by legal entities and individuals for treatment, medical rehabilitation and disease prevention, as well as for industrial use, for the purpose of obtaining profit or generating societal benefit through maintaining, restoring and improving population health.

The main properties of NHA include their natural origin and therapeutic use in a virtually unchanged natural state, mainly in resort settings, as well as the ability to act as a "resort-forming factor" (Law of Ukraine No. 2026-III, 2000; General characteristics of natural healing resources, 2025). The capacity of NHA to function as a "resort-forming factor" indicated that these assets were not merely resources for extraction, but fundamental elements around which entire economic "ecosystems", such as resorts and related services, could be developed. This feature emphasised their catalytic role in regional development: NHA were positioned as the core of an economic growth pole, capable of attracting investment, supporting the creation of comprehensive infrastructure and jobs, and contributing to the development of local communities. This indicated that their value extended beyond direct therapeutic use, positioning them as a driver of broader socio-economic growth.

Characteristics of the main types of entrepreneurial activities using NHA

The effective utilisation of NHA fundamentally relied on establishing viable entrepreneurial structures capable of translating natural potential into economic value. According to Article 1 of the Law of Ukraine No. 698-XII (1991), entrepreneurship is "a direct independent, systematic, at one's own risk activity in the production of products, performance of work, provision of services for the purpose of making a profit, which is carried out by individuals and legal entities registered as business entities in accordance with the procedure established by law". Also, based on Article 2 of the Law of Ukraine No. 4196-IX (2025): "economic activity is the activity in the area of social production, aimed at manufacture and sale of products, execution of works or providing services of value nature that have price distinction. If this activity is carried out for the purpose of generating a profit, then it is entrepreneurship". Entrepreneurial activity in the field of using natural healing assets was multifaceted, encompassing both traditional medical services and modern wellness- and eco-oriented areas. The most common types of entrepreneurial activities that effectively used natural healing assets were considered below.

1. Sanatorium-resort treatment was understood as traditional medical treatment and rehabilitation provided in sanatorium-resort facilities, which utilised natu-

ral healing resources within resort territories or medical and health resort areas (Sanatorium and resort treatment…, 2018; Law of Ukraine No. 2026-III, 2000). The primary focus was on the treatment of specific diseases and medical rehabilitation.

2. Wellness centres and SPA services. These facilities primarily focused on holistic health, prevention, relaxation, anti-ageing therapies and stress reduction for mostly healthy people (Kirkland, 2014; Marchenko & Ditrikh, 2020). They were often integrated into hotel complexes and offered a wide range of services, including mineral baths, mud wraps and thalassotherapy (the use of seawater and marine muds), alongside other services based on natural healing assets, as well as massages, cosmetic treatments, saunas and swimming pools.

3. Production of bottled mineral water. Enterprises were involved in the extraction and bottling (or source collection, where applicable) and sale of table, therapeutic-table and medicinal mineral waters. These waters were used both for daily consumption and for the treatment of specific diseases under a doctor's prescription. This business was characterised by consistently growing demand and a lack of seasonality (Analysis of the water market in Ukraine, 2024).

4. Mud therapy involved the therapeutic application of various types of medicinal muds used for treating skin conditions, musculoskeletal problems and other pathologies (Babov *et al.,* 2021). Mud hospitals and pelotherapy centres could operate either as independent enterprises or as part of large sanatorium complexes or hotels.

5. Climatotherapy involved the use of specific climatic conditions (such as mountain, marine or forest air, and solar radiation) to improve health (Protas, 2022). It was typically offered in sanatoriums or hotel complexes with medical centres.

6. Production of medical cosmetics and pharmaceutical preparations based on NHA involved the development and manufacture of products utilising minerals (salts), muds or other extracts derived from NHA. In particular, this included creams, masks, balms, shampoos, ointments, nutritional supplements and other products containing extracts of healing muds, mineral salts and plant components with proven therapeutic or beneficial properties.

7. Recreational tourism with an emphasis on natural wellness included health, educational (cognitive), ecological and sports tourism, as well as their combinations. The main goal of recreational tourism was the restoration of physical and mental well-being, namely rest and rejuvenation (Recreational tourism, 2025). This type of tourism mainly encompassed activities related to organising tours and active recreation, including visiting natural springs, bathing in thermal waters and natural mud bathing (in compliance with environmental standards), as well as hiking in ecologically pristine areas for climatotherapy. These were usually not classic medical institutions, but rather recreational facilities with a wellness focus.

8. Operation and management of NHA deposits ensured direct access to the natural healing assets themselves and involved geological exploration, reserve assessment, obtaining special subsoil-use permits, extraction (drilling wells for mineral waters, developing mud deposits) and supplying NHA for further use in medical facilities or for packaging and bottling into appropriate consumer containers (sealed vessels).

In addition to the aforementioned types of entrepreneurial activity in the field of NHA use, research and development (R&D) activities were also considered. This type of activity was not directly entrepreneurial in the sense of providing services to the end consumer; however, it served as a crucial catalyst for further entrepreneurial development in the NHA sector. Thus, the types of entrepreneurial activity effectively utilising NHA reflected the classical directions of this activity (Nebava *et al.,* 2011). In particular, manufacturing (production) entrepreneurship was distinguished, within which the business-process structure typically included production resources, production, finished products (works/services), goods, sales, gross income and the financial result. By contrast, commercial entrepreneurial activity was identified when the business process did not involve the production of goods. The diversification of entrepreneurial activities using NHA extended beyond traditional sanatoriums and included areas such as wellness, SPA, cosmetics, pharmaceuticals and various forms of recreational tourism. This trend reflected the evolution of consumer demand from purely treatment-oriented services towards disease prevention and a broader "healthy" lifestyle orientation. Future business success was considered to depend on identifying and meeting these broader, evolving trends in societal health and well-being. Key factors for this success included the scientific substantiation of the therapeutic properties of NHA, the application of modern technologies for NHA extraction, processing, stabilisation and use, ensuring high quality of goods and services, effective marketing, and the establishment of sustainable policies for NHA use.

International market analysis of NHA-based entrepreneurial activities

A detailed analysis of international experience for each of the aforementioned entrepreneurial activities utilising NHA was conducted using key metrics such as market size, growth rates, stability, investment attractiveness, profit margin and market sustainability. Each of these indicators played an important role in the comprehensive analysis and, collectively, provided a more complete picture of the economic feasibility, risks and potential associated with each of the above activities. For the purposes of detailed international comparison, sanatorium-resort treatment was integrated into medical tourism at this stage of the research. This approach was justified because sanatorium-resort treatment, in essence being travel undertaken for therapeutic purposes related to the treatment and prevention of diseases, was considered a medical service and operated as a sub-segment within the broader medical tourism economic segment, sharing common resources and a client base. It should be noted, however, that medical tourism is a broader concept encompassing any travel undertaken for the purpose of treatment (Medical tourism market size…, 2025), including trips to specialised clinics for surgical operations, dental procedures and similar services. A detailed description of all individual indicators would have occupied a substantial portion of this manuscript. Therefore, the information obtained was condensed and systematised by the types of entrepreneurial activity under study. Within the framework of this manuscript, systematised information on market sizes and their growth rates is presented in Table 1, together with the rationale for the underlying estimates.

Table 1. Quantitative assessments of global markets for entrepreneurial activities using NHA

Type of entrepreneurial activity	Total global market size in 2023-2025, (USD billion)	Market growth rate (CAGR), (%)	CAGR calculation period, (years)	Data justification
Medical tourism	31.23-41.79 (2024)*	23.0 16.12-17.8	2025-2032 2025-2034	(Medical tourism market size…, 2025; Medical tourism market performance…, 2025; Medical tourism market (2025-2030), 2025)
Wellness tourism	830 (2023)* 945.5 (2024)*	10.2 8.9	2023-2028 2025-2033	(Global wellness economy monitor, 2024; Bora, 2025)
SPA	136.8 (2023)* 13.43-99.79 (2024)*	6.1 5.81-12.72	2023-2028 2025-2032	(Global wellness economy monitor, 2024; Ecotourism market size, share & industry analysis…, 2025; Spa market: global industry analysis…, 2025; Spa market size & share analysis…, 2025)
Production of bottled (mineral) waters	348.64 (2024)* 309.21 (2025)*	6.4 4.6 6.7	2025-2030 2025-2032 2025-2034	(Bottled water market, 2025; Premium bottled water market, 2025; Suryawanshi, 2025)
Production of mud masks	8.3 (2023)*	14.3	2024-2031	(Global mud mask market size…, 2025)
Production of natural cosmetics	41.74-55.43 (2024)*	9.5 4.8**	2025-2034 2024-2029	(Natural cosmetics market report 2025, 2025; Singh, 2025)
Production of pharmaceutical products based on APIs	30.0 (2023)* 34.6 (2025)*	6.1	2023-2034	(Natural APIs market…, 2025; Plant-based API market…, 2024)
Nature/ecotourism	216.49 (2023)*	14.3	2024-2032	(Ecotourism market size, share & industry analysis…, 2025)
Thermal and mineral springs sector / tourism to this sector	62.7 / 50.19 (2023)*	9.2 / 14.8	2023-2028 / 2024-2030	(Global wellness economy monitor, 2024; Thermal springs tourism market (2025-2030), 2024)

Note: (*) – the year for which the data is provided; (**) – calculated CAGR value according to formula (1) based on data (Natural cosmetics market report 2025, 2025)
Source: formed by the author

The presence of multiple sources reporting different market size values for medical tourism and wellness tourism indicated the absence of a universally standardised definition and market-sizing methodology in market research. This disparity was likely to arise from the inherent overlap between medical and wellness travel, as trips frequently combined elements of both. For example, an individual may have sought medical treatment while also using SPA services or participating in recreational activities. This overlap could have led investors to conclude that a holistic view encompassing both medical and wellness dimensions of travel was essential. Companies that were able to offer integrated services (e.g., medical procedures combined with wellness retreats or post-operative recovery in a resort environment) were therefore likely to capture a larger share of this combined market, reducing the risks associated with narrowly defined segments. The scale of wellness tourism – nearly USD 1 trillion by 2024 (Spa market size & share analysis…, 2025) – suggested that medical tourism utilising NHA often fell within this broader, more comprehensive category, offering greater market potential.

Market trends and investment potential in medical and wellness tourism

Overall, medical and wellness tourism was showing exceptionally high growth rates after the pandemic. The pandemic had increased global public awareness of health and had highlighted the importance of preventive care and holistic well-being. This had led to a surge in demand for health-focused travel, especially for trips perceived as restorative or as offering specialised care that was not readily available or affordable in one's own country. This indicated strong market stability driven by fundamental changes in consumer behaviour, rather than temporary trends. This market could be regarded as resilient, with demand for medical services and wellness experiences remaining a constant driver. Investments in infrastructure and services that responded to this increased health awareness were likely to be sustainable and profitable in the long term.

Given strong growth forecasts for the medical and wellness tourism market and growing consumer demand for quality, affordable or specialised medical and healthcare services abroad, investment attractiveness was high. Government initiatives, such as the "Heal in India" campaign (Medical tourism market performance…, 2025), and strategic partnerships (Medical tourism market (2025-2030), 2025) were fostering growth and investment. Significant investments were observed in the US medical tourism market (from 6.2 billion USD in 2024 to 41.0 billion USD by 2034, with a CAGR forecast of 20.8%) (US medical tourism market…, 2025). Mergers and acquisitions (M&A) and venture capital (VC) activity in medical technology (a related sector) was showing positive momentum, with larger, more selective investments in companies with high growth potential (Gomez & Katz, 2025). The global medical tourism market was highly lucrative, demonstrating healthy profit margins. This conclusion was supported by rapid market growth and the high costs of medical care in developed countries (US medical tourism market..., 2025), which together indicated significant profit potential, especially for private service providers (Medical tourism market (2025-2030), 2025). Consequently, the desire among travel destinations to capitalise on this potential further underscored the profitability of this segment (Haigh, 2025).

The medical tourism market was driven by growing health awareness and the adoption of preventive medicine (Anderson, n.d.). The sustainable development of medical tourism was framed around three pillars: economic progress, social justice and environmental conservation (Castro, n.d.). Integrating sustainable development practices was expected to attract a wider audience and boost market growth (Bora, 2025). A major challenge to the growth of the medical tourism market involved limitations in routine post-treatment follow-up and post-operative care. For instance, complications could arise following medical procedures or surgeries, and subsequent medical monitoring or care could be costly (Medical tourism market size..., 2025). The overall global SPA market was demonstrating robust growth (Global spa market size..., 2025), with the medical/medi-SPA segment identified as the fastest-growing, and the expansion of medical spa centres representing the fastest-growing facility type (Spa market size & share analysis..., 2025). This reflected a shift from traditional relaxation services to more results-oriented, clinically proven services. According to experts (Spa market size & share analysis..., 2025), this trend was driven by an ageing population seeking anti-ageing and regenerative treatments, increased consumer awareness of advanced aesthetic procedures and a desire to achieve measurable health results in addition to relaxation. Consequently, investment in SPAs was increasingly expected to focus on the integration of healthcare services, advanced technologies and skilled healthcare professionals. This hybrid model offered higher revenue potential and targeted a more demanding, health-oriented clientele, thereby increasing market stability and profitability.

Investment attractiveness was substantial, driven by increasing public health awareness and the overall growth of the global SPA market. Technologically advanced SPA facilities were increasingly attracting patrons, and corporate wellness programmes were integrating SPA visits to reduce staff burnout and enhance employee retention (Spa market size & share analysis..., 2025). The key challenges for the SPA industry included high initial and operational costs, stringent licensing and regulatory requirements, and the recruitment and retention of qualified personnel. Profit margins for well-run SPAs were reported to range from 10% to 25%. The average day SPA in the United States was reported to earn between 500,000 USD and 1 million USD annually. The SPA services market was driven by rising household incomes and demand for professional massage therapy (Spa market size & share analysis..., 2025). Emphasis on consistent service quality and adaptation to emerging trends was paramount, while the integration of sustainable practices was expected to attract a broader consumer base and accelerate market growth.

Global bottled water market: Trends, investment potential, and sustainability

The Asia-Pacific region (China, Japan, India, Australia and New Zealand, South Korea, Thailand, Indonesia, Malaysia, Vietnam, and Singapore) constituted the largest bottled water market in 2024 (Bottled water market, 2025). This region contended with persistent water-quality and infrastructure challenges, resulting in high demand for bottled water as a reliable source of hydration. Europe was projected to lead the global mineral water market in 2025, commanding a 44.6% share (Suryawanshi, 2025). This outcome was attributed to rising preferences for premium bottled water, a robust tourism sector, and the presence of prominent global mineral water brands, notably Evian and San Pellegrino bottled water consumption in the United States reached 15.94 billion gallons (60.34 billion litres) in 2023, which consolidated its position as the most consumed packaged beverage and significantly exceeded carbonated soft drinks (11.84 billion gallons (44.82 billion litres)). This pattern was not merely a matter of convenience; it reflected a direct consumer preference for healthier hydration options. It was also associated with increasing public health awareness, concerns regarding obesity and lifestyle-related diseases, and deliberate consumer efforts to reduce sugar intake. Bottled water, particularly mineral water, was perceived as a "clean and health-conscious alternative" (Bottled water market, 2025). Consequently, the bottled mineral water industry was benefiting from a sustained shift in consumer behaviour towards healthier lifestyles. This established it as a highly stable market with relatively predictable demand, less susceptible to short-term fluctuations, and appealing for long-term investment, particularly in premium and functional segments (e.g., vitamin- and mineral-enriched water) that offered additional perceived health benefits (Suryawanshi, 2025).

The investment attractiveness of the bottled water market was assessed as moderate to high. Stable demand, consistent market growth and premiumisation trends contributed to market appeal (Bottled water market, 2025). However, despite substantial growth potential, the market was constrained by considerable risks associated with intense competition, stringent environmental regulation (e.g., taxes on plastic packaging or outright bans), and macroeconomic volatility (e.g., energy, packaging and transport price fluctuations directly affected costs and profitability), which collectively could position overall investment attractiveness closer to moderate. Investments were notably directed towards branding, marketing, distribution systems and infrastructure (Premium bottled water market, 2025). To bolster demand in the bottled water market, an imperative to utilise sustainable packaging (e.g., rPET, glass containers or aluminium cans) was identified, driven by prevailing consumer environmental concerns (Bottled water market, 2025). Average profit margins in water bottling were reported to range from 10% to 15% (Sheykin, 2025a). Revenue for small and medium-sized enterprises was reported to range from 500,000 USD to several million USD annually, while large facilities could exceed tens of millions of dollars. Overall profitability was supported by premium pricing for high-quality mineral water.

Market sustainability was supported by an increased focus on environmental sustainability, including responsible water sourcing, reduced packaging weight (PET bottle weight was reported to have been reduced by 51% from 2000 to 2014), and enhanced recycling efforts (International Bottled Water Association, n.d.). Bottled water production was reported to use less water and energy than the manufacture of other packaged beverages. The utilisation of recycled PET was increasing, with many companies offering bottles containing 50% to 100% rPET content. Nevertheless, the bottled water market continued to face negative societal perceptions associated with plastic waste, although industry experts argued that its environmental footprint was smaller than that of alternatives (e.g., glass and aluminium cans).

The thermal and mineral springs industry was intrinsically linked to the development and stewardship of natural healing resources. This segment was demonstrating revitalisation and was attracting substantial investment from both private entities and governments, with funds allocated to the refurbishment of ageing facilities and the enhancement of service standards. Investment momentum was associated with recognition of hydrotherapy's centuries-long history in regions such as Asia-Pacific and Europe, alongside growing consumer interest in nature-based experiences, cultural heritage and complementary therapeutic modalities (Thermal/mineral springs, n.d.). Governments were proactively promoting these sites as key components of wellness tourism. This sector of the wellness economy therefore represented a stable and expanding investment opportunity, particularly in regions with established traditions. The combination of historic practices with contemporary wellness services and infrastructure upgrades strengthened the investment rationale, while government involvement signalled long-term strategic support and regulatory de-risking, thereby enhancing market stability.

Consequently, the investment attractiveness of the thermal and mineral springs market was assessed as high owing to stable growth, governmental backing and expanding consumer interest in natural therapy and cultural experiences. This was supported by data indicating that over 350 new thermal and mineral springs development projects were launched globally between 2020 and 2024, with over 230 additional projects in preparation and development. The market presented investment opportunities, particularly in luxury service provision and the integration of advanced technologies (Exploring opportunities in Hot Springs Resort sector, 2025). Thermal and mineral springs establishments that incorporated SPA services generated over two-thirds of total industry revenue and exhibited higher revenue growth rates, which underscored the profitability of this segment when integrated with value-added SPA services. The sustainability of the thermal and mineral springs market was contingent upon a range of factors, including reliance on natural resources – particularly the quality and accessibility of the water source. At the same time, active governmental support, which promoted these sites as key wellness tourism offerings, signalled a focus on long-term viability (Thermal/mineral springs, n.d.). In addition, rising demand for unique, immersive cultural experiences supported sustainable development by reinforcing the value and preservation of local heritage.

Global mud-based and natural cosmetics market: Trends, investment potential, and sustainability

North America remained the leading market for Dead Sea mud cosmetics; however, the Asia-Pacific region was rapidly gaining momentum, particularly in the mud mask segment (Global mud mask market size..., 2025). The available data on mud therapy were primarily focused on mud masks and Dead Sea mud cosmetics, applications that largely belonged to the beauty and cosmetics sector. The robust growth of the mud cosmetics market was driven by consumer demand for natural and organic skincare products, perceived benefits for various dermatological conditions (e.g., detoxification, exfoliation and nourishment), and the rising influence of self-care practices. Therapeutic benefits (e.g., pain relief, improved circulation and stress reduction) were frequently cited as key drivers of adoption. While direct data on the size of the mud therapy market as a medical procedure (e.g., balneotherapy utilising mud applications) were scarce, the consistent growth of the mud-based cosmetics market demonstrated strong consumer acceptance and belief in mud's healing properties. This suggested an opportunity to expand into more formalised therapeutic applications by leveraging consumer trust in natural ingredients established within the cosmetics market. The primary challenge lay in quantifying the therapeutic segment and in scientifically validating and justifying the extension of medicinal applications within this domain.

Investment attractiveness, particularly within the cosmetics segment, was substantial. This was driven by rising incomes and the robust development of e-commerce (Global mud mask market size..., 2025). Considerable demand for natural and organic cosmetics was reported, and significant growth opportunities existed within premium formulations and influencer-promoted product segments. The primary challenges encompassed consumer health risks (notably skin sensitivities and allergic reactions), as well as regulatory hurdles, particularly with respect to the safety and labelling of cosmetic products. At the time of analysis, specific data on profit margins for the global mud mask market and, more broadly, for the mud therapy industry were not available in international analytical reports or other information sources. However, given the premium positioning of Dead Sea mud products, margins were expected to be robust. The global mud mask market was primarily driven by consumer preference for products based on natural ingredients; however, market stability was assessed as moderate due to intense competition, the volatility of consumer trends requiring continuous product-range updates, and susceptibility to global economic and logistical risks. Although these factors were documented and analysed in international sources, they limited market stability and exposed performance to fluctuations in demand, pricing, sales volumes and profitability.

The global natural cosmetics market was characterised by stable and continuous growth, largely driven by increasing consumer preference for natural, organic and eco-friendly products (Singh, 2025). A strong and consistent trend was observed across the natural cosmetics and pharmaceutical sectors: consumers were increasingly opting for "clean label" products, thereby avoiding synthetic chemicals and artificial ingredients. This shift was driven by concerns regarding potential health risks and by the desire for greater transparency and sustainability in the sourcing and production of natural products. The trend reflected a broader convergence of health and beauty, with consumers increasingly regarding what is applied to the body as comparable in importance to what is consumed. Within pharmaceuticals, the preference for "natural" translated into demand for herbal formulations that were perceived to be associated with fewer side effects (Natural APIs market..., 2025). Companies in these sectors were therefore expected to prioritise ingredient transparency, ethical sourcing practices and environmentally sustainable packaging. Investment opportunities were particularly strong for brands able to demonstrate these qualities credibly, as well as for research and development into advanced extraction technologies and green chemistry for natural active pharmaceutical ingredients (APIs). Additional competitive advantage was associated with the ability to secure organic or cruelty-free certifications (Kesharwani, 2025).

The investment attractiveness of the natural cosmetics and pharmaceuticals market was substantial, driven by robust consumer demand, rising incomes and technological advances in natural raw-material extraction. M&A activity was concentrated in high-margin clinical and sustainability-focused brands. Market challenges encompassed high costs associated with premium products, short product shelf life and regulatory complexities related to product certification (Natural and organic personal care products..., 2025). The natural API market was characterised by high profitability in biological APIs and rapidly increasing demand for herbal ingredients in medicinal products (Natural APIs market..., 2025). Sustainability factors in the natural cosmetics and pharmaceuticals market centred on sustainability principles, eco-friendly packaging and cruelty-free practices, while concurrently being driven by consumer demand for ethical consumption. Regulatory support for natural therapies and environmentally conscious pharmaceutical production also functioned as an enabling factor. Challenges included limited sourcing availability, specifically the restricted number of organic ingredient suppliers, and lower product stability observed in some natural formulations (Organic skin care products market..., 2025).

Nature-based and ecotourism: Market trends, investment potential, and sustainability

Nature-based tourism was positioned as "more than just a source of revenue – it is a strategic tool that... drives conservation, improves livelihoods, and supports local economies". It generated funding for biodiversity conservation through tourism concessions and visitor fees, particularly for protected areas and reserves (Nature-based tourism, 2024). This relationship suggested a direct linkage between environmental conservation and economic viability. By protecting natural assets, ecotourism enterprises not only attracted environmentally conscious travellers who were often willing to pay a premium (Castro, n.d.), but also secured government support and access to conservation-focused investment capital (Unlocking the potential of nature-based tourism..., n.d.). This premium typically reflected a surcharge for a unique experience and a direct contribution to environmental conservation. Investment in recreational tourism leveraging NHA was therefore expected to prioritise projects with strong conservation and community-engagement components. Such an impact-investing approach not only aligned with evolving consumer values, but also created a more sustainable and commercially viable business model, potentially unlocking additional financing sources, such as sovereign debt refinancing for conservation (e.g., blue bonds or nature bonds) (NatureVest is TNC's impact..., n.d.).

The investment attractiveness of the nature-based tourism market was substantial, owing to robust growth, escalating demand for sustainable tourism and its positive economic impact on local communities (Ecotourism market size, share & industry analysis..., 2025). Investors had opportunities for capital deployment within the sustainable tourism sector. Promising areas included eco-lodges, which offered accommodation designed to operate in harmony with nature, and sustainable transport solutions that reduced environmental impacts. NatureVest (an initiative of TNC – The Nature Conservancy) supported conservation-focused tourism investments (NatureVest is TNC's impact..., n.d.). Market challenges encompassed regulatory hurdles, market volatility and the need to balance conservation objectives with profitability.

Revenues from guided tours were reported to generate profit margins of 10% to 15%, while eco-lodge profit margins were reported to range from 15% to 20% (Sheykin, 2025b). Ecotourism revenues could be substantial and were reported to contribute to a 20-30% increase in household incomes in certain regions. The long-term viability of the nature-based and ecotourism market was underpinned by its foundational principles: environmental preservation and the sustainable use of natural resources (Ecotourism market size, share & industry analysis..., 2025). The sector contributed to biodiversity conservation and the creation of employment opportunities in rural communities (Nature-based tourism, 2024). Demand for ecotourism was increasing as consumers increasingly favoured sustainable travel options. The sustainability of the market also depended on the active participation of local communities (Ecotourism investments..., n.d.).

Climatotherapy in health tourism: Market potential, investment, and sustainability

Climatotherapy was regarded as a "health tourism product" and a "non-biomedical natural resource" used for therapeutic purposes and health promotion (Droli *et al.,* 2022). International sources did not provide sufficiently clear data to assess the size of the global climatotherapy market as a distinct sector within the health and treatment domain. However, available sources reported financial metrics characterising the costs associated with managing specific diseases that were frequently treated with climatotherapy. For instance, the annual cost of managing psoriasis per patient was reported to range from 2,077 USD to 13,132 USD. Specifically, the direct cost of Dead Sea climatotherapy, which covered European patients' flights, transfers, four-week accommodation and medical supervision, was reported to be 5,800 USD per patient (2020 data) (Emmanuel *et al.,* 2020). These estimates underscored the substantial financial resources required to address chronic health challenges of this nature.

