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The influence of social networks and psychological mechanisms on consumer behaviour in the era of digitalisation

Abstract. Social media platforms in the digital era have become the main tool for influencing consumer behaviour, integrating informational, emotional and social influences that transform the decision-making process through psychological mechanisms. The relevance of analysing these processes is growing in the context of a hyper-competitive environment and accelerated digitalisation. The aim of this study was to identify systemic patterns of interaction between social networks and psychological triggers that determine the dynamics of consumer choice, as well as to identify strategic marketing opportunities and potential risks arising from the fundamental digital transformation of business ecosystems. The work used an interdisciplinary methodological approach that synergistically combined content analysis of scientific sources, statistical data from leading international marketing agencies, methods of comparative analysis, systematisation and theoretical generalisation, which allowed for a comprehensive examination of the phenomenon of the influence of social networks on consumer behaviour. The results of the study showed that

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modern user behaviour is largely shaped by algorithmic content personalisation (increasing relevance by up to 70%) and cognitive biases (90% of consumer decisions are made under the influence of sensory and cognitive triggers). Over 70% of users have a positive perception of brands on social media. User content influences 80% of consumer decisions and increases conversion by 29%, while influencers strengthen trust in brands among 69% of consumers. However, a closed information environment reduces critical perception. Contradictory consequences have also been identified: an increase in impulsive purchases alongside an increase in reputational risks. Social networks function as a multifunctional ecosystem space where marketing practices, communication strategies and psychological influence at the subconscious level are synergistically combined. For business structures, this opens up strategic prospects for the implementation of personalised marketing strategies, but requires systematic risk management and a balanced approach between algorithmic efficiency and transparency in interactions with consumers. It has been proven that competitive advantages will be gained by brands that strategically integrate technological innovations with authenticity and social responsibility. The practical significance of the article lies in the possibility of using the research results to develop scientifically sound marketing strategies that take into account the psychological mechanisms of social media influence and predict behavioural trends in the digital consumer space

Keywords: digital marketing; neuromarketing; personalisation; cognitive biases; gamification; influencers

INTRODUCTION

The information and digital revolution has radically transformed the behaviour of modern consumers, with social platforms becoming the dominant factor influencing consumer preferences. Technological progress and changes in communication paradigms have contributed to the emergence of social networks as the main channel for influencing consumers, which companies actively use to implement product promotion strategies in the market in order to optimise economic results. In contemporary conditions, consumers make purchasing decisions not through the prism of their own practical experience or traditional advertising, but are guided by the collective opinion of