The absence of explicit market data indicated that climatotherapy was often integrated into broader health tourism packages or medical procedures rather than operating as a distinct, readily quantifiable market. Its economic viability was therefore likely to be linked to the value added to larger offerings (e.g., mitigation of long-term healthcare expenditure for chronic conditions) (Harari, 2020). While direct capital investment in climatotherapy centres was difficult to quantify, opportunities existed for investment in health and wellness tourism destinations that leveraged unique climatic conditions as "health devices" (Droli *et al.,* 2022). This required the development of evidence-based marketing strategies capable of quantifying climatotherapy effects and integrating them into comprehensive therapeutic and wellness offerings. Such an approach could have attracted patients seeking nature-based options for chronic conditions. Consequently, the economic viability of climatotherapy was more appropriately assessed not as a separate market, but in terms of patient-level cost-effectiveness and the added value generated for health tourism providers.

The investment attractiveness of climatotherapy as an independent sector within the wellness or medical industry was assessed as low to moderate. This assessment reflected the lack of clear market data, alongside the need for scientific validation and integration into broader health tourism offerings. Conversely, investment appeal could increase to moderate or high where climatotherapy services were integrated into established health tourism or medical treatment programmes that capitalised on NHA (Pessot *et al.,* 2021). Investment in research aimed at quantifying climatotherapy benefits, together with the development of evidence-based marketing strategies, could have supported its longer-term potential as a more distinct segment of the wellness economy. More broadly, climatotherapy was contingent upon the preservation of natural resources, including air quality, therapeutic environmental factors and specific microclimates. Given that sustainable development in health tourism emphasised the judicious use of natural resources (Castro, n.d.), this dependency presented inherent constraints. The core challenges facing climatotherapy included inadequate scientific substantiation of climatic effects on patients and the limited availability of robust research evidence, which hindered broader recognition and adoption.

Consolidated analysis of global markets using natural healing assets

The general results were presented on the basis of the data and conclusions derived from the detailed analysis of global markets for specific activities using NHA, in order to facilitate interpretation of the above information. The estimated forecast volumes of the above markets for activities using NHA, calculated according to formula (2), were presented in Figure 1.

The calculated projected volumes for the aforementioned activity markets using NHA characterised the aggregated value distribution across these markets up to 2028. To ensure robust calculation results, 2028 was set as the boundary condition, as this timeframe encompassed the limits of all reported CAGRs (Table 1). Figure 1 demonstrated that, by 2028, the three leading market sectors were projected to be wellness tourism, bottled and mineral water production, and nature and ecotourism. In turn, the projected market growth rates for activities using NHA through 2028 exhibited a distinct trend (Fig. 2).

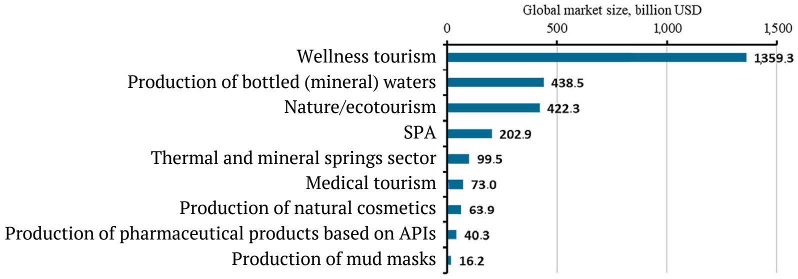

Figure 1. Distribution of the forecasted of the global market size for activities using NHA by 2028
Source: compiled by the author

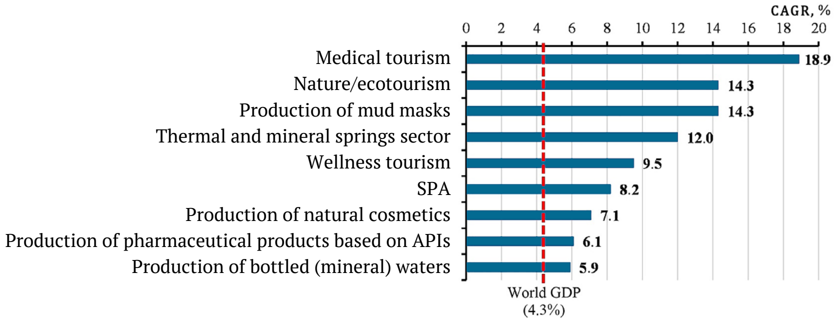

Figure 2. Compound annual growth rates (CAGRs) of the global markets size for activities using NHA in the period 2023-2028
Note: red dashed line indicates the calculated CAGR of World GDP
Source: compiled by the author

The medical tourism market was projected to exhibit the fastest growth, followed by nature and ecotourism development and mud mask production, which shared the same growth level. The thermal and mineral springs sector completed the top three. The growth rate of wellness tourism, the highest-value market in the analysis, ranked only fourth. It should be highlighted that the CAGR values of the global markets for the aforementioned activity areas using NHA exceeded that of world GDP. This indicated high potential and dynamic development within these markets, implying that they were expected to expand significantly faster than the global economy overall. Such a trajectory positioned the aforementioned markets as attractive investment prospects given their promise of high profitability. Investors seeking capital appreciation opportunities could therefore have favoured these economic sectors. These projected growth rates for activities using NHA also suggested greater resilience to potential economic downturns, as individuals often prioritised health-related expenditures during periods of economic hardship, which, in turn, enhanced market stability. The summarised results were also presented in summary Table 2 to support clearer interpretation of the above information.

Table 2 presented a quantitative and qualitative assessment of global markets for activities using NHA according to the following criteria: market stability, investment attractiveness, profit margin and market sustainability. Although these assessments were formed on the basis of the generalised detailed information presented above, additional justification for certain assessment features was provided. This primarily applied to the profit margin criterion, specifically the assessments "High (implicit)", "Implicit", and "High (with services)". For example, a high (implicit) profit margin in the medical or wellness tourism market indicated that profits captured by medical and healthcare institutions and intermediaries were substantial, but not always evident at first glance. This assessment reflected several features. First, medical tourism services were typically expensive, as they included not only medical and wellness procedures, but also logistics (flights, accommodation, interpreters, etc.), thereby creating wide scope for generating significant profits. Second, margins could be implicit because profitability was not derived solely from direct revenues from medical and wellness services. A substantial share of income could be generated through related services, such as intermediary services (medical and wellness tourism agencies received commissions for attracting patients, which could be significant), comprehensive packages (patients were offered "all-inclusive" packages rather than individual services, potentially including rehabilitation, spa treatments and excursions, thereby increasing overall pricing and profit), and price differentials (pricing often varied substantially between local residents and international patients, with the latter typically paying higher prices for procedures). In addition, given the extensive service ecosystem (consultations, procedures, accommodation and transfers), it was not always straightforward to determine the precise contribution of each component to profitability, thereby reinforcing the implicit nature of the margin. Thus, a high (implicit) margin indicated that participants in the medical and health tourism market (clinics, sanatoriums and agencies) generated significant profits that could be obscured by complex pricing structures and by revenue from complementary services.

Table 2. Assessment of criteria for global markets for activities using NHA

Type of entrepreneurial activity	Market stability	Investment attractiveness	Profit margin	Market sustainability	Key rationale / notes
Medical tourism	High	High	High (implicit)	High	Strong post-pandemic recovery, growing demand for quality/affordable healthcare, government support. Growing health awareness, medicalisation of wellness.
Wellness tourism	High	High	High (implicit)	High	
SPA	High	High	10% – 25%	High	
Production of bottled (mineral) waters	High	Moderate – High	10% – 15%	High	Stable market, driven by the transition to a healthy lifestyle, emphasis on environmental friendliness.
Production of mud masks	Moderate – High	High	High (implicit)	Moderate	Strong demand for natural cosmetics, perceived therapeutic benefits, growth of e-commerce. Demand for clean labels, natural ingredients, ethical consumption, investment in research and development (R&D).
Production of natural cosmetics	High	High	High (implicit)	High	
Production of pharmaceutical products based on APIs	High	High	High (implicit)	High	
Nature/ecotourism	High	High	10% – 20%	High	Growing demand for sustainable tourism, connection with nature, positive economic impact on communities.
Climatotherapy	Moderate	Low – Moderate	Implicit	Moderate	Integrated into medical/wellness tourism, requires scientific validation, depends on the preservation of natural conditions.
Thermal and mineral springs sector / tourism to this sector	High	High	High (with services)	Moderate-High	State and private support, growing interest in traditional healing, cultural aspects.

Source: compiled by the author

The stability of the mud mask market was assessed as moderate to high due to growing consumer demand for natural products and innovations that attracted new customers. However, market sustainability remained moderate, as the segment was exposed to changing trends, intense competition and external economic factors that could cause fluctuations in demand and profitability. These factors could generate unpredictability despite generally positive market dynamics. Overall, the market was developing, but not without material risks. General justifications for the qualitative assessments established for climatotherapy activities were also provided, despite the detailed discussion of this activity above. Given the characteristics of the climatotherapy segment, namely its integration with other wellness markets, its stability was assessed as moderate. As part of the broader medical and wellness tourism sector, it remained dependent on economic cycles and consumer demand, which could fluctuate. Its profit margin was assessed as implicit, as income was generated less from the therapy itself than from comprehensive service packages that included accommodation, meals and other related procedures. Investment attractiveness was assessed as low to moderate due to the lack of explicit market data and the need for substantial investment in scientific substantiation of effectiveness. Finally, market sustainability was assessed as moderate because it depended on the preservation of unique natural resources and on further research confirming medicinal value.

The profit margin of the thermal and mineral springs market was assessed as high (with services), as substantial revenues were generated not only from the springs themselves, but also through integration with highly profitable SPA services and luxury offerings. High growth rates were observed in this segment in association with such integration. Market sustainability was assessed as moderate–high because, although the sector depended on natural resources, its long-term viability was supported by growing demand for wellness tourism, active government support and investments aimed at preserving and modernising infrastructure. This indicated an ability to adapt and develop despite resource-related constraints. Thus, the consolidated analysis results were important for assessing markets using NHA, as they provided a comprehensive and comparative overview that was interpretable for stakeholders at different levels. The analysis enabled rapid identification of the scale and dynamic growth of this segment of the global economy. The results obtained could also serve as a basis for more in-depth examination of individual sectors by indicating areas of strength in development trajectories and in the utilisation of NHA.

International models of NHA integration into economic systems

International experience in the use of NHA in entrepreneurial activities demonstrated a variety of models that reflected national priorities, regulatory approaches and the investment climate. At the international level, three main models of integrating NHA into economic systems were most common: a state regulation model characterised by significant government involvement in the regulation, development and, often, operation of resorts and health facilities, with the aim of ensuring quality, accessibility and public health benefits; a private initiative model driven predominantly by private enterprises focused on market demand, innovation and profitability, which often resulted in a wide range of luxury service offerings and establishments; and a public-private partnership (PPP) model characterised by shared regulatory and management approaches in which the government and the private sector shared risks, responsibilities and benefits. PPP models covered a wide spectrum of arrangements, ranging from direct provision of services by the state to full privatisation. They were characterised by risk sharing and by the pursuit of common economic and socially significant objectives on mutually beneficial terms (Turchenko, 2024). This understanding was consistent with definitions provided by the United Nations Economic Commission for Europe (UNECE) (2017) and the Green Paper on Public-Private Partnerships and Community Law on Public Contracts and Concessions (2004).

The rationale for public ownership and management of NHA was based on the principle that certain resources, especially those that were limited and unique, were best classified as “public goods”. This economic concept defined a good that was both non-excludable (it was difficult to prevent people from benefiting) and non-rival (use by one person did not reduce the possibility of use by another). For example, protecting a thermal spring or a rare ecosystem ensured its preservation for future generations, a benefit that was difficult for a private enterprise to monetise (Sryberko & Stepanova, 2025). Thus, the role of the state was that of a long-term manager acting in the interests of the general public rather than for private profit. The state model offered several key advantages. It could ensure social equality and broad accessibility by preventing the formation of private monopolies that could under-supply a resource or charge fees that excluded large parts of the population. Furthermore, unlike the private sector, which was driven primarily by profit incentives, the public sector was oriented towards long-term sustainability and protection of NHA (Aggestam Pontoppidan *et al.,* 2024). This was particularly important for vulnerable assets such as hydrothermal aquifers, which could be threatened by over-pumping for agricultural or urban use (Global Wellness Institute, 2024). Finally, public management of these assets could generate revenue that flowed back to local communities, supporting public services and infrastructure that benefited both residents and tourists (Lee, 2024). At the same time, the public sector model also had significant drawbacks. The most common criticism concerned the lack of a direct profit motive, which could lead to operational inefficiencies and slow responses to market demand. State-owned enterprises could also be susceptible to political influence and bureaucratic obstacles that undermined management effectiveness. In addition, such entities could experience difficulties in raising the capital and securing the technical expertise required to develop and implement innovations at a pace that remained competitive in rapidly evolving markets.

International examples highlighted a spectrum of state involvement in the management of these assets. Hot Springs National Park in the United States provided an example of public administration. The National Park Service (NPS) had broad authority to regulate the use of hot spring water, distributing it to public fountains and to private businesses such as bathhouses and hotels (Hot Springs National Park..., 2024). The NPS acted as steward and regulator, ensuring sustainable water use while allowing private businesses to operate within a clear regulatory framework. This model demonstrated a public-oriented approach in which ownership of the underlying asset was retained by the state while use was leased to the private sector. In contrast, Oita Prefecture in Japan illustrated a more proactive public role in economic development. The regional government acted not only as regulator but also as a strategic planner that actively promoted "ONSEN culture". It explored new opportunities for thermal springs, including their use in tourism development, as a resource in medicine, healthcare and cosmetology, and as a sustainable energy source (Case studies in hot spring use for sustainable energy, 2019). These examples indicated that public administration could range from predominantly regulatory functions to active market development of NHA-based activities, depending on government strategy.

The private sector was a dominant force in many markets using NHA, including medical and wellness tourism and SPA services. The main principle driving this model was the profit motive, which incentivised companies to pursue efficiency and allocate resources to the most productive and profitable projects. As a result, profit incentives shaped both service quality and investment direction. The strengths of the private model were closely linked to this core principle. Competition motivated businesses to deliver high-quality or luxury, personalised and innovative services, which was crucial for attracting and retaining customers. For example, luxury SPAs such as the Four Seasons Hotel Toronto offered differentiated services, including "biohacking" and "holistic" treatments, which positioned them distinctly within the market (Toronto luxury spa & wellness, n.d.; Four seasons Toronto spa launches biohacking treatments, 2023). This focus on differentiated offerings and exceptional customer service created memorable experiences that encouraged repeat visits and favourable reviews. In addition, private enterprises could mobilise capital quickly and adapt to changing consumer needs. This capability was important in fast-evolving markets in which being first to market with emerging trends, such as sleep tourism (travel with an emphasis on improving sleep quality) or digital detox retreats (travel intended to reduce technology exposure and support mental well-being), could represent a major competitive advantage (2025 wellness tourism report, 2025). The profit motive also supported a sustained focus on operational efficiency. The case of Castle Hot Springs (n.d.), a private resort, illustrated this: by implementing a new software system, the resort was able to maximise the number of treatments per day and fill gaps in its event schedule, which directly increased revenue and improved financial reporting.

It should be noted that the strengths of the private model could also function as weaknesses. The pursuit of luxury services with high margins often led to high costs, which limited accessibility for wider audiences, as premium pricing and luxury amenities were primarily targeted at affluent travellers (service consumers) (Bora, 2025). Moreover, an exclusive focus on profit could generate adverse social and environmental consequences. For example, private development of medical tourism had been criticised for encouraging a parallel (private) healthcare system that was insufficiently responsive to local population needs. This could create a two-tier system in which private resources and expertise were siphoned from the public healthcare system to serve only the "marketable" segment of society (Ormond *et al.,* 2014). This contrasted with forms of health tourism which, when integrated with local communities and environmentally responsible practices, could stimulate regional development, create employment opportunities and improve local population health by promoting preventive care and reducing pressures on local health systems. The divergence in social outcomes between these trajectories indicated that the type of tourism and the governance model could produce fundamentally different consequences for community well-being. The private sector's capacity to monetise and revitalise NHA was illustrated by Castle Hot Springs (n.d.) in Arizona. This privately owned hotel used its mineral thermal waters to operate as a luxury all-inclusive wellness resort. The case highlighted how private capital restored a historic, fire-damaged asset that had not been used for over 40 years after 1976 and converted it into a profitable enterprise from 2019. In Australia, case studies in North-West New South Wales showed how private landowners could work with public services to manage and restore natural assets on private land. This model demonstrated that private property arrangements could be aligned with public-good outcomes, often with support from public services.

PPP represented a hybrid model in which public and private organisations entered into long-term contracts to finance, design, build and operate infrastructure or services (New WHO report..., 2023). This approach was gaining prominence as a strategic tool for governments seeking to address funding gaps and budget constraints, particularly for large-scale projects related to NHA-based infrastructure, such as modernising balneological clinics or expanding resort complexes. PPPs were described as a mechanism for "expanding access to the highest quality health services by attracting capital, management capacity and know-how from the private sector", which was relevant for elevating medical and wellness tourism built around unique NHA. One of the main advantages of PPPs was the capacity to share risks and financial burdens between the public and private sectors. For instance, private companies were incentivised to manage risks such as construction delays or cost overruns during the development of a thermal resort or specialised medical facility, as profitability often depended on project performance (The advantages and disadvantages of public-private partnerships, 2024). This risk-sharing approach supported more reliable implementation of NHA-related projects. In addition, PPPs provided the public sector with access to innovation and specialised private-sector expertise that might not have been available internally. The private sector could introduce advanced technologies, including modern water conservation methods for hydrothermal aquifers, streamlined operational processes and efficient management practices that accelerated NHA development and improved outcomes. By leveraging private capital, governments could implement NHA-related infrastructure projects – such as a multi-specialty medical facility near a mineral spring – that would otherwise have been financially unfeasible (Stucke & Humphreys, 2019).

Despite these advantages, PPPs also had significant disadvantages, particularly concerning the long-term management of public resources such as NHA. While PPPs could appear to provide short-term "relief for state budgets", contracts signed in the present could "significantly burden state budgets tomorrow" once assets became operational and payment obligations matured. Financial benefits were not guaranteed and were realised only when PPPs represented the "most cost-effective solution" compared with alternative financing and implementation options for NHA projects (New WHO report…, 2023). A core problem with PPPs was the potential blurring of boundaries between public objectives (sustainable use and accessibility of NHA) and private profit motives (Understanding public-private partnerships…, 2025). These long-term contracts (typically 20-30 years) could be politically and legally complex and difficult to monitor, which created risks of reporting gaps and opportunities for corruption, particularly in determining fair use and pricing of natural resources (The advantages and disadvantages of public-private partnerships, 2024). The private partner could be insulated from liability for poor-quality services and, in cases of geographic or legal monopoly (e.g., sole access to a unique spring), could increase fees for customers who could not switch providers. The World Health Organization (WHO) recommended that, for PPPs to be effective in the health sector, governments should first build internal capacity to design, plan and monitor these complex arrangements, as this was a core governmental function that could not be outsourced to external agencies (New WHO report…, 2023). Overall, many countries had used PPPs to accelerate development in healthcare and tourism. The World Bank and WHO had advocated PPPs as a means of expanding access to high-quality health services, while emphasising the need for sufficient institutional capacity to manage them effectively. Countries such as Malaysia, Thailand and the UAE had used government strategies and PPPs to position themselves as global medical tourism hubs (Government support and policy reforms…, 2025). This included joint initiatives to develop state-of-the-art healthcare clusters and to market services to international patients (Government support in medical tourism promotion…, 2025). These examples indicated that PPPs could be instrumental in developing medical tourism industries by combining private-sector investment with public policy and promotion.

Thus, the prevalence of different models (public, private and PPP) indicated the absence of a single best approach. The optimal model depended on context, national priorities (e.g., public health versus tourism revenues) and the specific characteristics of the NHA. PPPs, in particular, offered a flexible framework for leveraging private capital and efficiency while maintaining public oversight and pursuing social objectives. This indicated that the most effective model for integrating NHA into economic systems was situational and required strategic alignment between national health priorities, economic development goals and the specific attributes of NHA.

Comparative sectoral analysis of models

To better understand which models of integrating NHA into economic systems were the most effective, their application across different sectors of the health economy was analysed. Based on the industry report Medical tourism market (2025-2030) (2025), the private model dominated the medical tourism sector in 2024, as indicated by the private segment's revenue share of 54.47%. Private hospital chains and healthcare institutions, including Apollo Hospitals and Bumrungrad International Hospital, were key players in the market, driving innovation and attracting international patients. The role of the public sector in this market was primarily supportive and regulatory, creating an "enabling environment" through strategic policies such as visa facilitation, tax incentives and the promotion of international accreditation standards. The PPP model was particularly valuable for large-scale, capital-intensive projects, such as the development of specialised "healthcare clusters" that brought together service providers and research institutions in one location to offer patients a full range of services (Government support in medical tourism promotion…, 2025).

The wellness tourism and SPA markets were almost entirely driven by the private sector. Large international hotel chains such as Hilton, Hyatt and Four Seasons were key players, leveraging their brands and capital to offer differentiated luxury wellness services (Ecotourism market size, share & industry analysis…, 2025). The private sector's ability to innovate rapidly and create luxurious, personalised experiences represented its core competitive advantage. Although the market was profit-driven, the public sector could still play a crucial role by investing in public infrastructure such as parks, trails and pedestrian areas that benefited both local residents and tourists and supported a holistic wellness ecosystem (2025 wellness tourism report, 2025). Collaborative efforts, such as partnerships between private enterprises and local governments, could also function as a tool to promote destinations and ensure the quality of visitor experiences.

The management of unique NHA created a distinct set of challenges. The legal and economic arguments for state ownership of scarce resources such as aquifers and thermal springs were strong, as this was regarded as the most reliable way to ensure long-term conservation and prevent market failure. Private companies were likely to face the free-rider problem (Sryberko & Stepanova, 2025) and were therefore unlikely to deliver the full public value of the resource. The Hot Springs National Park model demonstrated a viable framework in which public ownership of an asset was combined with private use. The government retained custody of the underlying resource, while private companies operated facilities and services that used it, thereby supporting both conservation and commercial viability. This hybrid approach offered a practical solution for balancing NHA conservation with economic development.

The production of mud masks and natural cosmetics was almost entirely controlled by the private sector. This highly globalised market was shaped by consumer demand and commercial innovation. Its main driving forces were growth in disposable incomes, the rapid development of e-commerce and increased interest in specialised skincare products. Key players in this market included international companies such as Israeli AHAVA and Aroma Dead Sea, American Asutra and AVANI Supreme, and the British clinic HB Health, which specialised in natural products and advanced wellness services based on NHA. Within this market, natural medicinal ingredients were directly linked to commercial success, with production, sales and profits dependent on capital flows and market trends. To visualise the effectiveness of each model, a comparative matrix was developed based on key criteria such as innovation, capital mobilisation, operational efficiency, social equality, risk profile, sustainability and reporting (Table 3).

Table 3. Comparative matrix of business models

Criteria	Public sector model	Private sector model	Public-Private Partnership (PPP) Model
Innovations	Low (often slow adaptation due to bureaucracy)	High (profit motive drives continuous innovation and new service offerings)	Medium-high (uses private sector innovation within a defined framework)
Capital mobilisation	Low (depends on state budgets and tax revenues)	High (can quickly raise capital from investors and financial markets)	High (uses private capital to bridge gaps in public funding)
Operational efficiency	Low (lack of profit motive can lead to inefficiency and slow decision-making)	High (profit motive drives streamlined operations and productivity)	High (private sector experience and incentives drive operational efficiency)
Social equality and accessibility	High (main goal is to ensure broad public access and benefit)	Low (high costs often limit services to affluent consumers)	Variable (could be designed to facilitate public access, but there are risks of high fees and limited accountability to users)
Risk profile	High (bears all financial and operational risks)	Low for public (transfers risk to private sector); High for private (market, financial, operational risks)	Shared (risks are shared between public and private partners, often based on their ability to manage them)
Sustainability and conservation	High (long-term management is the main rationale)	Variable (possibility of short-term focus on profit over sustainability)	Variable (depends on contract terms and regulatory oversight, but can promote sustainable practices)
Reporting	High (directly accountable to citizens and public oversight)	High (accountable to shareholders and customers, including through feedback, competition)	Low (boundaries can be blurred and private partners can be shielded from reporting)

Source: developed by the author

The comparative sectoral analysis demonstrated that the choice of business model significantly influenced the effective use of NHA and the achievement of both economic and social objectives. The analysis differentiated spheres of influence: the private sector dominated medical tourism, wellness services and cosmetics production, while public ownership was most justified in the management of unique natural assets such as thermal springs in order to prevent market failures and ensure long-term resource conservation. The study also emphasised the importance of PPPs as a hybrid solution that combined the innovative potential and capital of private business with public oversight of resource preservation and the delivery of public benefits. This comparative analysis was relevant for policy development, investment strategies and NHA management, as it provided a basis for informed decisions regarding the optimal model for a specific NHA type and economic context.

Comprehensive practical recommendations for the use of NHA in Ukraine (considering international experience)

Based on a comprehensive analysis of international experience in the use of NHA, well-founded and practical recommendations were formulated for Ukraine. These recommendations, derived from global best practices, were intended to support Ukrainian entrepreneurs, investors and government authorities in making informed management decisions. For entrepreneurs, diversification of offerings beyond traditional sanatoriums was required, including development of wellness and SPA services, ecotourism, and products based on natural raw materials, particularly NHA. This diversification was expected to respond to growing consumer demand for preventive health solutions and holistic wellness experiences. A focus on niche markets was also recommended, using unique Ukrainian NHA (e.g., specific mineral waters, healing muds and distinctive climatic zones) to develop specialised services; the example of Israeli Dead Sea mud therapy illustrated how a unique natural resource could be converted into a recognisable, high-value offering. Investment in service quality and personalisation, together with the adoption of modern technologies, was expected to strengthen competitiveness. The integration of sustainable practices was also emphasised, as this was required to ensure long-term resource availability and to enhance appeal to environmentally conscious customers.

For investors, conducting thorough due diligence was identified as essential and was expected to include assessment of NHA characteristics, the local regulatory environment and market demand. Consideration of PPP models for large infrastructure projects was recommended, as this approach could reduce risks and leverage government support. A long-term investment horizon was required because many projects were capital intensive and associated with extended payback periods; therefore, emphasis on sustainable income generation was recommended. Portfolio diversification was also identified as beneficial, including investment across different NHA-based business types such as mineral water production and wellness resorts in order to spread risk. For government authorities, the development of a comprehensive national strategy for NHA development was recommended, integrating public health objectives, economic development priorities and environmental sustainability requirements. Regulatory optimisation was also identified as critical, including simplification of licensing procedures and establishment of transparent quality standards to attract investment. Investment in basic infrastructure – transport, utilities and digital connectivity – in potential resort areas was prioritised. Active promotion of PPP mechanisms for large-scale projects was also identified as an important element. In addition, human capital development was expected to be supported through vocational training programmes in order to address potential shortages of qualified personnel. Development of a national brand and marketing strategy to promote Ukraine's unique NHA internationally was also emphasised as a critical requirement.

Adaptation of international experience required strategic localisation that accounted for Ukraine's specific conditions. Priority was placed on leveraging existing natural assets, including mineral water reserves in Zakarpatska, Lvivska, Poltavska and Dnipropetrovska oblasts, as well as healing muds, estuary brine, the Black Sea and Azov Sea coasts, and other favourable climatic zones. Medical rehabilitation was identified as a priority in view of martial law in Ukraine. For this purpose, elements from Germany (state support for wellness programmes) and Israel (strict state supervision in medical tourism) were identified as potentially adaptable. It was also recommended that sustainability risks should be addressed proactively through environmental protection measures in order to avoid challenges observed in other contexts, including excessive-tourism pressures reported in Japan. Investment in digitalisation was also recommended, including online booking tools and customer relationship management (CRM) systems that had been implemented successfully in other countries. The development of vocational training programmes was also recommended to address labour market constraints, taking into account experiences reported in the Czech Republic.

Determination of priority areas for entrepreneurship development in the NHA domain in Ukraine was based on global trends, national needs and existing competitive advantages. Priority directions included medical rehabilitation and wellness tourism, ecotourism and recreational complexes, production of natural cosmetics and pharmaceuticals, bottled mineral water production, and specialised niche therapies. Economic development via NHA integration into entrepreneurial activity was assessed as dependent on the creation of an enabling ecosystem in which policy measures, investment flows and business initiatives were mutually supportive and coordinated. Optimal NHA development therefore required stakeholder synergy (government, entrepreneurs and investors) to balance economic growth, social accessibility and resource sustainability. The recommendations outlined a three-pillar approach to NHA integration in Ukraine, emphasising diversification of entrepreneurial models, targeted investment, and implementation of a comprehensive national strategy. The analysis indicated that an optimal NHA development model required coordinated action between government, investors and entrepreneurs to balance economic growth, social accessibility and resource sustainability.

However, movement from strategic guidelines to effective implementation required further detailed research. In particular, detailed study of international permitting and licensing systems for NHA-related activities was required. This would enable optimisation of Ukraine's regulatory framework, simplification of procedures for investors and entrepreneurs, and establishment of transparent quality and environmental safety standards. Without such focused research, recommendations for regulatory optimisation were expected to lack the specificity required for effective implementation, which could hinder the formation of clear and transparent rules needed to attract significant investment and realise the full potential of Ukraine's NHA.

DISCUSSION

The study, encompassing a comprehensive analysis of international experience in the utilisation of NHA, empirically confirmed the fundamental role of this sector in strategic economic recovery, especially in the context of post-war development. Analysis of global market dynamics highlighted the exceptional investment attractiveness of NHA-based segments. A key finding was that the CAGR of all nine analysed markets consistently exceeded the CAGR of World GDP. This positioned these sectors as highly profitable and resilient to macroeconomic shocks, which was important for prioritising investment in Ukraine. The results indicated that medical tourism demonstrated the highest projected annual growth rate (23.0% CAGR). This indicator was substantially higher than that of the largest segment by volume, wellness tourism (10.2% CAGR) (Medical tourism market (2025-2030), 2025). This pattern signalled a shift in global investment and consumer focus from general recreational activities to specialised, results-oriented medical and preventive services. Consequently, market demand for services utilising NHA was becoming increasingly selective, requiring not only relaxation but also clinically substantiated outcomes.

This trend towards the medicalisation of wellness aligned with conclusions reported in international academic research. D. Dryglas & M. Smith (2023), who analysed how Central European SPA resorts created complex "experiencescapes" for health tourism, supported the shift towards hybrid, scientifically validated wellness models as a necessary condition for achieving high profitability. Therefore, for Ukraine, strategic success was linked to integrating traditional sanatorium and resort treatment with high-technology medical procedures. Despite medical tourism's leadership in growth rates, wellness tourism, reaching nearly 1 trillion USD, ensured high stability for the sector. This substantial market volume provided demand resilience, which was supported by S.-H. Lee (2024), who emphasised that wellness tourism development, beyond direct economic benefits, generated significant positive socio-economic effects for local communities.

This substantiated the need for a national strategy that balanced rapid capitalisation of the most dynamic medical segments with the formation of a broad, stable base of wellness services.

The choice of CAGR as the principal tool for comparing market dynamics was scientifically justified. The use of formula (1) for calculating growth rates represented a standard methodology in international economic forecasting, as confirmed, inter alia, by A. Ahmed (2023) and H. Kaya (2025) in analyses of product export dynamics and market-size trend forecasting. Analysis of NHA-utilising sectors identified key barriers to commercialisation of traditional yet scientifically non-standardised resources. For Ukraine, which possessed unique natural assets (medicinal muds, distinctive climatic zones, etc.), overcoming these barriers was of strategic importance for full monetisation of these assets. The study indicated that traditional NHA-oriented segments such as climatotherapy had only moderate investment attractiveness and implicit profit margins. This limitation was associated with the absence of standardised market data and a deficit of scientific validation, which complicated positioning as an independent commercial product. At present, the economic value of climatotherapy was largely embedded within broader, complex wellness service packages. This situation created an investment opportunity. Despite low market transparency, the scientific community supported the therapeutic value of these procedures. A systematic review by J. Clark-Kennedy *et al.* (2021), which evaluated the impact of balneotherapy on mental health outcomes, reported a positive, though often undervalued, effect. To bridge the gap between scientifically supported efficacy and low market valuation, M. Droli *et al.* (2022) emphasised the need to develop evidence-based marketing approaches for formally positioning climate therapy as a distinct wellness tourism product.

The economic rationale for investment in scientific validation of climatotherapy was strengthened by its potential role in long-term management of chronic diseases. Research data indicated high costs of treating chronic conditions, reaching, for instance, up to 13,132 USD per year per patient with psoriasis. In this context, specialised climatic procedures, such as a four-week Dead Sea climatotherapy costing 5,800 USD, demonstrated economic feasibility. T. Emmanuel *et al.* (2020) and M. Harari (2020), analysing the efficacy of climatotherapy for dermatological patients, reported a favourable cost–benefit relationship in treating specialised diseases. Therefore, the economic value of these traditional NHA needed to be evaluated through the lens of long-term cost-effectiveness for the healthcare system as a whole, rather than solely through direct profit from tourism services.

In contrast to traditional therapeutic sectors, the production of natural cosmetics and APIs based on NHA demonstrated high investment attractiveness, stability and strong profitability. This segment was driven by growing demand for natural, organic and eco-friendly products, together with technological advances in natural raw-material extraction. Strategic diversification in this direction enabled export-oriented, high value added goods to be developed using reserves of minerals, healing muds and plant extracts. The transition from resource to finished product was essential for rapid monetisation. Scientific evidence supported this expediency, indicating that approximately 25% of modern medicines were derived from natural plant sources (Adetunji *et al.*, 2024; Sameen & Sultan, 2025). This provided a robust scientific and technical basis for utilising Ukrainian NHA in highly profitable pharmaceutical and cosmetology sectors, mirroring the success of global niche brands.

High profitability in natural product manufacturing could function as an important financial mechanism: capital accumulated by the private sector in commercially effective areas could be reinvested in, or attracted to, projects in less profitable but socially critical sectors such as medical rehabilitation. Diversification into commodity production (water, cosmetics and APIs) provided flexibility and reduced financial dependence on long-term investments exclusively in large infrastructure. Analysis of three main international models for NHA integration (public, private and PPP) showed that the optimal model was situational and needed to be determined by the specific asset and strategic objectives. The analysis confirmed that the public management model was most justified for unique, limited resources such as thermal springs or water-bearing horizons that could be classified as "public goods". The state's core function in this context was that of a long-term steward acting in the interests of the general public rather than for private profit. The need for state control over the natural assets themselves, which was important for preventing market failure and over-exploitation, was supported by A. Sryberko & Y. Stepanova (2025). The authors examined the definition of interests in natural-asset use in the context of "blue growth" and emphasised that state stewardship was required to ensure long-term sustainability and prevent over-exploitation driven by short-term private interests. Thus, state ownership of NHA extraction licences was required, while private-sector investment was expected to be concentrated in the service infrastructure that utilised these resources. Furthermore, E. Pessot *et al.* (2021), in a systematic review, emphasised that wellness tourism sustainability depended directly on preservation of unique natural resources and microclimates, a function that could rarely be fully ensured by the private sector alone.

The PPP model was identified as a key mechanism for large-scale and capital-intensive projects utilising NHA, as it enabled financial risk sharing and leveraged private-sector innovation. The emphasis on PPP as a tool for infrastructure modernisation paralleled evidence from critical infrastructure sectors. I. Turchenko (2024) highlighted PPP as a modern model for developing transport infrastructure, which could be extrapolated to the development of resort clusters and specialised medical facilities. This indicated that PPP represented not only a financing mechanism but also a management solution for accelerating NHA-sector development. However, the analysis also indicated that financial benefits from PPP were not guaranteed and were justified only when agreements represented the most cost-effective solution. Contract complexity (typically 20-30 years) and the potential blurring of responsibility between public goals (resource accessibility) and private profit required prioritisation of internal institutional capacity for planning, designing and monitoring these arrangements. The principal social risk of the private model was low social equity, as a focus on high margins constrained access to high-quality NHA services for the general population. This risk was particularly significant in Ukraine, where medical rehabilitation was a key state priority. Research by A. Asa & J. Nautwima (2025) suggested that medical tourism could deepen inequalities in access to health services by diverting resources and qualified personnel from local populations to wealthy international patients. Preventing a two-tier healthcare system was therefore critical. To reconcile private-sector efficiency with fulfilment of social functions, PPP arrangements aimed at utilising NHA needed to be designed with mandatory social obligations. This could include reserving a portion of modernised rehabilitation capacity for military personnel and affected populations funded by the state. Such an approach ensured that private capital investment in NHA infrastructure simultaneously supported state policy objectives for restoring human capital. The identified global trends indicated that Ukraine's NHA strategy needed to be two-pronged: financial capitalisation (through export of products and high-margin medical tourism) and social capitalisation (through mass medical rehabilitation). National prioritisation of medical rehabilitation and wellness tourism was justified, as it aligned with the highest observed global market dynamics (23.0% CAGR) and with immediate post-war population needs. Investment in rehabilitation based on natural resources (mineral waters, muds and climate) represented not only a social expenditure but also a critical investment in restoring work capacity and population health, which underpinned long-term economic growth (Medical tourism market (2025-2030), 2025). To translate high investment attractiveness into realised investment, institutional barriers needed to be removed. The analysis indicated that a primary source of uncertainty was the absence of detailed analysis of international experience in permitting and licensing systems for NHA-oriented activities. Foreign investors required a transparent and effective regulatory environment, and licensing transparency was no less important than project-level financial attractiveness. Optimising permitting procedures in line with international best practices therefore represented a necessary step to reduce investment risks and attract substantial private capital.

Overall, the analysis demonstrated that the NHA sector represented one of the most resilient and dynamic segments of the global economy, confirming the strategic expediency of its development in Ukraine. Growth of segments focused on medical and specialised wellness services indicated the need to modernise infrastructure and invest in scientific validation of traditional therapies. Optimal integration of NHA into Ukraine's economic system required a combined approach: retention of state control over natural resources themselves (to ensure sustainability and prevent market failure) alongside active use of PPP mechanisms for infrastructure modernisation and service provision. PPP agreements needed to include clear social obligations ensuring priority access to medical rehabilitation for affected populations. To move from strategic recommendations to operational implementation, the key direction for future research was a detailed institutional analysis of international licensing and permitting systems. Only the establishment of a transparent and effective regulatory environment would enable full realisation of the significant economic potential of Ukraine's natural healing assets.

CONCLUSIONS

The comprehensive study of international entrepreneurial activity in the use of NHA empirically confirmed their significant economic and social importance, which was critical for Ukraine's strategic recovery in the post-war period. The systematised quantitative analysis of global markets utilising NHA demonstrated their substantial scale and high investment attractiveness. By 2028, the three largest markets by volume were projected to be wellness tourism, valued at 1,359.3 billion USD, bottled (mineral) water production at 438.5 billion USD, and nature/ecotourism at 422.3 billion USD. It was established that the CAGR of all nine analysed global NHA markets exceeded the 4.3% CAGR of World GDP. Medical tourism exhibited the fastest growth at 18.9% CAGR, followed by nature/ecotourism and mud mask production, both at 14.3% CAGR. These results indicated high dynamism and resilience of these sectors to macroeconomic fluctuations. The comparative analysis, grounded in these quantitative indicators, revealed differentiated investment appeal across segments. For example, the medical tourism market was rated as high in stability, attractiveness and profitability, consistent with its leading CAGR. This substantiated the need for Ukraine to integrate traditional sanatorium and resort treatment with high-technology medical services. In contrast, the climatotherapy market was assessed as moderate–low in investment attractiveness, primarily due to limited market transparency associated with insufficient market data and scientific validation. Nevertheless, its potential economic value was supported by the high costs of managing chronic diseases (up to 13,132 USD per year for a patient with psoriasis), which indicated its prospective role as a cost-effective intervention within a long-term healthcare system perspective.

To achieve success, diversification beyond traditional sanatorium and resort treatment was required, encompassing wellness and SPA services, cosmetics production and recreational tourism. This aligned with the global shift in consumer priorities towards preventive and results-oriented health solutions. The analysis indicated that the PPP model represented an optimal mechanism for integrating NHA into the economic system, particularly for socially significant projects such as medical rehabilitation. This model combined private-sector innovation and financial capacity with public oversight of resources to support sustainability. At the same time, PPP implementation required rigorous institutional capacity for planning, contracting and monitoring. The strategic necessity of developing NHA in Ukraine, particularly with an emphasis on medical rehabilitation corresponding to the highest market dynamics and immediate national needs, was justified. The success of this process depended on a comprehensive approach and coordinated co-operation between the state, investors and entrepreneurs. To translate strategic recommendations into operational implementation and ensure sustainable economic development, institutional barriers needed to be removed. Therefore, future research perspectives should be directed towards detailed institutional analysis of international experience in permitting and licensing systems for NHA-related activities. This would support the formation of transparent and effective rules, which would provide a foundation for attracting significant investment and for realising the substantial potential of Ukraine's natural healing assets.

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CONFLICT OF INTEREST

None.

REFERENCES

[1] 2025 wellness tourism report. (2025). Retrieved from https://www.copperwellretreat.com/2025-wellness-tourism-report.

[2] Adetunji, T.L., Olisah, C., Acho, M.A., Oyetunde-Joshua, F., & Amoo, S.O. (2024). Global research trends and recent advances in medicinal plant-synthesized nanoparticles for cancer treatment. *Plants*, 13(20), article number 2836. doi: 10.3390/plants13202836.

[3] Aggestam Pontoppidan, C., Bisogno, M., Caruana, J., & Dabbicco, G. (2024). Safeguarding our roots: Natural resources accounting and reporting in the public sector. *Meditari Accountancy Research*, 32(7), 147-170. doi: 10.1108/medar-07-2023-2106.

[4] Ahmed, A. (2023). Measuring and analyzing the value exports of Saudi dates to Indonesia. *The Arab Journal of Scientific Research*, 7(7), 25-40. doi: 10.21608/ajsr.2023.296406.

[5] Analysis of the water market in Ukraine. (2024). Retrieved from https://pro-consulting.ua/ua/issledovanie-rynka/analiz-rynka-vody-v-ukraine-2024-god.

[6] Anderson, D. (n.d.). *Top digital health cities for preventive medicine abroad*. Retrieved from https://www.magazine.medicaltourism.com/article/top-digital-health-cities-for-preventive-medicine-abroad.

[7] Asa, A.R., & Nautwima, J.P. (2025). Health tourism in the Global South: Towards effective policy responses to emerging opportunities and challenges. *International Journal of Innovation and Economic Development*, 2(11), 7-22. doi: 10.18775/ijied.1849-7551-7020.2015.112.2001.

[8] Babov, K.D., Bezverkhniuk, T.M., & Kysylevska, A.Yu. (Eds). (2021). *Natural medicinal resources: User's alphabet*. Odesa: Polihraf.

[9] Bora, D. (2025). *Wellness tourism market size & outlook, 2025-2033*. Retrieved from https://straitsresearch.com/report/wellness-tourism-market.

[10] Bottled water market. (2025). Retrieved from https://www.grandviewresearch.com/industry-analysis/bottled-water-market.

[11] Brancu, C., & Turcu, O. (2025). Exploring the economic performance and market trends in the cosmetics industry: Insights and analysis. *Business & Management Compass*, 69(3), 23-32. doi: 10.56065/e31nkk40.

[12] Case studies in hot spring use for sustainable energy. (2019). Retrieved from https://www.pref.oita.jp/uploaded/attachment/2049215.pdf.

[13] Castle hot springs. (n.d.). Retrieved from https://book4time.com/castle-hot-springs-case-study/.

[14] Castro, L.A.T. (n.d.). *Medical tourism sustainable development*. Retrieved from https://www.magazine.medicaltourism.com/article/medical-tourism-sustainable-development.

[15] Clark-Kennedy, J., Kennedy, G., Cohen, M., & Conduit, R. (2021). Mental health outcomes of balneotherapy: A systematic review. *International Journal of Spa and Wellness*, 4(1), 69-92. doi: 10.1080/24721735.2021.1913368.

[16] Droli, M., Bašan, L., & Vassallo, F.G. (2022). Positioning climate therapy stays as a health tourism product: An evidence-based approach. *Emerging Science Journal*, 6(2), 256-272. doi: 10.28991/esj-2022-06-02-04.

[17] Dryglas, D., & Smith, M.K. (2023). A critical analysis of how central European spas create health tourism experiencescapes. *Tourism Planning & Development*, 21(5), 570-593. doi: 10.1080/21568316.2023.2259357.

[18] Ecotourism market size, share & industry analysis, by type, by traveler type, by booking mode, by age group, by passenger type and regional forecast, 2025-2032. (2025). Retrieved from https://www.fortunebusinessinsights.com/infographics/ecotourism-market-108700.

[19] Emmanuel, T., Lybæk, D., Johansen, C., & Iversen, L. (2020). Effect of Dead Sea climatotherapy on psoriasis; A prospective cohort study. *Frontiers in Medicine*, 7, article number 83. doi: 10.3389/fmed.2020.00083.

[20] Exploring opportunities in hot springs resort sector. (2025). Retrieved from https://www.datainsightsmarket.com/reports/hot-springs-resort-535543.

[21] Fernando, J. (2025). *Compound annual growth rate (CAGR) formula and calculation*. Retrieved from https://www.investopedia.com/terms/c/cagr.asp.

[22] Four seasons Toronto spa launches biohacking treatments. (2023). Retrieved from https://spaexecutive.com/2023/03/22/four-seasons-toronto-spa-launches-biohacking-treatments/.

[23] General characteristics of natural healing resources. (2025). Retrieved from https://kurort.gov.ua/zagalna-harakterystyka-pryrodnyh-likuvalnyh-resursiv/.

[24] Global mud mask market size by type of mud, by formulation, by application, by geographic scope and forecast. (2025). Retrieved from https://www.verifiedmarketresearch.com/product/mud-mask-market/.

[25] Global spa market size, share, and trends analysis report – industry overview and forecast to 2032. (2025). Retrieved from https://surl.li/hgtgjd.

[26] Global wellness economy monitor. (2024). Retrieved from https://globalwellnessinstitute.org/industry-research/2024-global-wellness-economy-monitor/.

[27] Global Wellness Institute. (2024). Hot springs & geothermal mineral waters. In C. Cavanah (Ed.), *Guide to hydrothermal spa & wellness development standards* (pp. 157-176). Miami: Global Wellness Institute.

[28] Gomez, M., & Katz, M. (2025). *Medtech M&A and VC signal positive momentum entering 2025*. Retrieved from https://www.goodwinlaw.com/en/insights/publications/2025/02/insights-practices-mdt-medtech-ma-vc-positive-momentum.

[29] Government support and policy reforms in health and medical tourism. (2025). Retrieved from https://www.health-tourism-news.com/news/government-support-and-policy-reforms-in-health-and-medical-tourism.

[30] Government support in medical tourism promotion: Exploring policies and incentives. (2025). Retrieved from https://www.magazine.medicaltourism.com/article/government-support-in-medical-tourism-promotion-exploring-policies-and-incentives.

[31] Green Paper on Public-Private Partnerships and Community Law on Public Contracts and Concessions. (2004, April). Retrieved from https://op.europa.eu/en/publication-detail/-/publication/94a3f02f-ab6a-47ed-b6b2-7de60830625e/language-enl.

[32] Haigh, L. (2025). *Developing a desirable medical tourism destination.* Retrieved from https://www.itij.com/latest/long-read/developing-desirable-medical-tourism-destination.

[33] Harari, M. (2020). Commentary: Effect of Dead Sea climatotherapy on psoriasis; A prospective cohort study. *Frontiers in Medicine*, 7, article number 586418. doi: 10.3389/fmed.2020.586418.

[34] Horozhankina, N.A., Horb, K.M., Grytsenko, A.V., & Tarasenko, H.Y. (2025). Development tendencies of the sanatorium and resort economy of Ukraine. *Current Issues of Economic Sciences*. doi: 10.5281/zenodo.14841385.

[35] Hot Springs National Park; Use of Thermal Water and Commercial Passenger-Carrying Vehicles. (2024). Retrieved from https://www.federalregister.gov/documents/2024/11/27/2024-27571/hot-springs-national-park-use-of-thermal-water-and-commercial-passenger-carrying-vehicles.

[36] International Bottled Water Association. (n.d.). Retrieved from https://bottledwater.org/learn-more-about-bottled-water/.

[37] International Monetary Fund. (2025). *Download WEO data: April 2025 edition*. Retrieved from https://www.imf.org/en/Publications/WEO/weo-database/2025/april.

[38] Kaya, H. (2024). An analysis of market size trends forecasting and range prediction in electric vehicles using machine learning algorithms. *Turkish Journal of Forecasting,* 9(1), 7-16. doi: 10.34110/forecasting.1485136.

[39] Kesharwani, P. (2025). *How to start your organic skincare brand in 2025.* Retrieved from https://learncanyon.com/how-to-start-your-organic-skincare-brand-in-2025/.

[40] Khumarova, N., & Kostetska, K. (2025). Substantiation of resource support for the sanatorium and resort sector rehabilitation. *Economic Innovations*, 27(1(94), 132-141. doi: 10.31520/ei.2025.27.1(94).132-141.

[41] Kirkland, A. (2014). What is wellness now? *Journal of Health Politics, Policy and Law*, 39(5), 957-970. doi: 10.1215/03616878-2813647.

[42] Kudinova, I., & Grishchenko, O. (2021). Medical tourism as a current trend of modern development in the field of Ukrainian tourism. *Economics and Business Management*, 12(3), 61-69. doi: 10.31548/bioeconomy2021.03-04.061.

[43] Law of Ukraine No. 2026-III "On Resorts". (2000, October). Retrieved from https://zakon.rada.gov.ua/laws/show/en/2026-14?lang=en#Text.

[44] Law of Ukraine No. 4196-IX "On the Peculiarities of Regulating the Activities of Legal Entities of Certain Organizational and Legal Forms in the Transitional Period and Associations of Legal Entities". (2025, January). Retrieved from https://zakon.rada.gov.ua/laws/show/4196-20?lang=en#Text.

[45] Law of Ukraine No. 698-XII "On Entrepreneurship". (1991, February). Retrieved from https://zakon.rada.gov.ua/laws/show/698-12?lang=en#Text.

[46] Lee, S.-H. (2024). Advantages of the wellness tourism and its future implications. *The Journal of Industrial Distribution & Business*, 15(7), 11-18. doi: 10.13106/JIDB.2024.VOL15.NO7.11.

[47] Marchenko, N.I., & Ditrikh, I.V. (2020). Prospects of wellness innivation in the hospitality industry. *Scientific Notes of Taurida National V.I. Vernadsky University*, 2(6), 65-69. doi: 10.32838/tnu-2663-5941/2020.6-2/12.

[48] Mayor, B., *et al. (*2021). State of the art and latest advances in exploring business models for nature-based solutions. *Sustainability*, 13(13), article number 7413. doi: 10.3390/su13137413.

[49] Medical tourism market (2025-2030). (2025). Retrieved from https://www.grandviewresearch.com/industry-analysis/medical-tourism-market.

[50] Medical tourism market performance, trends and strategic recommendations. (2025). Retrieved from https://www.towardshealthcare.com/insights/medical-tourism-market-sizing.

[51] Medical tourism market size, share & industry analysis, by healthcare services (medical treatment {cardiac procedures, oncology procedures, orthopedic & spine procedures, dental procedures, and others}, wellness treatment {cosmetic procedures, rejuvenation procedures, and others}, and alternative treatment), by service provider (public and private), and regional forecast, 2025-2032. (2025). Retrieved from https://www.fortunebusinessinsights.com/industry-reports/medical-tourism-market-100681.

[52] Natural and organic personal care products market to grow by USD 12.37 billion (2025-2029), rising demand among female consumers, ai impact on trends – Technavio. (2025). Retrieved from https://surl.li/krbdwm.

[53] Natural APIs market to reach US$ 57.5 billion by 2034 with a 6.1% CAGR as demand for plant-based drug ingredients grows. (2025). Retrieved from https://www.pharmiweb.com/press-release/2025-03-20/natural-apis-market-to-reach-us-575-billion-by-2034-with-a-61-cagr-as-demand-for-plant-based-drug-ingredients-grows-latest-report-by-tmr.

[54] Natural cosmetics market report 2025. (2025). Retrieved from https://surl.li/bwwnsm.

[55] Nature-based tourism. (2024). Retrieved from https://www.worldbank.org/en/topic/environment/brief/nature-based-tourism.

[56] NatureVest is TNC's impact investing and sustainable finance team. (n.d.). Retrieved from https://www.nature.org/en-us/about-us/who-we-are/how-we-work/finance-investing/naturevest/.

[57] Nebava, M.I., Adler, O.O., & Lesko, O.Y. (2011). *Economics and organization of enterprise's production activities* (Vol. 1). Vinnytsia: VNTU.

[58] New WHO report lays out concrete actions for governments to optimize public-private partnerships for health. (2023). Retrieved from https://www.who.int/europe/news/item/26-01-2023-new-who-report-lays-out-concrete-actions-for-governments-to-optimize-public-private-partnerships-for-health.

[59] Organic skin care products market size & share analysis – growth trends and forecast (2025-2030). (2025). Retrieved from https://www.mordorintelligence.com/industry-reports/organic-skin-care-market.

[60] Ormond, M., Mun, W.K., & Khoon, C.C. (2014). Medical tourism in Malaysia: How can we better identify and manage its advantages and disadvantages? *Global Health Action*, 7(1), article number 25201. doi: 10.3402/gha.v7.25201.

[61] Pessot, E., Spoladore, D., Zangiacomi, A., & Sacco, M. (2021). Natural resources in health tourism: A systematic literature review. *Sustainability*, 13(5), article number 2661. doi: 10.3390/su13052661.

[62] Plant-based API market by source (soy, pea, hemp, sunflower, rice), by form (liquid, powder, granules), by functionality, by distribution channel, by end user – global industry outlook, trends and forecast 2025-2034. (2024). Retrieved from https://dimensionmarketresearch.com/report/plant-based-api-market/.

[63] Premium bottled water market. (2025). Retrieved from https://www.gminsights.com/industry-analysis/premium-bottled-water-market.

[64] Protas, M.Yu. (2022). Technological aspects of organizing balneological and health tourism. In *Tourism and the hotel and restaurant industry: Materials of the scientific conference with international participation* (pp. 328-331). Zaporizhzhia: Zaporizhzhia Polytechnic National University.

[65] Recreational tourism. (2025). Retrieved from https://geohub.org.ua/node/2279.

[66] Sameen, S., & Sultan, M.A. (2025). The role of herbal extracts in modern integrative medicine: A comprehensive review. *Premier Journal of Biomedical Science*. doi: 10.70389/pjbs.100011.

[67] Sanatorium and resort treatment as one of the factors of preserving the country's labor potential. (2018). Retrieved from https://surl.lu/rzqftu.

[68] Shashero, A., Molodetskiy, A., Nikolaieva, O., & Kudelina, S. (2025). Modern resort business of Ukraine as a socio-economic system. *Journal of Education, Health and Sport*, 77, article number 60641. doi: 10.12775/JEHS.2025.77.60641.

[69] Sheykin, H. (2025a). *How much can ecotourism business owners earn?* Retrieved from https://finmodelslab.com/blogs/how-much-makes/ecotourism-and-nature-conservation.

[70] Sheykin, H. (2025b). *How to boost profits in your mineral water bottling business?* Retrieved from https://finmodelslab.com/blogs/profitability/mineral-water-bottling-plant.

[71] Singh, S. (2025). *Global natural cosmetics ingredients market.* Retrieved from https://www.marketresearchfuture.com/reports/natural-cosmetics-ingredients-market-26357.

[72] Spa market size & share analysis-growth trends & forecasts (2025-2030). (2025). Retrieved from https://www.mordorintelligence.com/industry-reports/spa-market.

[73] Spa market: Global industry analysis and forecast (2025-2032). (2025). Retrieved from https://www.maximizemarketresearch.com/market-report/spa-market/115472/.

[74] Sryberko, A., & Stepanova, Y. (2025). Defining interests in the use of natural assets of the shoreline protection belt in the context of blue growth. *Economics: Time Realities*, 2(78), 136-149. doi: 10.15276/etr.02.2025.15.

[75] Stucke, A., & Humphreys, D. (2019). Public-private partnerships for emerging market health. In *Global private health care: Materials of scientific conference with international participation*. Washington: International Finance Corporation.

[76] Suryawanshi, S. (2025). *Mineral water market size and share analysis – grouth trends and forecasts (2025-2032).* Retrieved from https://www.coherentmarketinsights.com/industry-reports/mineral-water-market.

[77] The advantages and disadvantages of public-private partnerships. (2024). Retrieved from https://snatika.com/single-blog/the-advantages-and-disadvantages-of-public-private-partnerships.

[78] Thermal springs tourism market (2025-2030). (2024). Retrieved from https://www.grandviewresearch.com/industry-analysis/thermal-springs-tourism-market-report.

[79] Thermal/mineral springs. (n.d.). Retrieved from https://globalwellnessinstitute.org/what-is-wellness/thermal-mineral-springs/.

[80] Toronto luxury spa & wellness. (n.d.). Retrieved from https://www.fourseasons.com/toronto/spa/.

[81] Turchenko, I.V. (2024). Modern models of public-private partnership in the development of domestic transport infrastructure. *South Ukrainian Law Journal*, 4, 57-65. doi: 10.32850/sulj.2024.4.11.

[82] Understanding public-private partnerships: How they work and key examples. (2025). Retrieved from https://www.investopedia.com/terms/p/public-private-partnerships.asp.
[83] United Nations Economic Commission for Europe. (2017). *Guidebook on promoting good governance in public-private partnerships.* Geneva: United Nations.
[84] Unlocking the potential of nature-based tourism: A pathway to conservation and economic resilience. (n.d.). Retrieved from https://enduringearth.org/unlocking-nature-based-tourism/.
[85] US medical tourism market by service provider (public and private), by service (medical treatment (orthopedic & spine procedures, oncology procedures, dental procedures, cardiac procedures, and others), wellness treatment (rejuvenation procedures, cosmetic procedures, and others), and alternative treatment), region and companies – industry segment outlook, market assessment, competition scenario, trends and forecast 2025-2034. (2025). Retrieved from https://market.us/report/us-medical-tourism-market/.
[86] Vašaničová, P., Košíková, M., Jenčová, S., Miškufová, M., & Korečko, J. (2025). Financial performance-based clustering of spa enterprises in Slovakia. *Journal of Risk and Financial Management*, 18(9), article number 482. doi: 10.3390/jrfm18090482.
[87] Yavorska, V., Nikolaeva, M., & Grigoriev, O. (2022). Development of health tourism in Ukraine. *Journal of Education, Health and Sport*, 12(9), 998-1006. doi: 10.12775/JEHS.2022.12.09.112.
[88] Zhang, W., Qin, Z., & Tang, J. (2022). Economic benefit analysis of medical tourism industry based on markov model. *Journal of Mathematics*, 2022, article number 6401796. doi: 10.1155/2022/6401796.

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Економічний потенціал природних лікувальних активів: тенденції світового ринку, бізнес-моделі та перспективи для України

■ **Анотація.** Економічне відновлення держав після масштабних конфліктів потребує стратегічної капіталізації високовартісних внутрішніх активів, здатних генерувати стійкі доходи та відновлювати виснажений людський капітал. Глобально значущі природні лікувальні активи України (ПЛА) становлять таку стратегічну пріоритетність. Метою дослідження було здійснення комплексного аналізу міжнародного бізнес-досвіду використання ПЛА для розроблення практичних рекомендацій щодо їх ефективного застосування в Україні. Методологія ґрунтувалася на системному аналізі, узагальненні та синтезі даних численних міжнародних звітів і наукових публікацій із застосуванням порівняльного аналізу для оцінювання критеріїв світових ринків і бізнес-моделей. Поняття ПЛА було визначено як природні лікувальні ресурси, зафіксовані у державних реєстрах і такі, що використовуються з метою отримання прибутку або суспільної вигоди. Проведено детальний аналіз світових підприємницьких ринків, що використовують ПЛА. Встановлено, що найбільшими за обсягом ринками станом на 2028 р. будуть оздоровчий туризм (1 359,3 млрд дол. США), виробництво бутильованої води (438,5 млрд дол. США) та екотуризм (422,3 млрд дол. США). Систематизовано ключові критерії (стабільність, інвестиційна привабливість, стійкість) для дев’яти ринкових сегментів, що підтвердило перевищення темпів зростання всіх ринків ПЛА над CAGR світового ВВП. Проаналізовано три основні міжнародні моделі інтеграції ПЛА (публічна, приватна та публічно-приватного партнерства), встановлено, що оптимальна модель визначається специфікою активу та стратегічними цілями. Розроблено комплексні практичні рекомендації для України, в яких медичну реабілітацію визначено ключовим пріоритетом. Отримані результати формують доказову основу для підприємців, інвесторів і органів державної влади України щодо вибору оптимальних бізнес-моделей та пріоритетних інвестиційних напрямів використання ПЛА

■ **Ключові слова:** курортна економіка; інвестиції; туризм; реабілітація; велнес; рекреація; публічно-приватне партнерство

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Effectiveness of Internet of Things migration into hybrid economic projects

Abstract. The study aimed to scientifically substantiate the economic feasibility of migrating hybrid economic projects to Internet of Things technology solutions and to identify the conditions under which such migration would deliver sustainable economic benefits. The methodological framework included comparative economic, structural-dynamic and scenario analysis, sensitivity assessment and financial modelling based on the calculation of net present value, return on investment, total cost of ownership and integral economic efficiency indicator. The empirical base covered data from Azerbaijan's logistics, agricultural and industrial segments for 2021-2025. The results showed that digitalisation provides economic benefits and stabilises revenue streams in all sectors studied. In logistics, the introduction of Internet of Things technologies reduces operational delays by 43% and transaction costs by 17%, resulting in a significant increase in profitability. In the agricultural sector, the use of sensor systems reduces operating costs by 18.8% and risk costs by 17.4%, reducing the total cost of ownership by 12.7%. In the industry, modernisation increases average annual revenues to 162,000 manats while reducing total costs to 298,000 manats, generating maximum net present value in an optimistic scenario. The integrated economic efficiency model revealed cross-sector differences: logistics demonstrates the most stable results, while industry has the greatest potential but remains sensitive to the cost of capital and the level of digital risks. The results confirm that the economic efficiency of digital migration is achieved by reducing operating costs, mitigating risks, increasing benefits, and complying with the architectural compatibility requirements of digital systems. The practical significance of the study is determined by the fact that the identified dependencies make it possible to develop economically sound scenarios for the implementation

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of Internet of Things in key sectors of Azerbaijan and to more accurately predict the expected effects at different cost levels and technological conditions

Keywords: digitalisation; operating costs; energy efficiency; discount rate; digital risks; sensitivity analysis

INTRODUCTION

The research relevancy is determined by the fact that in 2021-2025 the digital transformation of the economies of the South Caucasus countries, and above all Azerbaijan, entered a phase of intensive implementation of Internet of Things (IoT) technologies, which have become one of the key factors in restructuring the cost structure, increasing the efficiency of resource use and forming sustainable economic trajectories. In the context of rising energy prices, logistical volatility, climate fluctuations and the increasing complexity of industry chains, there has been a sharp increase in the need for quantitative assessment of the economic performance of IoT for heterogeneous (hybrid) projects. Azerbaijan faces several systemic economic challenges, including the high sensitivity of the agricultural sector to risks, increased logistics costs, and the need to modernise industry, which makes the analysis of the economic effects of IoT relevant for the development of rational investment decisions.

The regional context of the problem can be traced in the works of Azerbaijani researchers, demonstrating how IoT affects the economic mechanisms of urban, agricultural, and infrastructure systems. A study by A. Valiyev *et al.* (2022), based on urban projects in Azerbaijan, notes that the introduction of IoT platforms was a response to the problem of increasing operating costs and inefficient distribution of urban resources. The study demonstrated that digital services have stabilised infrastructure dynamics and contributed to cost reduction, which is crucial for an economy based on transport and energy hubs. Similar conclusions are presented in the work of A. Huseynova & O. Mazanova (2023), where the expansion of digital services is viewed as a factor shaping the economic adaptability of cities and gradually reducing the burden on municipal budgets.

The technical and resource aspects of digitalisation that have direct economic significance were revealed in a study by R. Imamguluyev *et al.* (2024). The study demonstrated that the transition to edge architectures has changed the nature of IoT systems: reducing data processing delays and dependence on centralised channels has lowered technological and transaction costs, which is relevant for hybrid projects where the cost of temporary delays and failures translates into direct financial losses. These observations emphasise that the economic attractiveness of IoT in Azerbaijan is directly linked to the development of local computing infrastructure. At the same time, an analysis of the identified studies reveals a significant scientific gap: despite the existence of works devoted to urban, infrastructural and computing aspects of the IoT, there are no comprehensive economic assessments of the cross-sectoral effects of digitalisation in Azerbaijan. The available studies analyse individual subsystems – urban digitalisation, resource optimisation or architectural solutions – but do not offer a holistic model describing how IoT affects the economy simultaneously in logistics, the agricultural sector and industry. In addition, there is insufficient quantitative data in the regional literature to compare the scalability of IoT effects and sensitivity to changes in cost parameters, which makes it difficult to build cross-sector economic models. In these circumstances, foreign research becomes substantial for filling the identified analytical gap. International studies demonstrate that the development of computing architecture directly influences the nature of economic dynamics. Thus, the study emphasised that distributed computing improves the quality of analytical models and enhances real-time forecasting.

This technological foundation is also evident at the macroeconomic level: a study by L. Xing (2024) demonstrates that the combination of edge technologies and cloud infrastructure contributes to the redistribution of production capacities between regions, smooths economic differences, and shapes a new type of regional mobility. The study also noted that strengthening digital infrastructure strengthens the connection between peripheral and central areas, reduces transaction barriers, and lowers the cost of spatial coordination. Research on urban transport systems developed in parallel. T. van Hoang (2024) confirmed that the integration of IoT into urban infrastructure has enabled cities to reduce their current resource consumption by improving the accuracy of transport and utility networks. The study also noted that IoT has become the basis for the formation of dynamic response systems that can be used for faster adjustments to the urban environment. This logically correlated with the results of macroeconomic observations: a study by H. Edquist *et al.* (2021) found that the spread of IoT at the country level contributed to an increase in total factor productivity, as digital systems restructured costs and improved the use of national resources. The study also noted that digitalisation had changed the nature of capital accumulation, strengthening the role of intangible assets.

Alongside infrastructure transformation, issues related to the digital trust environment were increasingly substantial. A review by A. Alkhateeb *et al.* (2022) showed that the combination of IoT and hybrid blockchain platforms reduced the uncertainty of economic transactions, while the transparency of data exchange strengthened the resilience of digital ecosystems, which is relevant for cross-sector hybrid projects. In addition, the formation of a trusted environment reduced transaction costs and ensured more reliable chains of interactions. The economic aspects of IoT application in the field of sustainable resource consumption were analysed in detail in a study by M. Albreem *et al.* (2023), which showed that the use of sensor systems and digital monitoring leads to a reduction in material and energy costs, forming an economically effective model for the functioning of public infrastructure. At the same time, the study emphasised that such ecosystems have increased the predictability of consumption and provided more stable conditions for long-term planning.

The transition to another plane of urban development was continued in a study by T. Song *et al.* (2021), which showed how IoT technologies have restructured the logic of Chinese megacities, reducing the costs of transport and utility systems. Additionally, the study noted that the introduction of sensors and intelligent platforms has strengthened control over urban dynamics, reducing uncertainty in load distribution processes. In the industrial sector, issues related to the protection of digital platforms have become key: the study by Z. Huma *et al.* (2021) determined that increasing the cyber resilience of industrial IoT systems reduced the probability of costly failures, which directly affected the economic performance of enterprises. The study also noted that improving the security of the digital environment increased confidence in the use of IoT in manufacturing operations.

Thus, studies in various fields, ranging from urban infrastructure and regional development to industrial systems and digital trust chains, have consistently shaped the understanding of how IoT has transformed the economic mechanisms of hybrid projects. Despite differences in context, all studies noted one trend: digitalisation has changed the cost structure, increased the accuracy of resource allocation, and created new trajectories of economic sustainability, although the extent of these effects remained dependent on technical, infrastructural, and institutional conditions. However, most of the studies analysed were limited to descriptive conclusions and offered virtually no quantitative models for assessing the economic effects of the IoT, leaving a significant gap between conceptual approaches and formalised economic analysis. The study aimed to provide a theoretical justification for the economic efficiency of migrating to IoT technologies in hybrid economic projects. The research objectives included analysing economic changes after migration to IoT technologies in hybrid projects, evaluating the results of IoT implementation using economic methods and industry examples, and identifying financial implications and key barriers affecting the economic performance of digital transformation.

MATERIALS AND METHODS

The study was conducted between January and October 2025 and had a theoretical and analytical focus based on the systematisation of international reports, standards and analytical materials devoted to the impact of IoT technologies on the economic efficiency of hybrid projects. The period 2021-2025 was chosen because it was during this time that Azerbaijan saw a transition from isolated digital initiatives to scalable IoT solutions, accompanied by the accelerated development of network infrastructure, a reduction in the cost of digital services, and the active introduction of sensor systems in key sectors of the economy. This period traced both the initial phase of IoT deployment and the formation of sustainable economic effects, making it representative for analysing the dynamics of digital transformation in the logistics, agricultural, and industrial segments. The information base was formed based on reports by the World Economic Forum (2024), reflecting the dynamics of the digital transformation of Azerbaijan's economy; reports by the Organisation for Economic Co-operation and Development (2022; 2024), containing macroeconomic parameters of digitalisation; as well as analytical materials from the World Bank (2024), which clarified the impact of digital technologies on structural changes in economic systems. The sources listed were studied using content analysis and comparative economic interpretation to identify key trends in digital transformation and determine the factors influencing the economic results of IoT technology implementation. Additionally, indicators from the S. Kemp (2025) report were used to quantitatively assess the country's level of digital maturity and the prevalence of IoT solutions in various sectors, which was necessary to form a representative background and justify the initial conditions of the study.

The technical and regulatory basis for the study was formed based on international standards and industry recommendations. The ISO/IEC 30141:2024 (2024) standard, was studied using structural and regulatory analysis to determine the principles of IoT system construction, their functional compatibility parameters, architectural levels, and requirements for the stability of distributed digital infrastructure. The analysis included reports by the European Commission (2024a; 2024b) published through the Interoperable Europe platform; these materials were examined using a normative-content analysis method to clarify the requirements for digital infrastructure compatibility and the parameters of standards for the implementation of IoT technologies in various sectors. Supplementary sources included materials from the International Renewable Energy Agency (2024) presented in the Renewables 2024 report; these were studied using content analysis to identify the characteristics of the implementation of digital sensor systems and IoT technologies in the renewable energy sector. A study by McKinsey & Company (2024), data from Cisco (2024) and analytical reports from Fortune Business Insights (2025) were analysed using comparative and analytical interpretation to incorporate global technological trends, network characteristics and economic parameters accompanying the digital transformation of industries.

The theoretical reconstruction of industry case studies was based on sources reflecting the application of IoT technologies in various sectors of the economy. These sources included research on logistics by E. Rahimov & J. Rahimov (2025) and were compared with industry and country indicators presented in World Bank (2024) reports, including data on the structure of transport costs, delivery times, the sustainability of logistics corridors, and the degree of digital technology implementation in freight transport operations. This comparison made it possible to reproduce the economic logic of digital supply chains, route monitoring mechanisms, and automated transport flow control. The agricultural cases were based on information from the Agricultural Research Centre (2024) and an analytical review by N. Baghirova (2023), which described precision farming mechanisms, sensor-based soil condition monitoring, and the use of IoT technologies to optimise water consumption in irrigation systems. Additional insights into rural and semi-peripheral digitalisation formats were provided by materials from E. Caldwell (2023), which presented the concept of "smart villages" and demonstrated the role of IoT in local economic modernisation, covering specific features of rural transformation in hybrid projects. The industrial analysis was reconstructed based on reviews by Fortune Business Insights (2025), as well as regulatory documents ISO/IEC 30141:2024 (2024) and European Commission (2024b). The purpose of studying these materials was to determine the directions for the implementation of IoT technologies in the industrial sector, clarify the technical architectures used, and identify the economic parameters that form the basis for the digital modernisation of production systems. The methodological research procedure included the application of economic models to assess the effectiveness of IoT implementation in hybrid projects. The central element was the net present value model used to describe the total economic effect over time. The economic assessment was conducted using formula (1):

$$NPV = \sum_{t=0}^{n} \frac{CF_t}{(1+r)^t} - I_0, \qquad (1)$$

where NPV – net present value of a digital project; CF_t – economic effect of IoT implementation during the period t; r – discount rate reflecting the cost of capital; I_0 – initial investment in digitalisation; n – estimation horizon. The return on investment (ROI) was modelled using formula (2):

$$ROI = \frac{B-C}{C} \times 100\%, \qquad (2)$$

where B – the cumulative economic benefits of implementing IoT; C – total costs of implementing and operating a digital system. The total cost of ownership (TCO) of digital infrastructure was calculated based on expression (3):

$$TCO = C_{init} + C_{oper} + C_{risk}, \qquad (3)$$

where C_{init} – initial implementation costs; C_{oper} – operating costs; C_{risk} – cost of risk events, including cyber threats, failures and integration errors. To assess the stability of the results, a sensitivity analysis was used to determine the extent to which changes in parameters affect the final economic effect. Sensitivity of the integral effect (S) was assessed using formula (4):

$$S = \frac{\Delta Eff/Eff}{\Delta X/X}, \qquad (4)$$

where Eff – overall economic effect; X – variable parameter that includes the cost of IoT infrastructure, risk level, and discount rate. The integral economic effect was described by the dependence (5):

$$Eff = f(NPV, ROI, TCO, R), \qquad (5)$$

where R – aggregated digital risk indicator. The software and analytical basis of the study included the use of MS Excel and IBM SPSS Statistics 28, which were used to parameterise calculations and model scenarios. All calculations were performed in three scenario modifications: baseline, optimistic, and pessimistic, with key parameters varying within 5-7%, which ensured the possibility of determining the conditions under which the migration of hybrid projects to IoT technologies becomes economically efficient.

RESULTS

Azerbaijan's initial digital environment and dynamics of IoT transformation (2021-2025)

The digital modernisation of Azerbaijan's economy in 2021-2025 was accompanied by accelerated development of network infrastructure, increased digital maturity and expanded use of IoT technologies in the logistics, agricultural and industrial sectors. According to a report by the World Economic Forum (2024), the country demonstrated steady growth in its Network Readiness Index, with the Connectivity sub-index increasing by approximately 12-15% due to the expansion of broadband coverage, the development of data centres and the introduction of edge computing solutions. At the same time, data from the Organisation for Economic Co-operation and Development (2022; 2024) show a steady decline in the cost of digital services and infrastructure components: prices for broadband connections and basic IoT networks have fallen by 5-12%, and the cost of deploying digital platforms and sensor systems – by 8-15%. These changes have increased the accessibility of IoT technologies for real sector enterprises and expanded their potential for use in logistics, agricultural systems and industry.

According to a World Bank (2024) report, by 2025, Azerbaijan will have developed a comprehensive digital infrastructure, including smart logistics corridors, sensor-based crop yield monitoring systems, and predictive analytics in industry. Updates from S. Kemp (2025) showed that the level of digital maturity in the country, calculated based on aggregated indicators from ITU, GSMA, Cisco Digital Readiness Index, and the World Bank's Digital Development Index, has increased by almost 10 points compared to 2021. This growth was accompanied by the expansion of the IoT ecosystem: the number of active IoT connections in logistics increased by 18%, in the agricultural sector by 14%, and in industry by 11%. This dynamic formed the basis for further calculations of CF_t, B and C, reflecting the economic effects of IoT integration in key sectors of the economy.

Technological conditions were also central in the dynamics of digitalisation. According to Cisco (2024) industry IoT reports, average network latency decreased and data transmission stability increased, resulting in a 6-8% reduction in C_{oper} in sectors that actively use IoT sensors. Analytical materials from McKinsey & Company (2024) showed that the development of industrial digitalisation led to an average increase in operational productivity of 8-10% in segments with a high degree of automation. In addition, the International Renewable Energy Agency (2024) report on Renewables 2024 technology emphasised that in the energy segment, the introduction of IoT-oriented monitoring systems has reduced C_{init} costs by 5-7% through intelligent distribution of generation and digital diagnostic systems. These factors reflected the multidimensional dynamics of the country's digital transformation and formed the initial economic environment for subsequent NPV, ROI and TCO calculations. Table 1 systematises Azerbaijan's key macroeconomic and digital indicators for 2021-2025.

Table 1. Macroeconomic parameters of digital maturity and IoT penetration in Azerbaijan (2021-2025)

Indicator	2021	2022	2023	2024	2025
Digital Maturity Index (DataReportal)	54	58	61	63	64
IoT penetration in logistics, %	22	25	27	32	36
IoT penetration in the agricultural sector, %	15	17	19	23	26
IoT penetration in industry, %	18	20	22	26	29
Reduction in C_{oper}, %	-	2	3	5	6
Reduction in C_{init}, %	-	1	3	4	5
Estimated growth CF_t in sectors, %	-	4	6	8	10
Network reliability growth (Cisco), %	3	5	8	10	12

Note: the 2025 figures reflect preliminary estimates as of Q1-Q3 2025
Source: compiled by the authors based on Organisation for Economic Co-operation and Development (2022; 2024), World Bank (2024), World Economic Forum (2024), International Renewable Energy Agency (2024), Cisco (2024), McKinsey & Company (2024), S. Kemp (2025)

As Table 1 shows, Azerbaijan's digital maturity demonstrated steady growth in 2021-2025: the integral index increased from 54 to 64 points, reflecting the acceleration of digital transformation and the expansion of infrastructure capabilities. The fastest progress was in logistics, where IoT penetration rose from 22% to 36%, while industry and agriculture also showed steady expansion in the use of sensor systems and digital solutions. At the same time, there was a steady decline in operating and initial costs (C_{oper} and C_{init}), reaching 6% and 5% respectively in 2025, indicating the formation of economies of scale and technological optimisation. Growth CF_t in the sectors increased to 10%, indicating the emergence of the first sustainable economic effects from the introduction of IoT. The increase in network reliability for 2021-2025 highlights the impact of technological conditions, primarily the expansion of bandwidth and increased network resilience, as reflected in Cisco reports. Taken together, these indicators confirm that Azerbaijan has moved into a phase of deep digitalisation, where the scaling of IoT systems is beginning to have a direct impact on costs, productivity and the structure of economic effects.

Overall, analysis of Azerbaijan's initial digital environment for 2021-2025 demonstrates the formation of a sustainable technological base capable of ensuring a reproducible economic effect from the introduction of IoT into hybrid projects. The growth in digital maturity, the expansion of IoT use in key industries, and the reduction in cost parameters C_{oper} and C_{init} have created the conditions for increased operational productivity and economic returns, reflected in growth CF_t. Strengthening network reliability and the development of energy digitalisation have increased the predictability of the effects of IoT implementation, which improves the reliability of subsequent calculations using *NPV*, *ROI* and *TCO* models. Thus, the emerging digital dynamics not only determine the technological background of the analysis but also set the initial economic conditions within which the effectiveness of migrating hybrid projects to IoT technologies will be assessed.

Economic effects of digitalisation in the logistics sector

The digital transformation of Azerbaijan's logistics sector in 2021-2025 was accompanied by a systematic review of the structure of transaction and C_{oper}, which directly affected the values of costs *C* and economic benefits *B* used in return on investment calculations (2). According to data from E. Rahimov & J. Rahimov (2025), the introduction of IoT technologies into transport and logistics processes has significantly reduced the time spent on searching for, identifying and confirming the status of cargo due to automated sensor systems and tracking modules. This has led to a reduction in transaction costs associated with information processing and coordination of operations between supply chain participants. World Bank (2024) materials confirm that the use of IoT devices in the route monitoring system has reduced the average time to locate transport hubs and increased the predictability of logistics operations, resulting in a reduction in operational delays, which previously accounted for up to 12-15% of total delivery time.

Network parameters also had a significant impact on the cost structure. According to Cisco (2024), optimisation of network delays and increased connection stability improved the continuity of IoT sensors, which reduced the average amount of unplanned downtime and lowered C_{oper}. The Organisation for Economic Co-operation and Development (2024) notes that the digitalisation of supply chains has led to a reduction in the unit cost of processing a unit of cargo through the automation of acceptance, digital verification and early detection of route deviations. These changes have accelerated routing and improved the accuracy of arrival time forecasts, which has increased the aggregate benefit *B* by reducing late penalties, optimising transport loading and increasing turnover.

The transition to IoT infrastructure also affected the structure of initial costs C_{init}. Although the introduction of digital sensors and IoT platforms required additional investment, the subsequent reduction in C_{oper} proved to be more significant, leading to an increase in the difference between economic benefits *B* and total costs *C*. This dynamic is directly determined by the expression of return on investment presented in formula (2), where the final *ROI* value depends on the growth of *B* and the simultaneous reduction of *C* that occurs when supply chains are digitised. The data obtained in the analysis by the World Bank (2024) and E. Rahimov & J. Rahimov (2025) indicate that the aggregate economic effect consists not only in a reduction in transaction and C_{oper}, but also in an increase in the speed of logistics operations, which increases the final values of CF_t and contributes to an increase in the productivity of supply chains. Table 2 summarises the key economic indicators characterising the effect of IoT implementation in logistics, including the values of *B*, *C* and the calculated *ROI*.

Table 2. Economic effects of applying IoT in logistics (*B*, *C* and *ROI*)

Indicator	Before IoT	After IoT	Change, %
Total benefits *B*, million USD	12.4	17.1	38
Total costs *C*, million USD	9.8	8.1	-17
Operational delays, % of time	14	8	-43
Identification and search cost, USD/transaction	1.9	1.1	-42
ROI, %	26.5	111.1	319

Source: compiled by the authors based on World Bank (2024), Cisco (2024), Organisation for Economic Co-operation and Development (2024), E. Rahimov & J. Rahimov (2025)

The calculated figures presented in Table 2 show a marked increase in profitability following digitalisation. The 38% increase of *B* reflects the effect of optimising transport utilisation, reducing delays and improving routing accuracy. The 17% decrease of *C* corresponds to a reduction in transaction and C_{oper}, as well as a reduction in downtime due to improved network parameters, as reported by Cisco (2024). The more than fourfold increase in *ROI* emphasises that the implementation of IoT generates significant economic benefits even with moderate capital expenditures. Figure 1 shows the dynamics of *ROI* changes before and after the implementation of IoT in the logistics sector of Azerbaijan, illustrating the transition to a more efficient cost and benefit structure.

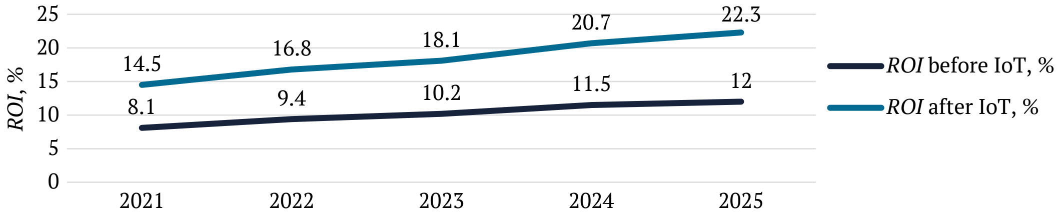

Figure 2. *ROI* dynamics before and after the implementation of IoT in logistics
Source: compiled by the authors based on World Bank (2024), Cisco (2024), Organisation for Economic Co-operation and Development (2024), E. Rahimov & J. Rahimov (2025)

Following Figure 1, the introduction of IoT into logistics processes has led to a sustained and statistically significant improvement in the profitability of operations. In the period before the introduction of IoT (2021-2022), the *ROI* remained at 9-11%, reflecting the limitations of traditional routing models, the prevalence of manual control procedures, and poor integration of digital data transmission channels. The local growth in 2023 was due to the digitalisation of individual transport sections, but it did not lead to a systemic change in financial results. The situation changed significantly after the deployment of a sensor-based IoT infrastructure, the introduction of automated tracking systems and the application of intelligent route optimisation algorithms. Starting in 2024, the *ROI* indicator shows steady growth to 16-18%, and in 2025 to 21-22%, which indicates a pronounced economic effect of the digitalisation of the logistics sector. The increase in profitability is associated with a reduction in operational delays, lower transaction costs, reduced costs for searching, identifying and monitoring cargo, as well as increased accuracy and speed of operations. An additional effect was the stabilisation of financial dynamics: after the introduction of IoT, the amplitude of *ROI* fluctuations is significantly reduced, and the trajectory becomes more predictable. This is relevant for hybrid economic projects, as such projects combine several industry segments operating under different technological and pricing conditions. Their revenue and cost flows are formed from heterogeneous components – logistical, agricultural, and industrial – each of which has volatility. As a result, any fluctuations in one segment are instantly reflected in the aggregate CF_t and *C*. Therefore, increasing the stability of flows and reducing cost uncertainty makes it possible to stabilise economic results, reduce the probability of cascading fluctuations, and ensure the predictability of efficiency over the investment horizon. Such stabilisation indicates that digitalisation affects not only the absolute value of economic benefits (*B*), but also their regularity and reliability. Overall, the analysis of *ROI* dynamics confirms that the implementation of IoT transforms logistics processes towards higher economic performance, reduces transaction and C_{oper}, and ensures the formation of stable, predictable financial effects. These conclusions form the basis for further calculations of the effectiveness of migration to IoT based on the integral indicators of *NPV*, *ROI*, and *TCO* in hybrid economic projects.

Economic results of IoT implementation in Azerbaijan's agricultural systems

The digitalisation of Azerbaijan's agricultural sector in 2021-2025 was accompanied by the accelerated introduction of precision farming systems, smart irrigation solutions, and soil and climate monitoring sensors. According to data from the Agricultural Research Centre (2024), the expansion of IoT infrastructure in crop production has made it possible to establish optimal irrigation and nutrition regimes for crops, as well as to reduce the uncertainty associated with climatic and soil fluctuations. A study by N. Baghirova (2023) highlights that the introduction of sensor systems on farms in the Shirvan and Ganja regions has reduced C_{oper} by 12-18% in the first two years of operation through reduced water and fertiliser consumption. Additional data from E. Caldwell (2023) show that the use of IoT-oriented monitoring systems has reduced crop losses caused by late diagnosis of diseases and uneven irrigation by approximately 10-15%. These indicators directly contribute to an increase in the effect *B* (economic benefits) generated by higher yields and reduced non-production losses. The International Renewable Energy Agency (2024) report notes similar trends in energy-intensive subsectors, where the introduction of IoT in pumping stations and fertigation systems has reduced energy consumption by 8-12%, which has also reduced C_{oper} and increased energy efficiency.

The economic interpretation of the effects obtained is reflected in the change in the structure of total costs presented in formula (3). This indicator is of key importance for agricultural projects, as a large proportion of costs are associated with operating cycles and risks caused by weather uncertainty, soil degradation and water resource instability. The introduction of IoT systems has made it possible to reduce C_{oper} through process automation, reduce C_{risk} due to accurate monitoring data, and partially offset the initial investment (C_{init}) through increased economic results *B*. Table 3 systematises the main *TCO* parameters in Azerbaijan's agricultural projects before and after the introduction of IoT.

Table 3. The structure of the *TCO* indicator (C_{init}, C_{oper}, C_{risk}) in Azerbaijan's agricultural projects

Indicator	Before IoT implementation (thousand manat)	After IoT implementation (thousand manat)	Change, %
C_{init}	52	56	7.7
C_{oper}	138	112	-18.8
C_{risk} (agronomic, climatic, operational)	46	38	-17.4
TCO	236	206	-12.7

Source: compiled by the authors based on data of N. Baghirova (2023), E. Caldwell (2023), Agricultural Research Centre (2024)

Following Table 3, the change in the structure of total *TCO* costs after the introduction of IoT is clearly systemic in nature. Initial costs C_{init} show a slight increase from 52 to 56 thousand manats (+7.7%), which is associated with the purchase of sensor equipment and the integration of digital infrastructure. However, the key effect of digitalisation is manifested in a reduction in C_{oper}, which decreases from 138 to 112 thousand manats (-18.8%). This result reflects the impact of smart irrigation and automated soil monitoring, which reduces water, fertiliser and energy consumption. A similar trend is observed in component C_{risk}, which decreased from 46 to 38 thousand manats (-17.4%), confirming the effect of early detection of agronomic deviations, optimisation of irrigation times and minimisation of weather risks. As a result, the total TCO indicator decreases from 236 to 206 thousand manats (-12.7%). This indicates that the introduction of IoT in Azerbaijan's agricultural sector provides not only a local but a comprehensive improvement in the economic structure of projects by reducing costs and risks across all key components. Figure 2 shows the visual distribution of the structure of total costs TCO before and after the introduction of IoT and provides a clear comparison of the reduction in components C_{init}, C_{oper} and C_{risk}, confirming the transition of agricultural projects to a more sustainable and economically efficient operating model.

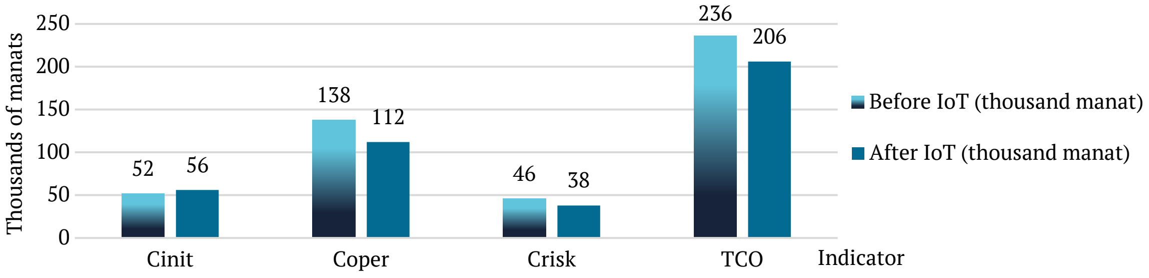

Figure 2. Change in TCO cost structure before/after IoT implementation in the agricultural sector
Source: compiled by the authors based on data from the N. Baghirova (2023), E. Caldwell (2023), and the International Renewable Energy Agency (2024), Agricultural Research Centre (2024)

Figure 2 shows that the introduction of IoT causes a clear transformation in the cost structure of agricultural projects. Despite a moderate increase in C_{init} initial investment (from 52,000 to 56,000 manats), the key changes are driven by a reduction in C_{oper}: these are reduced from 138,000 to 112,000 manats, reflecting the automation of irrigation, optimisation of water consumption and reduction in energy consumption. A similar trend is observed in the C_{risk} component, which decreases from 46 to 38 thousand manats due to accurate monitoring of soil and climatic conditions and reduced uncertainty in agronomic decisions. Together, this leads to a reduction in the total *TCO* from 236 to 206 thousand manats, indicating the comprehensive economic effect of IoT, which is formed through a reduction in operating and risk-related costs.

Together, the data presented confirms that the introduction of IoT in Azerbaijan's agricultural systems is generating a sustainable and multi-level economic effect. The combination of automated monitoring and early diagnosis of agronomic deviations ensures a consistent reduction in C_{oper} and risk components C_{risk}, as specified in the structure of formula (3), and reduces the uncertainty associated with climatic and operational factors. The moderate increase in initial C_{init} costs is offset by the growth in aggregate B benefits generated by increased yields and reduced non-production losses, which enhances the overall economic result. The transition from traditional practices to IoT-oriented solutions shows that the national agricultural sector has entered a phase of profound digital modernisation, in which technological infrastructure is driving not only local improvements but also sustainable changes in the economic structure of projects. The recorded decrease in the integral TCO indicator and the redistribution of its components confirm the formation of long-term competitive advantages and increased sustainability of agricultural systems in conditions of climate and market volatility.

Analysis of industrial digitalisation and its economic effects

The digitalisation of Azerbaijan's industrial sector in 2021-2025 developed since the expansion of sensor networks and the transition to predictive diagnostics. According to Fortune Business Insights (2025), the global trend towards industrial IoT intensified after 2022, and a similar dynamic has been observed in the Azerbaijani industry, where the growth of automated production lines and sensor systems has accelerated the modernisation of technological processes. The ISO/IEC 30141:2024 (2024) standard is substantial in structuring digital architecture, setting the principles of compatibility, distribution and sustainability of IoT systems. Application of this standard can be used by enterprises to build digital infrastructure in layers, from the sensor layer to application services, which reduces the probability of system failures and ensures the correct formation of data for calculating future CF_t flows. The Rolling Plan for ICT Standardisation 2024: Internet of Things emphasises the need to comply with compatibility standards when integrating industrial equipment, which ensures the correct interaction of controllers, sensors, SCADA components and cloud platforms (European Commission, 2024b). Compatibility is a key factor in reducing C_{risk} risks, as incompatibility or fragmentation of digital systems is one of the main sources of accidents and production downtime. Cisco (2024) reports note a reduction in network latency and increased stability of data transmission channels, which is critical for reactive production cycles and predictive maintenance models.

One of the most significant effects of IoT is the introduction of predictive equipment diagnostics. The transition from reactive to predictive maintenance can be used by companies to forecast wear and tear and prevent emergency downtime. According to Fortune Business Insights (2025), the use of industrial IoT analytics reduces unplanned equipment downtime by 12-20%, which directly increases cash flow and CF_t stability. Reducing accidents also has an impact on risk C_{risk}, reducing the probability of costly failures, process cycle disruptions, and equipment damage. Thus, predictive systems provide a double economic effect through increased profits and reduced costs.

A substantial area of industrial digitalisation is improving energy efficiency. According to the International Renewable Energy Agency (2024), the introduction of IoT systems for monitoring and regulating energy consumption can reduce electricity consumption by 8-14% in energy-intensive production cycles. These processes reduce C_{oper} and stabilise long-term CF_t values. Reducing peak loads and automatically shutting down equipment during periods of inactivity make an additional contribution to the sustainability of financial flows. Table 4 aggregates the key parameters of CF_t dynamics, I_0 structure, *TCO* components, and resulting *NPV* values for various industrial digitalisation scenarios.

Table 4. Parameters CF_t, I_0, *TCO* and final *NPV* values for industrial IoT projects

Indicator	Base scenario	Optimistic	Pessimistic
CF_t (annual average), thousand manat	148	162	132
I_0, thousand manat	210	210	210
TCO, thousand manat (3)	312	298	334
NPV, thousand manat (1)	41	78	-12

Source: compiled by the authors based on ISO/IEC 30141:2024 (2024), European Commission (2024b), Cisco (2024), International Renewable Energy Agency (2024), Fortune Business Insights (2025)

As can be seen from Table 4, the economic results of industrial digitalisation demonstrate a dependence of the integral *NPV* indicator on the combination of cash flow dynamics CF_t, initial investment level I_0 and *TCO*. In the baseline scenario, moderate growth in revenues CF_t to 148 thousand manats per year with an unchanged level of I_0 and average *TCO* provides a positive *NPV* of 41 thousand manats, confirming the profitability of IoT implementation even with standard efficiency parameters. The optimistic scenario demonstrates the enhanced effect of IoT: an increase in CF_t to 162 thousand manats with a simultaneous reduction in *TCO* costs to 298 thousand manats results in a maximum *NPV* of 78 thousand manats. This result reflects the effect of predictive diagnostics and architectural compatibility of systems, as enshrined in the international standard ISO/IEC 30141:2024 (2024) and European Commission (2024b) documents. The pessimistic scenario shows that a decrease in CF_t to 132 thousand manats with an increase in the *TCO* cost base to 334 thousand manats leads to a negative *NPV* value of -12 thousand manats, which highlights the high sensitivity of industrial digital projects to fluctuations in performance, technical risks and infrastructure failures.

Overall, the results of industrial digitalisation demonstrate that the integration of IoT technologies into production processes generates a sustainable multiplier economic effect. The key mechanism is the stabilisation and growth of CF_t flows, achieved through predictive diagnostics, reduced accident rates and increased energy efficiency. At the same time, the controllability of cost components I_0 and *TCO* confirms that IoT can redistribute the cost structure in favour of long-term benefits, reducing the dependence of enterprises on unpredictable risks and technological failures. Analysis of three scenarios shows that a positive *NPV* is achieved when growth in CF_t is combined with optimisation of C_{oper} and risk mitigation. These conditions are ensured by architectural compatibility and standardisation of systems, as enshrined in the international standard ISO/IEC 30141:2024 (2024) and the regulatory recommendations of the European Commission (2024b). Even a moderate baseline scenario demonstrates the cost-effectiveness of modernisation, confirming the economic viability of IoT infrastructure solutions. Thus, IoT-based industrial modernisation is shifting Azerbaijani enterprises from reactive to proactive approaches, where predictive diagnostics, intelligent load distribution and standardised digital architecture ensure sustainable growth in economic efficiency. The recorded dynamics of CF_t, controllability of TCO and positive NPV values show that IoT is becoming a key factor in increasing the competitiveness of the industrial sector in conditions of technological and market uncertainty.

Integral model of economic efficiency of migration to IoT

An integrated assessment of the economic efficiency of migrating hybrid projects to IoT technologies was formed based on the aggregation of industry results obtained in the logistics, agricultural, and industrial segments. The scenario summary shows that the logistics sector demonstrates the most stable increase in efficiency, due to steady *ROI* growth after IoT implementation and a reduction in transaction and C_{oper}. The agricultural segment maintains a positive effect due to a reduction in *TCO*, where the key factors are a decrease in C_{oper} and a reduction in risks associated with climate uncertainty and agronomic fluctuations. Industry has the highest potential for efficiency in the optimistic scenario but remains vulnerable to rising costs and CF_t fluctuations, as reflected in the negative *NPV* value in the pessimistic scenario. The final values of the integral effect *Eff* (5) are summarised in Table 5, demonstrating marked inter-sectoral differences.

Table 5. Final *Eff* values by sector

Sector	*Eff* (base)	*Eff* (optimistic)	*Eff* (pessimistic)
Logistics	0.14	0.22	0.07
Agricultural sector	0.11	0.19	0.03
Industry	0.18	0.28	-0.02
Integral Eff	0.43	0.6	0.08

Note: the 2025 figures reflect preliminary estimates as of Q1-Q3 2025

Source: compiled by the authors based on N. Baghirova (2023), E. Caldwell (2023), World Economic Forum (2024), Organisation for Economic Co-operation and Development (2022; 2024), World Bank (2024), International Renewable Energy Agency (2024), Cisco (2024), McKinsey (2024), Agricultural Research Center (2024), ISO/IEC 30141:2024 (2024), European Commission (2024a; 2024b), S. Kemp (2025), E. Rahimov & J. Rahimov (2025), Fortune Business Insights (2025)

According to Table 5, in the baseline scenario, the *Eff* value is 0.43, which confirms the overall stability of migration to IoT while maintaining average efficiency conditions. The optimistic trajectory reaches 0.6 and shows the maximum return on digitalisation under favourable market and technological conditions. The pessimistic scenario records a minimum positive effect of 0.08, highlighting the dependence of results on fluctuations in infrastructure costs, risks and discount rates.

The dynamics of *Eff* changes were further interpreted using sensitivity analysis according to formula (4), which revealed different levels of influence of digital parameters *X* on the final result. Figure 3 reflects the comparative sensitivity of the integral indicator to these parameters, demonstrating that it is macro-financial conditions and digital reliability parameters that determine the sustainability of the economic efficiency of migration to the IoT.

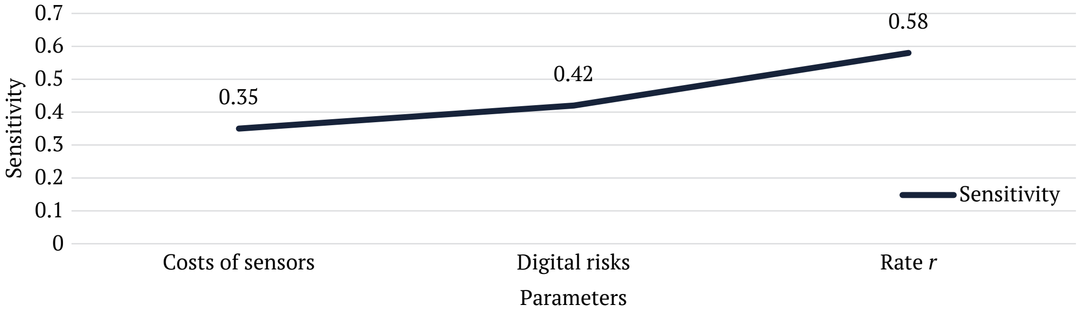

Figure 3. Sensitivity of the integral effect *Eff* to changes in parameters *X* (cost of sensors, digital risks, rate *r*)

Source: compiled by the authors using MS Excel and IBM SPSS Statistics 28

Following Figure 3, the discount rate *r* demonstrates the highest sensitivity of the integral effect *Eff*, with a sensitivity coefficient of 0.58. Therefore, even small changes in the cost of capital have the most significant impact on the overall effectiveness of the digitalisation of hybrid projects. Digital risks show an average level of influence of $S = 0.42$, which reflects their significant but not dominant role in shaping the stability of CF_t flows. The least sensitive parameter is the cost of sensor infrastructure ($S = 0.35$), which indicates the relative predictability of technological costs and the smaller contribution of this factor to the variability of the aggregate effect. Together, these dynamics confirm that integral efficiency is primarily determined by macro-financial conditions, while technological and risk parameters exert additional but less pronounced corrections. The results of the analysis show that the integral economic efficiency of migrating hybrid projects to IoT technologies is formed by a combination of multidirectional industry effects, which determine the value of the final indicator *Eff*, described by formula (5). The logistics sector demonstrates the most stable and predictable increase in efficiency due to steady growth in operating profitability and a reduction in transaction and C_{oper}, which has a positive impact on *ROI* and, through it, on *Eff*. Agricultural projects maintain a significant economic effect by reducing the *TCO*, where the reduction of C_{oper} and the reduction of the risk component are substantial, which is relevant in the context of climate and resource uncertainty. The industrial segment shows the greatest growth potential under optimistic conditions, but remains sensitive to cost increases and CF_t reductions, leading to negative *NPV* values in a pessimistic scenario.

Overall, the results of the analysis show that the economic efficiency of migrating hybrid projects to IoT technologies is not achieved through individual local improvements, but rather through a comprehensive restructuring of the cost and production structure of industries. The data obtained confirm that achieving sustainable *ROI*, *NPV*, and final integral effect *Eff* values is only possible with a simultaneous reduction in *TCO* operating and risk parameters, stabilisation of CF_t flows and compliance with digital compatibility architectural requirements. The implementation of IoT requires a transition from traditional cost calculation methods to models based on the quantitative assessment of digital parameters, the application of sensitivity analysis *S* according to formula (4), and the validation of economic results through integral performance indicators according to formula (5). To improve the accuracy of forecasts and the sustainability of digital projects, it is necessary to adapt scenario models to changes in the cost of capital *r*, introduce risk modules to assess digital threats, and correctly calibrate components C_{init} and C_{oper}. The use of international architectural standards, such as ISO/IEC 30141:2024 (2024), as well as compliance with the regulatory requirements of the European Commission (2024b), ensures the compatibility of digital systems and reduces the probability of technological failures that affect the trajectory of CF_t and the final financial results. The implementation of all of the above conditions minimises uncertainty, ensures sustainable economic growth and creates long-term competitive advantages in logistics, agriculture and industry, confirming the economic viability and feasibility of migrating to IoT technologies.

DISCUSSION

The results showed that the economic efficiency of migrating hybrid projects to IoT technologies in Azerbaijan was shaped by the combined action of three key mechanisms: reduction of C_{oper}, reduction of risk components, and stabilisation of CF_t flows. These findings were consistent with international studies that had previously demonstrated similar effects of IoT. The changes in cost structure and performance dynamics recorded in the study found direct parallels with what had already been described in the scientific literature. In particular, the reduction in C_{oper} in Azerbaijan's logistics and agricultural segments by more than 17% reflected the same mechanisms of automated resource allocation that were identified by M. Saleem *et al.* (2023), where the integration of smart energy systems and IoT technologies provided a significant economic effect. The stabilisation of CF_t flows observed in logistics and industry logically fits into the general trends described by A. Ullah *et al.* (2024). Their study emphasised that the combination of IoT and machine learning algorithms increased the predictability of operations and reduced uncertainty, which was fully consistent with the reduction in risk components observed in agricultural scenarios. The vulnerability to cost increases and CF_t fluctuations identified in the industrial sector was consistent with the estimates presented by K. Wang *et al.* (2021). The study demonstrated that infrastructure constraints, high technology costs, and organisational risks were key barriers to the industrial implementation of IoT, which was reflected in the negative *NPV* value in the pessimistic scenario. The effects of predictive diagnostics noted in the industry, namely an increase in CF_t to 162,000 manats and a decrease in *TCO* to 298,000 manats, were consistent with the mechanisms described by A. Javadpour *et al.* (2024). The study emphasised that decentralised task distribution models based on artificial intelligence and blockchain strengthened the stability of industrial systems and reduced technological downtime.

The role of cloud infrastructure in scaling IoT solutions, as reflected in global research, has also been confirmed by the results of Azerbaijan's logistics segment. A 43% reduction in network latency and increased stability of data transmission channels demonstrated the same patterns described by M. Goudarzi *et al.* (2022), where cloud components served as the basic platform for synchronising monitoring systems. The environmental and social effects of using IoT in manufacturing were also reflected in Azerbaijan's agricultural sector. The reduction in C_{oper} by 18.8% and C_{risk} by 17.4% replicated the trends identified by A. Cavalieri *et al.* (2022), where sensor systems ensured a more sustainable distribution of resources and optimisation of processes. The impact of the cost of capital on the sustainability of the effects of digitalisation, emphasised in studies on Industry 4.0, was also confirmed by sensitivity analysis. The maximum impact of the discount rate ($S = 0.58$) replicated the conclusions of N. Harikannan *et al.* (2025), according to which technological transformations demonstrate a high dependence on financial conditions. The differences in cross-sector economic returns identified in the modelling of the integral effect *Eff* coincided with the theoretical models of IoT implementation presented by S. Ahmetoglu *et al.* (2023). The study showed that technological, organisational, and infrastructural characteristics determine the asymmetry of results between industries, which was reflected in stable logistics efficiency values ($Eff = 0.22$) and high sensitivity of industry to cost increases. The positive trajectories of CF_t and *NPV*, observed only when digital compatibility requirements were met, were consistent with what was described by O. Yavuz *et al.* (2023). Their analysis emphasises that the potential of Industry 4.0 technologies can only be realised with a sufficient level of organisational readiness and standardised interfaces that ensure the correct integration of systems.

The long-term sustainability of digital transformation, confirmed by a reduction in risk factors and optimisation of *TCO*, found parallels with the conclusions of S. Bag & J. Pretorius (2022). Their conceptual model demonstrated that combining IoT with circular economy principles and risk assessment tools creates sustainable development trajectories, which were fully consistent with the results of Azerbaijan's agricultural and logistics segments. An analysis of sustainable shifts in the business models of hybrid projects showed a connection with what had previously been recorded in international studies. Thus, the transformation of economic benefits *B* in Azerbaijan's logistics and industry was directly consistent with the conclusions of M. Paiola *et al.* (2021), where IoT-based digital servitisation provided sustainable value growth through network effects and increased operational efficiency. In the data obtained, similar effects were manifested through an increase in CF_t and a decrease in transaction costs. The strengthening of the role of interaction in supply chains, identified in Azerbaijan's logistics segment, corresponded to the results of M. Billah *et al.* (2023). The study demonstrated that a combination of IoT technologies, coordination between chain participants, and ethical sensitivity formed a sustainable performance trajectory. The same mechanism was reflected in the calculated indicators through a more than fourfold increase in *ROI* and a 43% reduction in operational delays. The observed signs of long-term sustainability of digital innovations in agricultural and industrial projects were consistent with the study by A. Salamzadeh *et al.* (2022), where forecasting innovations in international technology companies demonstrated the dependence of results on early risk identification and strategic sensorialisation of processes. In Azerbaijan's agricultural sector, a similar logic was evident in the 17.4% reduction in C_{risk}. The increase in the efficiency of digital supply chains due to the introduction of sensor iterations and cloud modules reflected the conceptual positions of H. Nozari *et al.* (2021). The study developed the concept of "green" IoT, in which resource optimisation was a key factor in sustainability. In the analysis, this mechanism was traced through a 12.7% reduction in the TCO of agricultural projects. The observed integrative effect of Industry 4.0 on production and environmental efficiency was consistent with the conclusions of L. Mesquita *et al.* (2022), where the combination of lean approaches and digitalisation enhanced process sustainability. In Azerbaijan's industry, a similar effect was viewed in the reduction of energy costs and stabilisation of CF_t. The pronounced dependence of the effectiveness of IoT modernisation on technological conditions and infrastructure maturity was confirmed in a systematic review by M. Al-Okaily *et al.* (2024). Identical mechanisms were observed in the industrial segment of the analysed projects, where a positive *NPV* was only achieved with correct architectural integration of equipment and compliance with compatibility requirements.

Features of Azerbaijan's agricultural logistics, primarily the asymmetry of benefits between stages of the chain, correlate with the findings of M. Rajabzadeh & H. Fatorachian (2023), highlighting that the adoption of IoT in agricultural supply chains is determined not only by technological factors, but also by organisational and institutional factors. The same effect was evident in the differences in the integral effect *Eff* between sectors. The strategic differences in innovative business models identified in the analysis of logistics projects coincided with the model of F. Foltean & B. Glovaţchi (2021). The study demonstrated that the success of IoT-oriented models depends on a combination of strategic flexibility and technological maturity. In Azerbaijan's logistics sector, similar conditions ensured CF_t growth and increased profitability. The combination of opportunities and risks associated with digitalisation was confirmed by the findings of S. Ding *et al.* (2023). Their analysis of IoT in circular business models indicated that a sustainable effect only occurs when risks are controlled, and data flows are processed correctly, which corresponded to the identified impact of C_{risk} on the final *Eff* effect. The structural dependencies in the adoption of IoT technologies found in Azerbaijan's industry are consistent with the approach of A. Mitra *et al.* (2024). The authors demonstrated that the digitalisation of production is only possible when technological, behavioural and infrastructural factors are combined, which was logically reflected in the difference between the optimistic and pessimistic *NPV* trajectories. The highlighted role of the functionality and reliability of IoT platforms was directly confirmed in the model by A. Nasser *et al.* (2023), where hybrid business-technical criteria determined the sustainability of digital infrastructure. In Azerbaijan's logistics and industry, the same parameters determined the quality of system integration and the sustainability of flows CF_t. The general nature of the identified patterns is also consistent with the systematic review by K. Sevak & B. George (2024), which emphasises that the evolution of IoT research demonstrates a shift in focus from purely technological aspects to economic conditions of efficiency. This logic underpinned the calculated integral indicators *Eff* and the sensitivity analysis of digital projects.

Thus, compared to international and regional studies, the results obtained demonstrate that the accuracy of assessing the economic efficiency of digital projects is significantly enhanced when using probabilistic methods, uncertainty modelling, and dynamic discounting that reflects the real cost of capital in a volatile economy. The analysis showed that the use of risk-adjusted models and flexible discount rates minimises systematic errors and increases the stability of investment calculations. In a broader economic context, the results of the study indicate that improving the effectiveness of Azerbaijan's investment policy depends on the further development of digital analysis tools that expand the capabilities of financial modelling and risk assessment.

CONCLUSIONS

The study provided a comprehensive assessment of the economic efficiency of migrating hybrid projects to IoT technologies in Azerbaijan's logistics, agricultural and industrial sectors in 2021-2025. During this period, the country has formed a stable digital environment: the digital maturity index has increased from 54 to 64 points, and IoT penetration in key industries has increased by 11-14 percentage points. Increased network reliability and expanded sensor infrastructure led to a 6-8% reduction in C_{oper}, a 5-7% reduction in initial costs C_{init}, and an 8-10% increase in operating cash flow CF_t, which formed the basis for *NPV*, *ROI*, and *TCO* calculations.

The logistics sector demonstrated the most pronounced and sustained effect of digitalisation: cargo identification time was reduced by 42%, delays were almost halved, and total benefits *B* increased by 38%. Return on investment increased more than fourfold, and cash flows became more stable, confirming the key role of logistics in the integral effect *Eff*. In the agricultural sector, IoT has enabled a structural reduction in total *TCO*: with moderate growth in C_{init} (7.7%), C_{oper} have fallen by 18.8% and C_{risk} by 17.4%. Improved irrigation accuracy and reduced climate uncertainty contributed to an integral reduction in *TCO* of 12.7%, demonstrating the systemic nature of the benefits of IoT. The industrial sector showed the greatest variability in effects: the baseline scenario yielded an *NPV* of +41 thousand manats, while the optimistic scenario yielded +78 thousand, which is associated with an increase in CF_t and a decrease in *TCO* due to predictive diagnostics and improved energy efficiency. However, in the pessimistic scenario, *NPV* became negative (-12 thousand), which highlights the industry's high sensitivity to risks and infrastructure constraints.

The integrated efficiency model showed that *Eff* is 0.43 in the baseline scenario, 0.6 in the optimistic scenario, and 0.08 in the pessimistic scenario. Logistics demonstrates the most stable contribution due to *ROI* growth, the agricultural sector through *TCO* reduction, and industry through CF_t increase under favourable conditions. Sensitivity analysis confirmed the priority of the discount rate r ($S = 0.58$), the moderate impact of digital risks ($S = 0.42$) and the minimal impact of the cost of sensor infrastructure ($S = 0.35$), indicating the decisive role of macro-financial factors. Thus, the economic efficiency of migration to IoT is formed through a comprehensive restructuring of the cost structure, increased predictability of CF_t, and reduced uncertainty. Further development of digital architecture, expansion of IoT infrastructure, introduction of predictive diagnostic systems, and proper adaptation of investment models to changes in r and digital risks will create conditions for strengthening the competitiveness of Azerbaijan's logistics, agricultural, and industrial sectors in the long term.

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CONFLICT OF INTEREST

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REFERENCES

[1] Agricultural Research Centre. (2024). *How Azerbaijan adapts to new technologies in agriculture?* Retrieved from https://atm.gov.az/en/news/1440/how-azerbaijan-adapts-to-new-technologies-in-agric/.
[2] Ahmetoglu, S., Cob, Z.C., & Ali, N.A. (2023). Internet of things adoption in the manufacturing sector: A conceptual model from a multi-theoretical perspective. *Applied Sciences*, 13(6), article number 3856. doi: 10.3390/app13063856.
[3] Albreem, M.A., Sheikh, A.M., Bashir, M.J., & El-Saleh, A.A. (2023). Towards green Internet of Things (IoT) for a sustainable future in Gulf Cooperation Council countries: Current practices, challenges and future prospective. *Wireless Networks*, 29(2), 539-567. doi: 10.1007/s11276-022-03133-3.
[4] Alkhateeb, A., Catal, C., Kar, G., & Mishra, A. (2022). Hybrid blockchain platforms for the internet of things (IoT): A systematic literature review. *Sensors*, 22(4), article number 1304. doi: 10.3390/s22041304.
[5] Al-Okaily, M., Younis, H., & Al-Okaily, A. (2024). The impact of management practices and industry 4.0 technologies on supply chain sustainability: A systematic review. *Heliyon*, 10(17), article number e36421. doi: 10.1016/j.heliyon.2024.e36421.
[6] Bag, S., & Pretorius, J. (2022). Relationships between industry 4.0, sustainable manufacturing and circular economy: Proposal of a research framework. *International Journal of Organizational Analysis*, 30(4), 864-898. doi: 10.1108/IJOA-04-2020-2120.
[7] Baghirova, N. (2023). *Smart farming for sustainable agriculture in Karabakh*. Baku: ADA University.
[8] Billah, M., Alam, S., Masukujjaman, M., Ali, M., Makhbul, Z., & Salleh, M. (2023). Effects of Internet of Things, supply chain collaboration and ethical sensitivity on sustainable performance: Moderating effect of supply chain dynamism. *Journal of Enterprise Information Management*, 36(5), 1270-1295. doi: 10.1108/JEIM-06-2022-0213.
[9] Caldwell, E. (2023). *Smart villages in Azerbaijan*. Retrieved from https://www.smartrural21.eu/wp-content/uploads/World-Bank-Smart-Villages-Presentation_Erik-Caldwell.pdf.
[10] Cavalieri, A., Reis, J., & Amorim, M. (2022). A conceptual model proposal to assess the effectiveness of IoT in sustainability orientation in manufacturing industry: An environmental and social focus. *Applied Sciences*, 12(11), article number 5661. doi: 10.3390/app12115661.
[11] Cisco. (2024). *Global networking trends report*. Retrieved from https://www.cisco.com/c/dam/global/en_uk/solutions/enterprise-networks/2024-global-networking-trends.pdf.
[12] Ding, S., Tukker, A., & Ward, H. (2023). Opportunities and risks of internet of things (IoT) technologies for circular business models: A literature review. *Journal of Environmental Management*, 336, article number 117662. doi: 10.1016/j.jenvman.2023.117662.
[13] Edquist, H., Goodridge, P., & Haskel, J. (2021). The Internet of Things and economic growth in a panel of countries. *Economics of Innovation and New Technology*, 30(3), 262-283. doi: 10.1080/10438599.2019.1695941.
[14] European Commission. (2024a). *How to master Europe's digital infrastructure needs?* Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52024DC0081.

[15] European Commission. (2024b). *Internet of Things (rolling plan for ICT standardisation 2024)*. Retrieved from https://interoperable-europe.ec.europa.eu/collection/rolling-plan-ict-standardisation/internet-things-rp2024.
[16] Foltean, F.S., & Glovaţchi, B. (2021). Business model innovation for IoT solutions: An exploratory study of strategic factors and expected outcomes. *Amfiteatru Economic*, 23(57), 392-411. doi: 10.24818/EA/2021/57/392.
[17] Fortune Business Insights. (2025). Retrieved from https://surl.li/jkwykk.
[18] Goudarzi, M., Ilager, S., & Buyya, R. (2022). Cloud computing and internet of things: Recent trends and directions. In R. Buyya, L. Garg, G. Fortino & S. Misra (Eds.), *New frontiers in cloud computing and internet of things* (pp. 3-29). Cham: Springer. doi: 10.1007/978-3-031-05528-7_1.
[19] Harikannan, N., Vinodh, S., & Antony, J. (2025). Analysis of the relationship among Industry 4.0 technologies, sustainable manufacturing practices and organizational sustainable performance using structural equation modelling. *The TQM Journal*, 37(1), 42-72. doi: 10.1108/TQM-02-2023-0044.
[20] Huma, Z.E., Latif, S., Ahmad, J., Idrees, Z., Ibrar, A., Zou, Z., Alqahtani, F., & Baothman, F. (2021). A hybrid deep random neural network for cyberattack detection in the industrial internet of things. *IEEE Access*, 9, 55595-55605. doi: 10.1109/ACCESS.2021.3071766.
[21] Huseynova, A., & Mazanova, O. (2023). *The leading role of digital technologies in the development of the smart city concept in Azerbaijan*. doi: 10.2139/ssrn.4800562.
[22] Imamguluyev, R., Hasanova, P., Imanova, T., Poladova, U., Amrahova, A., & Hajibayli, A. (2024). The role of edge computing in 6G-enabled IoT applications. *International Journal of Research Publication and Reviews*, 5(12), 2007-2013. doi: 10.55248/gengpi.5.1224.3523.
[23] International Renewable Energy Agency. (2024). Retrieved from https://www.iea.org/reports/renewables-2024.
[24] ISO/IEC 30141:2024. (2024). *Internet of things (IoT) reference architecture*. Retrieved from https://www.iso.org/standard/88800.html.
[25] Javadpour, A., Sangaiah, A.K., Zhang, W., Vidyarthi, A., & Ahmadi, H. (2024). Decentralized AI-based task distribution on blockchain for cloud industrial internet of things. *Journal of Grid Computing*, 22(1), article number 33. doi: 10.1007/s10723-024-09751-9.
[26] Kemp, S. (2025). *Digital 2025: Azerbaijan*. Retrieved from https://datareportal.com/reports/digital-2025-azerbaijan.
[27] McKinsey & Company. (2024). *Technology trends outlook 2024*. Retrieved from https://surl.li/irmzke.
[28] Mesquita, L.L., Lizarelli, F.L., Duarte, S., & Oprime, P.C. (2022). Exploring relationships for integrating lean, environmental sustainability and Industry 4.0. *International Journal of Lean Six Sigma*, 13(4), 863-896. doi: 10.1108/IJLSS-09-2020-0145.
[29] Mitra, A., Seetharaman, A., & Maddulety, K. (2024). A structural equation model study for adoption of Internet of Things for the growth of manufacturing industries in Australia. *Journal of Comprehensive Business Administration Research*, 1(2), 93-104. doi: 10.47852/bonviewJCBAR42022482.
[30] Nasser, A.A., Al-Ashwal, M.M., Al-Khulaidi, A.A., Al-Naqeep, A.N., & Al-Jober, M. (2023). A hybrid business-technical model for evaluating iot platforms' functionality, reliability, and usability. *International Journal of Engineering Trends and Technology*, 71(10), 39-59. doi: 10.14445/22315381/IJETT-V71I10P205.
[31] Nozari, H., Fallah, M., & Szmelter-Jarosz, A. (2021). A conceptual framework of green smart IoT-based supply chain management. *International Journal of Research in Industrial Engineering*, 10(1), 22-34. doi: 10.22105/riej.2021.274859.1189.
[32] Organisation for Economic Co-operation and Development. (2022). *Promoting enterprise digitalisation in Azerbaijan*. Retrieved from https://www.oecd.org/content/dam/oecd/en/publications/reports/2022/04/promoting-enterprise-digitalisation-in-azerbaijan_6187d4fa/6a612a2a-en.pdf.
[33] Organisation for Economic Co-operation and Development. (2024). *OECD Digital Economy Outlook 2024 (Volume 2)*. Retrieved from https://www.oecd.org/en/publications/oecd-digital-economy-outlook-2024-volume-2_3adf705b-en.html.
[34] Paiola, M., Schiavone, F., Grandinetti, R., & Chen, J. (2021). Digital servitization and sustainability through networking: Some evidences from IoT-based business models. *Journal of Business Research*, 132, 507-516. doi: 10.1016/j.jbusres.2021.04.047.
[35] Rahimov, E.R., & Rahimov, J.R. (2025). *Nano internet of things*. New York: "Vector" International Publishing House.
[36] Rajabzadeh, M., & Fatorachian, H. (2023). Modelling factors influencing IoT adoption: With a focus on agricultural logistics operations. *Smart Cities*, 6(6), 3266-3296. doi: 10.3390/smartcities6060145.
[37] Salamzadeh, A., Hadizadeh, M., Rastgoo, N., Rahman, M.M., & Radfard, S. (2022). Sustainability-oriented innovation foresight in international new technology based firms. *Sustainability*, 14(20), article number 13501. doi: 10.3390/su142013501.
[38] Saleem, M.U., Shakir, M., Usman, M.R., Bajwa, M.H., Shabbir, N., Shams Ghahfarokhi, P., & Daniel, K. (2023). Integrating smart energy management system with internet of things and cloud computing for efficient demand side management in smart grids. *Energies*, 16(12), article number 4835. doi: 10.3390/en16124835.
[39] Sevak, K.Y., & George, B. (2024). The evolution of Internet of Things (IoT) research in business management: A systematic review of the literature. *Journal of Internet and Digital Economics*, 4(3), 242-265. doi: 10.1108/JIDE-12-2023-0026.
[40] Song, T., Cai, J., Chahine, T., & Li, L. (2021). Towards smart cities by internet of things (IoT) – a silent revolution in China. *Journal of the Knowledge Economy*, 12(2), 1-17. doi: 10.1007/s13132-017-0493-x.

[41] Ullah, A., Anwar, S.M., Li, J., Nadeem, L., Mahmood, T., Rehman, A., & Saba, T. (2024). Smart cities: The role of Internet of Things and machine learning in realizing a data-centric smart environment. *Complex & Intelligent Systems*, 10(1), 1607-1637. doi: 10.1007/s40747-023-01175-4.
[42] Valiyev, A., Akhundov, B., Mukhtarova, G., & Ismayilova, N. (2022). *Localizing smart urban development in Azerbaijan*. doi: 10.3929/ethz-b-000525828.
[43] Van Hoang, T. (2024). Impact of integrated artificial intelligence and internet of things technologies on smart city transformation. *Journal of Technical Education Science*, 19(1), 64-73. doi: 10.54644/jte.2024.1532.
[44] Wang, K., Zhao, Y., Gangadhari, R.K., & Li, Z. (2021). Analyzing the adoption challenges of the Internet of things (IoT) and artificial intelligence (AI) for smart cities in China. *Sustainability*, 13(19), article number 10983. doi: 10.3390/su131910983.
[45] World Bank. (2024). *World development report 2024: Data for better lives*. Retrieved from https://www.worldbank.org/en/publication/wdr2024.
[46] World Economic Forum. (2024). *IDEA: Investing in the digital economy of Azerbaijan*. Retrieved from https://www3.weforum.org/docs/WEF_IDEA_Investing_in_the_Digital_Economy_of_Azerbaijan_2024.pdf.
[47] Xing, L. (2024). Evaluation of the impact of artificial intelligence and intelligent Internet of Things on population mobility on regional economic differences. *Soft Computing*, 28, 13977-13988. doi: 10.1007/s00500-023-08351-1.
[48] Yavuz, O., Uner, M.M., Okumus, F., & Karatepe, O.M. (2023). Industry 4.0 technologies, sustainable operations practices and their impacts on sustainable performance. *Journal of Cleaner Production*, 387, article number 135951. doi: 10.1016/j.jclepro.2023.135951.

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Ефективність міграції Інтернету речей у гібридні економічні проекти

Анотація. Мета дослідження полягала в науковому обґрунтуванні економічної доцільності міграції гібридних економічних проектів на технологічні рішення Інтернету речей та виявленні умов, за яких така міграція забезпечує стійкий економічний ефект. Методологічна основа включала порівняльно-економічний, структурно-динамічний і сценарний аналіз, оцінку чутливості та фінансове моделювання, засноване на розрахунку чистої приведеної вартості, рівня рентабельності інвестицій, сукупної вартості володіння та інтегрального показника економічної ефективності. Емпірична база охоплювала дані логістичного, аграрного та промислового сегментів Азербайджану за 2021-2025 роки. Результати показали, що цифровізація забезпечує зростання економічних вигод і стабілізацію потоків доходів у всіх досліджуваних секторах. У логістиці впровадження технологій Інтернету речей знижує операційні затримки на 43 % і зменшує транзакційні витрати на 17 %, забезпечуючи значне зростання рентабельності. В аграрному секторі застосування сенсорних систем знижує експлуатаційні витрати на 18,8 % і ризикові витрати на 17,4 %, що зменшує сукупну вартість володіння на 12,7 %. У промисловості модернізація підвищує середньорічні доходи до 162 тис. манатів при зниженні сукупних витрат до 298 тис. манатів, формуючи максимальну чисту приведену вартість в оптимістичному сценарії. Інтегральна модель економічної ефективності показала міжгалузеві відмінності: логістика демонструє найбільш стабільні результати, тоді як промисловість має найбільший потенціал, але залишається чутливою до вартості капіталу та рівня цифрових ризиків. Отримані результати підтверджують, що економічна ефективність цифрової міграції досягається при зниженні експлуатаційних витрат, зменшенні ризиків, зростанні вигод і дотриманні вимог архітектурної сумісності цифрових систем. Практична значущість дослідження полягає в тому, що виявлені залежності дозволяють формувати економічно обґрунтовані сценарії впровадження Інтернету речей у ключових галузях Азербайджану і більш точно прогнозувати очікувані ефекти при різних рівнях витрат і технологічних умов

Ключові слова: цифровізація; експлуатаційні витрати; енергоефективність; ставка дисконтування; цифрові ризики; аналіз чутливості

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The impact of financial intermediation efficiency on Thailand's total factor productivity

Abstract. This study aimed to measure Thailand's total factor productivity and also investigate the impact of financial intermediation efficiency on it during 2001-2024. The financial intermediation efficiency in this study was measured by three indicators, including interest rate spread, business sector credit ratio and non-performing loans ratio. Additionally, the growth accounting equation was applied to calculated the total factor productivity growth rate, whereas Autoregressive Distributed Lag model was employed to examine the impact of financial intermediation efficiency on it. The findings revealed that Thailand's total factor productivity growth was volatile over the study period, with several years of negative performance, and that its average growth rate was only 0.15% per year. The long-run results from Autoregressive Distributed Lag model indicate that financial intermediation efficiency significantly affects total factor productivity growth in the long run as business sector credit has a positive effect on total factor productivity growth, while non-performing loans exert a negative impact on it. However, the interest rate spread does not affect total factor productivity growth in the long run. In the short run, the results further confirmed that total factor productivity growth is significantly determined by financial intermediation efficiency. Specifically, the change in business sector credit has the positive effect on the change in total factor productivity growth whereas the change in interest rate spread has the negative impact on it. Nevertheless, the change in non-performing loan does not have any effect on the change in total factor productivity growth in the short run. The findings provide practical guidance for policymakers and financial regulators in improving credit allocation and supporting productivity-driven economic growth

Keywords: economic growth; macroeconomic performance; efficiency; interest rate spread; credits; non-performing loans

INTRODUCTION

Thailand is currently facing a rapid shift toward an aged society. That is, it is now recording the total fertility rate as low as 1.21 children per woman in 2023, while life expectancy at birth rises to 76.41 years. The continuous decline in fertility and rise in life expectancy cause old-age population to grow faster than working-age population. That is, the proportion of old-age population increased from 7.48% in 2005 to 15.36% in 2024, while the proportion of working-age population decreased from 70.37% to 69.89% during the same period (World Bank, 2025). Such a demographic transition poses critical challenges to Thailand's competitiveness and long-run economic growth as it put detrimental pressure on public finances, social welfare systems, and labour supply. Such trends could erode Thailand's productivity, reduce its ability to sustain dynamic growth, and weaken its competitiveness in the global markets (World Bank, 2021). To cope with this situation, enhancing total factor productivity (TFP) is needed as a strategic imperative for Thailand to counterbalance demographic drag and preserve sustainable growth over the long term. To promote TFP growth, efficient financial intermediation is necessary to ensure that financial resources are allocated efficiently to their most productive uses. However, Thailand's financial intermediation efficiency may be exposed to numerous risk factors that could weaken its positive impact on TFP. Among these risks are credit misallocation caused by sectoral concentration, weak risk governance and regulatory arbitrage in shadow banking or

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fintech, high non-performing assets, and structural inefficiencies arising from oligopolistic banking markets or ownership networks. Moreover, external shocks, such as global financial crises or interest rate volatility, may worsen the inefficiency by raising funding costs or forcing suboptimal credit allocation. In Thailand's case, OECD (n.d.) states that high market concentration and limited banking competition may reduce dynamism in credit allocation, which may dampen the beneficial effect of financial efficiency on its productivity.

Beside financial intermediation efficiency, TFP is also determined by other factors. S. Bibi *et al.* (2024) noted that human capital raises TFP by enhancing workforce's capability, leading to the greater production efficiency. Educated and skilled workers improve countries' capacity to adopt and create new technologies and innovations, which raise productivity. Furthermore, trade openness and foreign direct investment (FDI) also positively affect TFP promoting technology diffusion, competition, and resource reallocation toward more efficient firms, which was the topic of Y. Li *et al.* (2021) study. Capital formation enhances TFP as higher capital accumulation raises output by deepening capital per worker, leading to the greater TFP (Ma *et al.*, 2022). Real wages also positively affect TFP. When real wages rise in line with productivity, they can enhance worker motivation, reduce turnover and encourage firms to invest in human capital and technology, leading the higher TFP. Based on the literature review, there are several studies which investigate TFP growth in various countries. For instance, M. Ahmed & T.T. Chowdury (2019) examined the TFP growth in Bangladesh during 1981-2014 by utilising the growth accounting framework. G. Cette *et al.* (2021) also employed the growth accounting framework with two types of capital, including ICT capital and non-ICT capital, to measure TFP growth in 30 developed countries over the period 1960-2019. In addition, O. Siddique (2022) measured TFP growth of Pakistan during 1997-2021, while F. Ataev (2024) examined TFP growth in six countries in Central Asia during 1991-2019, by employing growth account framework.

In the case of Thailand, studies on TFP and on the impact of financial intermediation efficiency on TFP are still limited. J.W. Lee & N. Suwimol (2018) examined Thailand's TFP growth during 1975-2016 as proxied by ratio of value added to GDP and ratio of tax to total revenue, and found that product innovation and development policy are positively related to TFP growth while N.Z. Abidin *et al.* (2020) utilised Malmquist productivity index to measure TFP growth of Thailand, including seven ASEAN+3 countries over the period 1981-2014, and examined the effects of capital formation, human capital and FDI on TFP growth by employing panel VAR. Based on existing studies on Thailand's TFP, several research gaps remain to be addressed. Studies on Thailand's TFP growth need to be updated, as the existing ones are considerably outdated. Empirical studies on the impact of financial intermediation efficiency on TFP growth remains scarce in the context of Thailand. Previous studies commonly used the number of workers as a proxy for the labour input in TFP growth. However, this approach may not fully reflect reality, as the labour supply is constrained by the size of the working-age population and does not capture the cost or quality dimension of labour input, potentially leading to inaccuracies in the estimation of TFP growth. Due to the demographic constraints and Thailand's need to shift toward productivity-driven growth, this study aimed to investigate the impact of financial intermediation efficiency on Thailand's TFP over the period 2001-2024 with the primary objective of shedding more light on the appropriate policies to reform the financial sector in order to boost Thailand's TFP.

MATERIALS AND METHODS

Growth accounting framework to measure TFP growth

This study employed the growth accounting framework to measure Thailand's TFP growth over the period 2001-2024. Output was measured by real GDP, capital input is represented by two indicators, including (1) real gross fixed capital formation in construction and (2) real gross fixed capital formation in machinery and equipment, while labour input is measured by the real cost of labour, calculated as employment multiplied by the average wage. This study relied on Thailand's quarterly economic data, totally 96 quarters, obtained from secondary sources. The data utilised in this study include real GDP and real gross fixed capital formation, which are obtained from the National Economic and Social Development Council (NESDC, n.d.), labour force, employment rate, average real wage, and mean years of schooling of employed workers, which are obtained from the National Statistical Office (NSO, n.d.), as well as interest rate spread, total loans, business sector credits, non-performing loans, and exports and imports, which are obtained from the Bank of Thailand (n.d.). The growth accounting equation utilised to calculate TFP growth is somewhat modified from R.M. Solow (1957) as the following:

$$\frac{\Delta Y}{Y} = \frac{\Delta A}{A} + \alpha\frac{\Delta Kc}{Kc} + \beta\frac{\Delta Kme}{Kme} + \delta\frac{\Delta L}{L}, \tag{1}$$

where Y – real GDP; Kc – real gross fixed capital formation in construction; Kme – real gross fixed capital formation in machinery and equipment; L – real cost of labour; A – TFP; α – elasticity of real GDP with respect to real gross fixed capital formation in construction, indicating percentage change in real GDP as real gross fixed capital formation in construction changes by one percent; β – elasticity of real GDP with respect to real gross fixed capital formation in machinery and equipment, indicating percentage change in real GDP as real gross fixed capital formation in machinery and equipment changes by one percent; δ – elasticity of real GDP with respect to real cost of labour, indicating percentage change in real GDP as real cost of labour changes by one percent. Based on the equation (1), growth of real GDP is caused by (1) the growth of inputs, including real gross fixed capital formation in construction, real gross fixed capital formation in machinery and equipment and real cost of labour $\left(\alpha\frac{\Delta Kc}{Kc} + \beta\frac{\Delta Kme}{Kme} + \delta\frac{\Delta L}{L}\right)$ and (2) the TFP growth $\left(\frac{\Delta A}{A}\right)$. Therefore, the TFP growth rate can be calculated by the following equation:

$$\frac{\Delta A}{A} = \frac{\Delta Y}{Y} - \alpha\frac{\Delta Kc}{Kc} - \beta\frac{\Delta Kme}{Kme} - \delta\frac{\Delta L}{L}. \tag{2}$$

The growth rate of output (real GDP) and three inputs can be calculated from the available of Thailand. However, the elasticity of real GDP with respect to three inputs (α, β

and δ) can be calculated by employing the Cobb-Douglas production function as the following:

$$Y = AKc^{\alpha}Kme^{\beta}L^{\delta}. \tag{3}$$

The Cobb-Douglas production function is linearised by converting it into its natural logarithmic form. Moreover, quarterly dummy variables are included in the equation to capture seasonal variations. The equation to be estimated is presented as follows:

$$lnY = lnA + \alpha lnKc + \beta lnKme + \delta lnL + \Sigma_{i=1}^{3}\gamma_i Q_i + \mu, \tag{4}$$

where Q_i – quarterly dummy variables; i – 1, 2, 3. Quarter 4 is assigned as the base quarter. After estimating equation (4), the elasticity of real GDP with respect to three inputs will be obtained as the regression coefficients. Thereafter, the TFP growth rate for each period was calculated using equation (2) presented above.

Econometric model to examine the impact of financial intermediation efficiency

Model specification to examine the impact of financial intermediation efficiency on Thailand's growth was as follows:

$$TFP_t = \alpha + \beta_1 INT_t + \beta_2 BUS_t + \beta_3 NPL_t + \\ + \beta_4 CAP_t + \beta_5 SCL_t + \beta_6 TRD_t + \mu_t, \tag{5}$$

where *TFP* – TFP growth rate (%); *INT* – interest rate spread (%); *BUS* – business sector credit (% of total credit); *NPL* – non-performing loan (% of total credit); *CAP* – gross fixed capital formation (% of GDP); *SCL* – mean years of schooling of employed workers (years) in natural logarithms; *TRD* – export and import (% of GDP); μ – residual term. It should be noted that *INT*, *BUS* and *NPL* represent financial intermediation efficiency, *CAP* – represents capital formation, *SCL* represents human capital and *TRD* represents trade openness. Augmented Dickey-Fuller (ADF) unit root test for all variables under specifications with and without a deterministic trend was used. The Breusch-Godfrey LM test statistic and the White's test statistic were also used. An Autoregressive Distributed Lag (ARDL) model was chosen for this study because it is a flexible econometric approach capable of analysing both short-run and long-run relationships among variables in time-series data (Pesaran *et al*., 2001). The ARDL model for bound testing is specified as follows:

$$\Delta TFP_t = \alpha_0 + \Sigma_{i=1}^{p}\,\alpha_{1i}\Delta TFP_{t-i} + \Sigma_{j=0}^{q1}\,\beta_{1j}\,\Delta INT_{t-j} + \Sigma_{j=0}^{q2}\,\beta_{2j} \\ \Delta BUS_{t-j} + \Sigma_{j=0}^{q3}\,\beta_{0j}\,\Delta NPL_{t-j} + \Sigma_{j=0}^{q4}\,\beta_{4j}\,\Delta CAP_{t-j} + \Sigma_{j=0}^{q5}\,\beta_{5j}\,\Delta SCL_{t-j} + \\ + \Sigma_{j=0}^{q6}\,\beta_{6j}\,\Delta TRD_{t-j} + \delta_1\,TFP_{t-1} + \delta_2\,INT_{t-1} + \delta_3\,BUS_{t-1} + \delta_4 \\ NPL_{t-1} + \delta_5\,CAP_{t-1} + \delta_6\,SCL_{t-1} + \delta_7\,TRD_{t-1} + \\ + \gamma_1\,Q_1 + \gamma_2\,Q_2 + \gamma_3\,Q_3 + \varepsilon_t, \tag{6}$$

where denotes the first difference operators; p, q_1, q_2, q_3, q_4, q_5, q_6, are optimal lag lengths; δ_1 to δ_7 represent the long run relationship; β_1 to β_6 describe the short run dynamic; Q_1, Q_2 and Q_3 are dummy variables of quarter 1, 2 and 3, respectively. The analysis began with unit root tests to determine the stationarity of each variable and to ensure that none are integrated of order two. After it was confirmed that all variables are either I(0) or I(1), the ARDL bounds testing procedure developed by M.H. Pesaran *et al.* (2001) was employed to examine the existence of a long-run relationship between TFP growth and explanatory variables. If cointegration did exist, the unrestricted Error Correction Model (ECM) was estimated to examine the short-run dynamics and the speed of adjustment towards long-run equilibrium. The ECM model was specified as follows:

$$\Delta TFP_t = \varphi_0 + \Sigma_{i=1}^{p}\,\varphi_{1i}\,\Delta TFP_{t-i} + \Sigma_{j=0}^{q1}\,\psi_{1j}\,\Delta INT_{t-j} + \Sigma_{j=0}^{q2} \\ \psi_{2j}\,\Delta BUS_{t-j} + \Sigma_{j=0}^{q3}\,\psi_{3j}\,\Delta NPL_{t-j} + \Sigma_{j=0}^{q4}\,\psi_{4j}\,\Delta CAP_{t-j} + \Sigma_{j=0}^{q5} \\ \psi_{5j}\,\Delta SCL_{t-j} + \Sigma_{j=0}^{q6}\,\psi_{6j}\,\Delta TRD_{t-j} + \lambda ECM_{t-1} + \\ + \vartheta_1\,Q_1 + \vartheta_2\,Q_2 + \vartheta_3\,Q^3 + \mu_t, \tag{7}$$

where *ECM* represents the error correction term which should be negative to reflect the convergence toward the long-run equilibrium.

RESULTS AND DISCUSSION

Table 1 presents descriptive statistics of output and input data of Thailand. The findings revealed that the value of annual output as measured by real GDP increased from 5,435.36 billion baht in 2001 to 11,179.50 billion baht in 2024. As looking at annual inputs, the value of real cost of labour equalled 7,354.97 billion baht in 2004 whereas the value of real gross fixed capital formation equalled 2,637.31 billion baht, consisting of 899.64 billion baht for construction and 1,737.67 billion baht for machinery and equipment.

Table 1. Descriptive statistics of Thailand's output and inputs, billion baht

Statistics	Real GDP	Real gross fixed capital formation			Real cost of labour
		Construction	Machinery & equipment	Total	
M	2,181.72	177.12	357.86	534.98	1,455.76
SD	449.10	41.29	78.20	110.00	306.86
Q1/2001	1,378.08	110.08	182.75	292.83	927.56
Year 2001	5,435.36	449.49	741.10	1,190.58	3,988.11
Q4/2024	2,920.67	214.22	481.61	695.83	1,881.67
Year 2024	11,179.50	899.64	1,737.67	2,637.31	7,354.97

Source: prepared by the author based on NSO (n.d.) and NESDC (n.d.)

According to the results of OLS regression analysis shown in Table 2, all input variables, including gross fixed capital formation for construction and for machinery and equipment and cost of labour, significantly determine Thailand's real GDP. Thus, the elasticities of real GDP with respect to each input can be summarised as follows:

- elasticity of real GDP with respect to real gross fixed capital formation in construction (α) is 0.2345. That is, 10 percent increase in real gross fixed capital formation in construction will lead to 2.345 percent increase in real GDP;
- elasticity of real GDP with respect to real gross fixed capital formation in machinery and equipment (β)

is 0.2333. That is, 10 percent increase in real gross fixed capital formation in machinery and equipment will lead to 2.333 percent increase in real GDP;

- elasticity of real GDP with respect to real cost of labour (δ) is 0.5040. That is, 10 percent increase in real cost of labour will lead to 5.040 percent increase in real GDP.

Moreover, sum of the elasticities of real GDP with respect to three inputs ($\alpha + \beta + \delta$) are 0.9718, indicating that Thailand's production exhibits nearly constant return to scale.

Table 3 reports the annual growth rates of Thailand's real GDP and TFP over the period 2001/02-2023/24. The data show that real GDP growth fluctuated considerably, ranging from a peak of 7.51% in 2009/10 to a sharp contraction of -6.05% in 2019/20 during the COVID-19 crisis, with an overall average growth rate of 3.23% per year. In contrast, TFP growth exhibited even greater volatility, with several years of negative performance, including substantial declines in 2004/05, 2007/08, and 2019/20, while its highest growth occurred in 2016/17 at 4.41%. Over the study period, Thailand's average TFP growth rate was only 0.15% per year, indicating relatively weak productivity gains compared with output growth. The pattern of positive GDP growth alongside negative TFP growth in multiple years suggests that economic expansion was driven primarily by input accumulation rather than productivity improvements.

Table 2. Estimate of Cobb-Douglass production function

Variable	Coefficient	Std. error	*t* stat	*p* value
Constant	1.6576***	0.2208	7.5100	0.0000
lnKc	0.2345***	0.0445	5.2700	0.0000
lnKmc	0.2333***	0.0276	8.4500	0.0000
lnL	0.5040***	0.0439	11.4700	0.0000
Q_1	0.0323***	0.0112	2.8800	0.0050
Q_2	-0.0443***	0.0125	-3.5300	0.0010
Q_3	-0.1063***	0.0163	-6.5200	0.0000
Adjusted $R^2 = 0.9788$, *F* statistic = 731.73, *p* value = 0.0000, observations = 96				

Note: *** indicates statistical significance at 1% level
Source: prepared by the author

Table 3. The annual growth rates of Thailand's real GDP and TFP

Year	01/02	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12	12/13
GDP	6.15	7.19	6.29	4.19	4.97	5.44	1.73	-0.69	7.51	0.84	7.24	2.69
TFP	2.57	0.73	-1.49	-3.88	2.25	3.20	-1.78	2.41	0.26	-2.60	-2.36	0.07
Year	**13/14**	**14/15**	**15/16**	**16/17**	**17/18**	**18/19**	**19/20**	**20/21**	**21/22**	**22/23**	**23/24**	**Mean**
GDP	0.98	3.13	3.44	4.18	4.22	2.11	-6.05	1.55	2.58	2.02	2.54	3.23
TFP	-0.94	-1.64	1.15	4.41	1.77	0.78	-6.04	0.25	0.88	1.15	2.25	0.15

Note: GDP – real GDP growth rate (% per year); TFP – TFP growth rate (% per year)
Source: prepared by the author

Table 4 presents the descriptive statistics for the key determinants of TFP employed in this study. The interest rate spread exhibits a mean value of 1.10%, with relatively low standard variation of 0.14, ranging from 0.92% to 1.46%. Business sector credit averages 54.88% of total credit, with a standard deviation of 9.11. Its values span from 44.85% to 75.57%. Non-performing loan shows a mean of 6.50% of total credit and a standard deviation of 4.71, with a minimum of 2.56% and a maximum of 22.35%. Gross fixed capital formation records a mean of 24.55% of GDP, with relatively limited standard deviation of 1.94 and values ranging between 20.25% and 29.54%. The average years of schooling has a mean of 7.46 years, with a standard deviation of 1.19, reflecting gradual progression in educational attainment over time. Its range extends from 5.44 to 9.41 years. Finally, trade openness, as measured by the share of exports and imports relative to GDP, averages 108.08%, with a standard deviation of 10.87, and ranging from 81.97% to 136.53%. Overall, the descriptive results highlight substantial variation across macroeconomic and financial indicators, particularly in credit quality and trade openness, suggesting notable shifts in economic structure over the sample period.

Table 4. Descriptive statistics of determinants of TFP

Variable	Description	Unit	*M*	*SD*	Max	Min
INT	Interest rate spread	%	1.10	0.14	1.46	0.92
BUS	Business sector credit	% of total credit	54.88	9.11	75.57	44.85
NPL	Non-performing loan	% of total credit	6.50	4.71	22.35	2.56
CAP	Gross fixed capital formation	% of GDP	24.55	1.94	29.54	20.25
YSCL	Mean years of schooling	Years	7.46	1.19	9.41	5.44
TRD	Export and import	% of GDP	108.08	10.87	136.53	81.97

Note: mean years of schooling in natural logarithm (SCL) will be used in the ARDL model instead of YSCL
Source: prepared by the author based on NSO (n.d.), NESDC (n.d.) and Bank of Thailand (n.d.)

Table 5 presents the results from ADF unit root test for all variables under specifications with and without a deterministic trend. The findings reveal that *TFP* and *CAP* are stationary at level under at both specifications, while the remaining variables (*INT*, *BUS*, *NPL*, *SCL*, and *TRD*) fail to reject the null hypothesis of a unit root at level. However, all variables become stationary after first differencing, as evidenced by statistically significant ADF statistics at the 5 percent level across both model specifications, with and without trend. These results confirm that the variables are integrated of order one, I(1), supporting the suitability of cointegration and ARDL approaches for subsequent empirical analysis. Table 6 reports the results of the ARDL bounds test for cointegration. The computed *F* statistic is 4.662, which is greater than the upper-bound critical values at the 1%, 5%, and 10% significance levels (4.43, 3.61, and 3.23, respectively). Since the *F* statistic is higher than the I(1) critical values for all significance levels, the null hypothesis that there is no long-run relationship can be rejected. Consequently, the results confirm the existence of a long-run cointegrating relationship between TFP and its determinants in the ARDL model.

Table 5. Results from ADF test for stationarity

Variable	Constant without trend				Constant with trend			
	Level		First difference		Level		First difference	
	t stat	*p* value	*t* stat	*p* value	*t* stat	*p* value	*t* stat	*p* value
TFP	-4.479***	0.0002	-8.343***	0.0000	-4.459***	0.0018	-8.292***	0.0000
INT	-1.720	0.4210	-6.203***	0.0000	-1.652	0.7713	-6.214***	0.0000
BUS	-2.065	0.2588	-8.197***	0.0000	-1.431	0.8515	-8.332***	0.0000
NPL	-2.220	0.1992	-5.585***	0.0000	-1.978	0.6136	-5.648***	0.0000
CAP	-3.203**	0.0198	-3.869***	0.0023	-3.372*	0.0552	-3.980***	0.0094
SCL	-2.323	0.1646	-2.944**	0.0405	-1.323	0.8822	-3.509**	0.0384
TRD	-2.157	0.2223	-4.451***	0.0002	-2.245	0.4643	-4.414***	0.0021

Note: *, **, *** indicate 10%, 5% and 1% significance level, respectively
Source: prepared by the author

Table 6. Results from ARDL bound test for cointegration

F bound test		Bound critical value		
Test statistic	Value	Significance level	I(0)	I(1)
F statistic	4.662	1%	3.15	4.43
		5%	2.45	3.61
		10%	2.12	3.23

Source: prepared by author

The optimal ARDL(4,1,2,1,4,0,1) model, determined according to the minimum AIC criterion, is estimated, and the results are reported in Table 7. The findings reveal that the Breusch-Godfrey LM test statistic and the White's test statistic are not statically significant at any level, showing that there are no serial correlation and heteroskedasticity problem in the ARDL model. In addition, the adjusted R^2 of 0.9046 suggests that 90.46 percent of the total variation in TFP growth can be explained by the explanatory variables the model. These results confirm that the ARDL model is statistically robust, stable and suitable for interpreting both short- and long-run dynamics of Thailand's TFP growth.

The long-run results clearly reveal that financial intermediation efficiency significantly affects TFP growth in the long run, as two out of three indicators of financial intermediation efficiency have statistically significant impacts of TFP growth. Specifically, business sector credit (*BUS*) has a significant positive effect on TFP growth. Its regression coefficient of 1.1342 suggests that a one percent increase in credit extended to the business sector leads to a 1.1342 percent rise in the TFP growth rate. In contrast, *NPL* exert a significant negative impact on TFP growth, with a coefficient of -1.4411, indicating that the TFP growth rate is likely to decline by 1.4411 percent if the ratio of non-performing loans to total credit increases by one percent. However, the *INT* has the insignificant long-run effect on TFP growth, implying that financial cost differentials do not directly influence long-term productivity once other factors are controlled for.

Beside business sector credit, *CAP* and the *SCL* also have the significant positive effect on TFP growth rate. The regression coefficient of *CAP*, which equals 0.4947, indicates that TFP growth rate will increase by 0.4947 percent if the ratio of gross fixed capital formation to GDP rises by one percent. Furthermore, the coefficient of *SCL*, which is 27.8461, suggests that a one percent increase in the mean years of schooling of employed workers will lead to 0.2785 percent increase in TFP growth rate. Nevertheless, the findings indicate that *TRD* does not have any significant impact of TFP growth.

Table 7. Estimated long-run and short-run coefficients of the ARDL model

Variable	Coefficients	Std. error	*t* stat	*p* value
Long-run estimates: ARDL(4,1,2,1,4,0,1) based on AIC **Dependent variable:** *TFP(t)*				
INT	-0.7945	5.1262	-0.1500	0.8770
BUS	1.1342**	0.4986	2.2700	0.0260

Table 7. Continued

Variable	Coefficients	Std. error	*t* stat	*p* value
Long-run estimates: ARDL(4,1,2,1,4,0,1) based on AIC **Dependent variable:** *TFP(t)*				
NPL	-1.4411**	0.6034	-2.3900	0.0190
CAP	0.4947*	0.2643	1.8700	0.0650
SCL	27.8461**	13.7607	2.0200	0.0460
TRD	-0.0869	0.0626	-1.3900	0.1690
Short-run estimates ARDL(4,1,2,1,4,0,1) based on AIC **Dependent variable:** Δ*TFP*				
Δ*TFP*(*t*-1)	0.0682	0.2575	0.2600	0.7920
Δ*TFP*(*t*-2)	-0.1676	0.1799	-0.9300	0.3550
Δ*TFP*(*t*-3)	-0.4266***	0.1045	-4.0800	0.0000
Δ*INT*(*t*)	-22.6769**	10.79863	-2.1000	0.0390
Δ*BUS*(*t*)	2.6202**	1.0933	2.4000	0.0190
Δ*BUS*(*t*-1)	-1.7573*	0.9657	-1.8200	0.0730
Δ*NPL*(*t*)	0.5932	1.2249	0.4800	0.6300
Δ*CAP*(*t*)	-9.1659***	0.6624	-13.8400	0.0000
Δ*CAP*(*t*-1)	-4.6996***	1.0069	-4.6700	0.0000
Δ*CAP*(*t*-2)	-1.4901	1.0558	-1.4100	0.1620
Δ*CAP*(*t*-3)	-3.7363***	0.9099	-4.1100	0.0000
Δ*SCL*(*t*)	23.0883**	10.3784	2.2200	0.0290
Δ*TRD*(*t*)	-0.2902*	0.1714	-1.6900	0.0950
ECM(*t*-1)	-0.7998***	0.1604	-4.9863	0.0000
Quarterly dummy variables				
Q_1	-9.5758*	4.9792	-1.9200	0.0580
Q_2	-1.2897	5.0285	-0.2600	0.7980
Q_3	-9.4477**	4.6927	-2.0100	0.0480
Observation			91 Quarters	
Adjusted R^2			0.9046	
Breusch-Godfrey LM test for autocorrelation			$\chi^2 = 6.4480$, *p* value = 0.1681	
White's test for heteroskedasticity			$\chi^2 = 92.0000$, *p* value = 0.4510	

Note: *, **, *** indicate 10%, 5% and 1% significance level, respectively
Source: prepared by the author

In the short run, the results shed light on how temporary shocks and lagged effects influence TFP adjustments. The short-run results further confirm that TFP growth is significantly determined by financial intermediation efficiency. Specifically, the change in business sector credit (Δ*BUS*) has the positive and statistically significant effect on change in TFP growth whereas the change in interest rate spread (Δ*INT*) has the significantly negative impact on the change in TFP Growth. These findings imply that the short-term expansion in business credit help boost output and productivity through increased working capital and production activity while the higher interest rate spread reduce firms' incentives to invest efficiently in the short term. Anyway, the change in non-performing loan (Δ*NPL*) does not have any significant effect on the change in TFP growth in the short run.

Additionally, the three quarter-lagged changes in TFP (ΔTFP_{t-3}) are significantly negative, indicating that a rise in TFP three quarters earlier leads to a slowdown in the current quarter, likely due to diminishing short-run returns or cyclical fluctuations. As looking at the other short-run determinants, the change in capital formation (Δ*CAP*) and its lag terms are significantly negative, indicating that the excessive capital expansion in the short run is likely to cause a decline in TFP growth due to the inefficiencies in utilising new capital stock. Likewise, the change in trade openness (Δ*TRD*) is also negative and significant, implying that the expansion of export and import in the short run leads to the decline in TFP growth. On the other hand, the change in mean years of schooling (Δ*SCL*) has a positive and significant short-run effect on the change in TFP growth, implying that the improvement in education immediately benefits TFP growth. According to Table 7, the error correction term (ECM_{t-1}) is significantly negative, confirming the existence of a stable long-run equilibrium relationship among TFP growth and its determinants. Its coefficient of -0.7998 indicates a strong adjustment, indicating that deviation from the long-run equilibrium is corrected by approximately 80% within one quarter. Specifically, when TFP growth deviates from its long-run equilibrium due to short-run shocks, the system will adjust rapidly toward its long-run equilibrium.

This study fills the research gap regarding Thailand's production performance and TFP. Specifically, this study found that the country's production exhibits nearly constant return to scale, implying the optimal scale of production of the economy. In addition, labour and capital factors contribute similarly to overall production, reflecting balanced production structure within Thai economy. In terms of TFP growth, this study found that Thailand's average TFP growth rate over the study period (2001-2024) was low (0.15% per year), implying that Thailand's economic expansion was driven mainly by capital and labour accumulation rather than productivity improvements. These results bridge the gap left by the studies of J.W. Lee & N. Suwimol (2018) and N.Z. Abidin *et al*. (2020), which mainly examined the determinants of TFP growth rather than measuring the actual TFP growth rate.

This study provides the significant evidence that financial intermediation efficiency affects Thailand's TFP growth in both the long run and the short run. In the long run, TFP growth is positively influenced by business sector credit, suggesting that an expansion in business credit enhances the country's overall productivity by facilitating investment, innovation and operational efficiency among business firms. These findings are consistent with those of F. Manaresi & N. Pierri (2018) and S.M. Cakici (2024). Furthermore, non-performing loans have the adverse impact on TFP growth in the long run, implying that the greater level of bad debt limits business credit provision, causes resource misallocation, and eventually reduces the country's overall productivity. These results are consistent with the findings of A.S. Serrano (2022).

Unlike S. Gilchrist *et al*. (2012), this study found that the interest rate spread does not significantly influence overall productivity in the long run. This is because Thailand's financial system maintains relatively stable spreads, while long-term productivity tends to be influenced more by other factors such as business credit provision and loan quality rather than interest rate differentials. Specifically, Thailand's interest rate spread ranged from 0.92% to 1.46%, with the average value of 1.10%, showing a relatively stable spread over the 24-year period.

Figure 1 illustrates the changes in Thailand's TFP growth rate, business sector credit, and non-performing loans. It shows that both business sector credit and non-performing loans exhibited a downward trend, causing TFP to grow slowly over the study period. More specifically, while financial institutions in Thailand were able to efficiently manage loan quality and reduce non-performing loans, they were likely to extend more credit to households rather than to the business sector. It should be noted that greater business sector credit tends to increase TFP growth, whereas a higher level of non-performing loans leads to a decline in TFP growth.

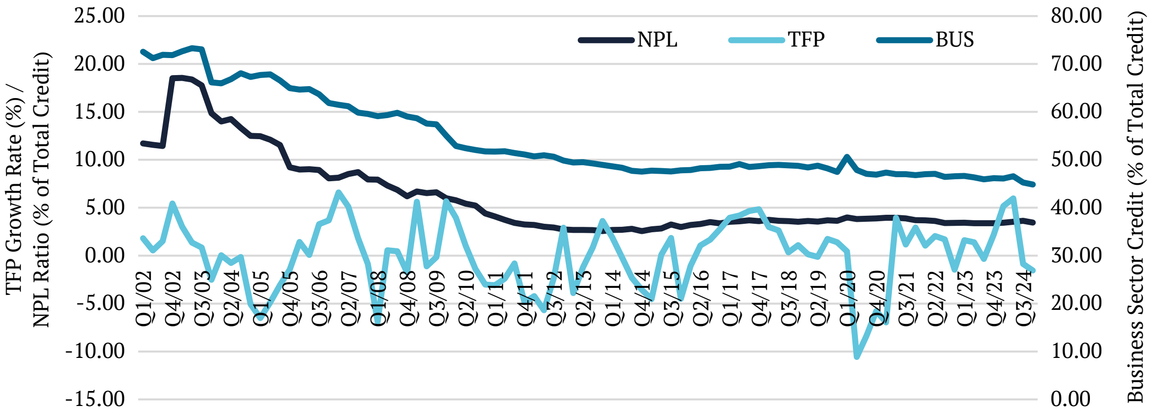

Figure 1. TFP growth rate, business sector credit and non-performing loans in Thailand

Source: made by the author

In the short run, business sector credit also positively influences TFP growth. However, non-performing loans do not affect TFP growth in the short run, probably because financial institutions can still operate relatively normally despite some bad debt, as they may temporarily absorb losses or roll over debts. As a result, the greater non-performing loans in short run do not immediately affect the country's TFP growth. In contrast, the interest rate spread does not affect TFP growth in the long run but it does in the short run. It is because the interest rate spread reflects short-term fluctuations in financial intermediation costs rather than structural efficiency. In the short run, changes in the spread are likely to immediately influence borrowing costs and investment decisions, affecting TFP growth temporarily.

As looking at the remaining determinants of TFP growth, human capital, as measured by mean years of schooling of employed workers, positively influences TFP growth in both the long run and the short run, confirming the crucial role of education and human capital accumulation in improving labour productivity, which, in turn, leads to greater overall productivity. These findings are consistent with S. Bibi *et al*. (2024). However, capital formation negatively affects TFP growth in the short run while it positively affects TFP growth in the long run. This is because, in the short run, the new capital stock tends to be underutilised, causing inefficient resource reallocation and the lower TFP growth, before it becomes fully utilised in the long run and positively influences TFP growth. This long-run relationship between capital formation and TFP growth is consistent with L. Ma *et al*. (2022).

According to the findings from this study, several policies are recommended to boost Thailand's TFP growth. Policies should focus on expanding business sector credit through efficient financial intermediation to support productive investment and innovation, particularly for SMEs and technology-driven industries, while controlling personal loan provision, which is non-productive. Furthermore, policies to strengthen credit risk assessment and promote prudent lending standards are required to reduce non-performing loans in the long run while measures to support efficient debt restructuring are also essential to prevent NPL accumulation and financial instability in the short run. In addition, the Bank of Thailand should manage short-term interest rate movements to avoid abrupt fluctuations in borrowing costs which could be harmful to TFP growth.

Additionally, policies to enhance human capital through continuous investment in education, vocational training and digital skills development should be consistently implemented, to improve labour productivity and, thereby, the country's overall productivity. Meanwhile, policies should focus on the full utilisation of new capital stock and workforce upskilling to mitigate transitional inefficiencies in the short run and on promoting productive capital formation in high-technology and green sectors in the long run. Finally, international trade policy should focus on promoting export quality and value addition through industrial upgrading and technology adoption to ensure that export expansion in the short run positively contributes to the country's overall productivity.

Trade openness adversely affects TFP growth in the short run. This finding contradicts Y. Li *et al*. (2021). The negative impact in the short run arises because greater imports are likely to cause an immediate disruption to domestic production while greater exports tend to have firms prioritise meeting external demand over efficiency gains, leading to short-run inefficiency. In addition, the negative impact of export is also stemming from the dominance of low value-added and labour-intensive industries in the country's export structure. Therefore, export expansion does not necessarily translate into productivity improvement.

TFP represents the portion of output growth which is not explained by the accumulation of observable inputs such as capital and labour. It reflects improvements in technological progress, efficiency, human capital, and institutional quality that enable an economy to produce more output with the same resources (Solow, 1957). In other words, TFP captures how effectively a country transforms inputs into economic output, encompassing both innovation and the diffusion of knowledge (Hulten, 2001).

TFP serves as a vital measure of an economy's efficiency in utilising inputs (capital, labour, technology, etc.) to generate output. In growth accounting frameworks, TFP is often regarded as the "residual" that captures improvements in technologies, managerial practices, institutional quality, and resource allocation beyond mere accumulation of inputs (Cardarelli & Lusinyan, 2015). The greater TFP implies that a country is deriving more output from the given amount of input, which is needed when input boosts become limited – as is the case in aging societies. Empirical studies have consistently found that over the long run, differences in living standards and growth trajectories across countries are largely explained by variations in TFP rather than input accumulation alone (OECD, n.d.). Therefore, promoting TFP growth is crucial for Thailand to achieve the sustainable development in an environment of demographic headwinds.

Financial intermediation efficiency refers to how well financial institutions mobilise savings, allocate credit, manage risks, and facilitate transactions, all at minimal cost and friction. According to T. Philippon (2015), there are several key indicators of financial intermediation efficiency, including the interest rate spread (difference between lending and deposit rates), non-performing loan (NPL) ratios, operating cost to total assets, and the share of private sector credit to GDP. A highly efficient financial intermediation system will reduce transaction costs, mitigate information asymmetries, and support better risk assessment, thereby improving capital allocation and encouraging innovation (Liu & Li, 2022). Accordingly, the higher financial intermediation efficiency can foster faster technology diffusion, firm-level upgrading, and ultimately raise the aggregate TFP of the economy (Han & Shen, 2015).

Malmquist productivity index (MPI) is one of the most commonly used techniques for measuring TFP. Such index measures changes in TFP over time by comparing the efficiency of production across two periods. It decomposes productivity change into efficiency change (catching up to the frontier) and technological change (shifts in the frontier). MPI is widely used because it can be applied in both cross-sectional and panel settings using Data Envelopment Analysis (DEA). This technique was utilised to examine TFP changes in various countries by several studies such 30 OECD countries during 1971-2011 (Shen *et al*., 2017), East Asian countries during 2002-2010 (Le *et al*., 2019), Middle East and North African countries during 1995-2016 (Fathi & Ghorbanian, 2021) and 49 African countries during 2000-2019 (Myeki *et al*., 2023). Note that MPI gives the relative TFP changes, not the absolute level. This is because it is computed as distance to a best-practice frontier built from the sample group via DEA, so each country's productivity is measured relative to peers and reference periods.

Stochastic frontier analysis (SFA) is another frontier-based analytic technique commonly adopted to measure TFP changes. SFA, introduced by D.J. Aigner *et al*. (1977) and W. Meeusen & J. van den Broeck (1977), is a parametric econometric approach that estimates a production frontier while distinguishing random noise from inefficiency. It assumes that output deviations from the frontier are partly due to statistical noise and partly to inefficiency, modeled as a composed error term with a symmetric random error and a non-negative inefficiency component. SFA decomposes TFP growth into technical change (frontier shifts), efficiency change (movement toward or away from the frontier), and scale or allocative efficiency effects (Kumbhakar & Lovell, 2000; Coelli *et al*., 2005).

There are several studies which employ stochastic frontier analysis (SFA) to measure TFP in many countries worldwide such as 15 former Soviet Union countries (Arazmuradov *et al*., 2014), 36 Sub-Saharan African countries (Garzarelli & Liman, 2019), Middle East and North African countries (Malik & Masood, 2021) and Turkiye (Yiğiteli & Şanlı, 2024). Nevertheless, efficiency from SFA measures technical efficiency, showing how well inputs are used relative to the best-practice frontier, while TFP reflects both efficiency and technological progress over time. Hence, SFA efficiency is only a component of TFP, not equivalent to it (Kumbhakar & Lovell, 2000).

Another technique which is widely adopted to measure TFP changes is the growth accounting framework. It is an economic method used to decompose the sources of economic growth into the contributions of capital, labour, and TFP. The growth account framework is generally based on a production function, often a Cobb-Douglas function or a translog function, where the growth in output is explained by growth in inputs, and the residual, or TFP, accounts for growth not explained by factor inputs, reflecting the improvement in technology, efficiency and organisation (Solow, 1957; Hulten, 2001). Unlike MPI, TFP growth which is derived from the growth accounting framework represents absolute or aggregate TFP growth. It measures the change in the economy's overall productivity level over time, after accounting for the weighted contributions of labour and capital growth.

Furthermore, there are also numerous studies which focus on the determinants of TFP. Among various determinants of TFP, financial intermediation efficiency is considered as one of the most important determinants of TFP. Financial intermediation efficiency refers to how effectively the financial system channels savings into productive investment at minimal cost and risk. Greater efficiency reduces transaction costs, mitigates information asymmetries, and enhances credit allocation, enabling capital to flow toward more productive firms and innovation, thereby raising. Several empirical studies (Yao, 2011; Philippon, 2015; Gupta *et al.*, 2021) consistently find that countries are likely to experience the higher TFP growth with the greater financial intermediation efficiency. In other words, a more efficient financial sector decreases the cost of capital and increases aggregate TFP, since resources are efficiently utilised in production rather than intermediation.

In accordance with T. Philippon (2015) who investigated how efficiently the U.S. financial system transforms savings into productive investment by estimating the unit cost of financial intermediation, the ratio of the financial sector's income to the value of intermediated assets, there are presumably three major indicators of financial intermediation efficiency, including (1) interest rate spread which represents cost of intermediation, (2) credit to business sector which represent volume of productive intermediation and (3) non-performing loans (NPLs) which represents credit quality and risk. High interest spread, inefficient credit allocation and excessive NPLs reflect intermediation inefficiency which detrimentally affect TFP growth.

A higher interest rate spread, indicating higher intermediation costs or financial frictions, can negatively affect TFP. Since it raises firms' cost of borrowing, discouraging productive investment and leading to capital misallocation. It also signals inefficiencies in financial intermediation, where savings are not efficiently channelled to the most productive firms (Gilchrist *et al.*, 2012). Additionally, credit provided to the business sector positively affects TFP by enabling firms to invest in technology and innovation. As credit flows easily to productive firms, it supports capital deepening and innovation adoption, thereby raising aggregate TFP (Manaresi & Pierri, 2018; Cakici, 2024). High NPLs reduce TFP by weakening banks' balance sheets, limiting credit to productive firms, and causing resource misallocation. This restricts investment, innovation, and technological upgrading (Serrano, 2022).

Hence, this study measured Thailand's TFP growth during 2001-2024 and investigated the impact of financial intermediation efficiency on it to fill these research gaps. The cost of labour, rather than the labour force, is employed to measure TFP growth, thereby capturing the role of augmented labour in production. Furthermore, this study utilised two types of capital formation, including construction and machinery and equipment, to calculate TFP growth, instead of using overall capital formation, in order to enhance the accuracy of TFP estimates, as different types of capital assets exhibit distinct productivity contributions. In terms of measurement, this study employed the growth accounting framework to measure Thailand's TFP growth because it provides a transparent decomposition of output growth into contributions from capital, labour, and productivity without imposing strong functional form assumptions or frontier estimations required by the Malmquist index or SFA. Unlike the Malmquist index, which measures relative productivity changes based on benchmark comparisons across decision-making units, the growth accounting framework yields absolute TFP levels over time, making it suitable for national-level analysis. Meanwhile, SFA was not appropriate in this context, as it is primarily designed to estimate firm or industry level technical efficiency rather than aggregate productivity at the national level.

CONCLUSIONS

This study measured Thailand's TFP growth during 2001-2024 by employing the growth accounting framework and finds that Thailand's TFP growth was highly volatile, with several years of negative performance, including substantial declines in 2004/05, 2007/08, and 2019/20, while its highest growth occurred in 2016/17 at 4.41%. Over the study period, Thailand's average TFP growth rate was only 0.15% per year. This study also examined the impact of financial intermediation efficiency on TFP growth using ARDL model. The findings reveal that financial intermediation efficiency significantly affects TFP growth in the long run as business sector credit has a positive effect on TFP growth, while non-performing loans exert a negative impact on it. However, the interest rate spread does not affect TFP growth in the long run.

In the short run, the results further confirm that TFP growth is significantly determined by financial intermediation efficiency. Specifically, the change in business sector credit has the positive effect on the change in TFP growth whereas the change in interest rate spread has the negative impact on it. Nevertheless, the change in non-performing loan does not have any effect on the change in TFP growth in the short run. Regarding the other factors, the findings reveal that human capital positively affects TFP growth in both the long run and the short run while capital formation positively affects TFP growth in the long run but negatively affects it in the short run. Furthermore, trade openness negatively affects TFP growth in the short run but has no impact on it in the long run. Further research could extend the analysis by incorporating institutional quality, digital financial inclusion, and regional disparities to better explain productivity dynamics in emerging economies.

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REFERENCES

[1] Abidin, N.Z., Yussof, I., & Karim, Z.A. (2020). Total factor productivity shock and economic growth in selected Asean+3 countries: A new evidence using a panel var. *International Journal of Business and Society*, 21(3), 1366-1383. doi: 10.33736/ijbs.3355.2020.

[2] Ahmed, M., & Chowdury, T.T. (2019). Total factor productivity in Bangladesh: An analysis using data from 1981 to 2014. *The Bangladesh Development Studies*, 42(1), 23-75. doi: 10.57138/VYCR2766.

[3] Aigner, D.J., Lovell, C.A.K., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics*, 6(1), 21-37. doi: 10.1016/0304-4076(77)90052-5.

[4] Arazmuradov, A., Martini, G., & Scotti, D. (2014). Determinants of total factor productivity in former Soviet Union economies: A stochastic frontier approach. *Economic Systems*, 38(1), 115-135. doi: 10.1016/j.ecosys.2013.07.007.

[5] Ataev, F. (2024). Estimating total factor productivity by growth accounting: Evidence from the central Asia region. *Journal of Eastern European and Central Asian Research*, 11(6), 1066-1078. doi: 10.15549/jeecar.v11i6.1928.

[6] Bank of Thailand. (n.d.). *Statistics and dissemination: Financial institutions*. Retrieved from https://www.bot.or.th/en/statistics/financial-institutions.html.

[7] Bibi, S., Bibi, M., Fahim, H., & Shahid, S. (2024). Impact of human capital on total factor productivity: A case study of Pakistan. *Journal of Asian Development Studies*, 13(4), 576-583. doi: 10.62345/jads.2024.13.4.47.

[8] Cakici, S.M. (2024). Total productivity and financial development. *International Journal of Arts, Humanities and Social Sciences*, 5(2), 2693-2555. doi: 10.56734/ijahss.v5n2a2.

[9] Cardarelli, R., & Lusinyan, L. (2015). Total factor productivity slowdown: Evidence from the U.S. states. *IMF Working Papers*, 2015, article number 116. doi: 10.5089/9781513520834.001.

[10] Cette, G., Devillard, A., & Spiezia, V. (2021). Growth factors in developed countries: A 1960-2019 growth accounting decomposition. *Comparative Economic Studies*, 64, 159-185. doi: 10.1057/s41294-021-00170-3.

[11] Coelli, T., Rao, D.S.P., O'Donnell, C., & Battese, G. (2005). *An introduction to efficiency and productivity analysis*. New York: Springer. doi: 10.1007/b136381.

[12] Fathi, F., & Ghorbanian, E. (2021). Sustainability of total factor productivity in the countries of the MENA region with an emphasis on ecological footprint. *Advanced Environmental Science*, 19(3), 177-192. doi: 10.52547/envs.2021.36910.

[13] Garzarelli, G., & Limam, Y.R. (2019). Physical capital, total factor productivity, and economic growth in sub-Saharan Africa. *South African Journal of Economic and Management Sciences*, 22(1), article number a2309. doi: 10.4102/sajems.v22i1.2309.

[14] Gilchrist, S., Sim, J.W., & Zakrajšek, E. (2012). *Misallocation and financial market frictions: Some direct evidence from the dispersion of borrowing costs*. Retrieved from https://www.federalreserve.gov/pubs/feds/2012/201208/201208pap.pdf.

[15] Gupta, A.D., Sarker, N., Rahman, M.F., & McMillan, D. (2021). Relationship among cost of financial intermediation, risk, and efficiency: Empirical evidence from Bangladeshi commercial banks. *Cogent Economics and Finance*, 9(1), article number 1967575. doi: 10.1080/23322039.2021.1967575.

[16] Han, J., & Shen, Y. (2015). Financial development and total factor productivity growth: Evidence from China. *Emerging Markets Finance and Trade*, 51, 261-274. doi: 10.1080/1540496X.2014.998928.

[17] Hulten, C.R. (2001). *Total factor productivity: A short biography*. Retrieved from https://www.nber.org/system/files/chapters/c10122/c10122.pdf.

[18] Kumbhakar, S.C., & Lovell, C.A.K. (2000). *Stochastic frontier analysis*. Cambridge: Cambridge University Press. doi: 10.1017/CBO9781139174411.

[19] Le, T.L., Lee, P.P., Peng, K.C., & Chung R.H. (2019). Evaluation of total factor productivity and environmental efficiency of agriculture in nine East Asian countries. *Agricultural Economics*, 65(6), 249-258. doi: 10.17221/50/2018-AGRICECON.

[20] Lee, J.W., & Suwimol, N. (2018). Relationships between development policy, SMEs and total factor productivity in Thailand. *Journal of Transnational Management*, 23(4), 138-153. doi: 10.1080/15475778.2018.1509423.

[21] Li, Y., Wu, Y., Chen, Y., & Huang, Q. (2021). The influence of foreign direct investment and trade opening on green total factor productivity in the equipment manufacturing industry. *Applied Economics*, 53(57), 6641-6654. doi: 10.1080/00036846.2021.1947961.

[22] Liu, P., & Li, H. (2022). The impact of banking competition on firm total factor productivity. *Economic Research-Ekonomska Istrazivanja*, 35(1), 4008-4028. doi: 10.1080/1331677X.2021.2010109.

[23] Ma, L., Xu, F., & Iqbal, N. (2022). The impact of capital enrichment on total factor productivity from the perspective of innovation capability. *Journal of Applied Economics*, 25(1), 644-667. doi: 10.1080/15140326.2022.2048342.

[24] Malik, M.A., & Masood, T. (2021). A decomposition analysis of total factor productivity growth in MENA countries: Stochastic frontier analysis approach. *Middle East Development Journal*, 13(2), 347-366. doi: 10.1080/17938120.2021.1987147.

[25] Manaresi, F., & Pierri, N. (2018). *Credit supply and productivity growth*. Retrieved from https://www.bis.org/publ/work711.pdf.

[26] Meeusen, W., & van den Broeck, J. (1977). Efficiency estimation from Cobb-Douglas production functions with composed error. *International Economic Review*, 18(2), 435-444. doi: 10.2307/2525757.

[27] Myeki, L.W., Matthews, N., & Bahta, Y.T. (2023). Decomposition of green agriculture productivity for policy in Africa: An application of Global Malmquist-Luenberger Index. *Sustainability*, 15(2), article number 1645. doi: 10.3390/su15021645.

[28] NESDC. (n.d.). *National account: Info/statistics*. Retrieved from https://www.nesdc.go.th/en/info/national-accounts/.

[29] NSO. (n.d.). *Labor force survey*. Retrieved from https://www.nso.go.th/nsoweb/nso/survey_detail/9u?set_lang=en#gsc.tab=0.

[30] OECD. (n.d.). *Strengthening productivity analysis for policymaking in Thailand*. Paris: OECD Publishing. doi: 10.1787/0b8d13ac-en.

[31] Pesaran, M.H., Shin, Y., & Smith, R.J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, 16(3), 289-326. doi: 10.1002/jae.616.

[32] Philippon, T. (2015). Has the US finance industry become less efficient? On the theory and measurement of financial intermediation. *American Economic Review*, 105(4), 1408-1438. doi: 10.1257/aer.20120578.

[33] Serrano, A.S. (2022). Loan renegotiation and the long-term impact on total factor productivity. *Latin American Journal of Central Banking*, 3(4), article number 100074. doi: 10.1016/j.latcb.2022.100074.

[34] Shen, Z., Boussemart, J.P., & Leleu, H. (2017). Aggregate green productivity growth in OECD's countries. *International Journal of Production Economics*, 189, 30-39. doi: 10.1016/j.ijpe.2017.04.007.

[35] Siddique, O. (2022). Total factor productivity and economic growth in Pakistan: A five-decade overview. *The Pakistan Development Review*, 61(4), 583-601. doi: 10.30541/v61i4pp.583-602.

[36] Solow, R.M. (1957). Technical change and the aggregate production function. *The Review of Economics and Statistics*, 39(3), 312-320. doi: 10.2307/1926047.

[37] World Bank. (2021). *The macroeconomic and fiscal impact of aging in Thailand*. Retrieved from https://documents1.worldbank.org/curated/en/099350003222219814/pdf/P17209001e7d880100a38b000363da086b7.pdf.

[38] World Bank. (2025). *DataBank: World development indicators*. Retrieved from https://databank.worldbank.org/source/world-development-indicators.

[39] Yao, Y. (2011). Financial intermediation development and total factor productivity growth: Evidence from Chinese mainland provincial panel data. *Modern Economy*, 2011(2), 868-873. doi: 10.4236/me.2011.25097.

[40] Yiğiteli, N.G., & Şanlı, D. (2024). Decomposition of total factor productivity growth in Türkiye regions: A panel stochastic frontier approach. *Eurasian Economic Review*, 14, 275-300. doi: 10.1007/s40822-023-00255-7.

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Вплив ефективності фінансового посередництва на сукупну факторну продуктивність Таїланду

Анотація. Метою цього дослідження було оцінити сукупну факторну продуктивність Таїланду та проаналізувати вплив ефективності фінансового посередництва на неї у період 2001-2024 років. Ефективність фінансового посередництва у дослідженні вимірювалася за допомогою трьох показників: процентної маржі, частки кредитування бізнес-сектору та рівня проблемних кредитів. Для розрахунку темпів зростання сукупної факторної продуктивності застосовано метод обліку зростання, тоді як модель авторегресії з розподіленими лагами використано для оцінювання впливу ефективності фінансового посередництва. Отримані результати свідчать, що зростання сукупної факторної продуктивності в Таїланді впродовж досліджуваного періоду було нестабільним, із кількома роками від'ємної динаміки, а середній річний темп зростання становив лише 0,15 %. Довгострокові оцінки моделі авторегресії з розподіленими лагами показали, що ефективність фінансового посередництва істотно впливає на зростання сукупної факторної продуктивності: кредитування бізнес-сектору має позитивний вплив, тоді як проблемні кредити негативний. Водночас процентна маржа не чинить значущого довгострокового вплив. У короткостроковому періоді результати також підтвердили, що зростання сукупної факторної продуктивності суттєво визначається ефективністю фінансового посередництва. Зокрема, зміна обсягів кредитування бізнес-сектору позитивно впливає на зміну темпів зростання сукупної факторної продуктивності, тоді як зміна процентної маржі має негативний ефект. Разом із тим зміна рівня проблемних кредитів не чинить впливу на зміну темпів зростання сукупної факторної продуктивності у короткостроковому періоді. Отримані результати мають практичне значення для формування політики покращення розподілу кредитних ресурсів та підтримки продуктивно орієнтованого економічного зростання

Ключові слова: економічне зростання; макроекономічна результативність; ефективність; процентна маржа; кредитування; проблемні кредити

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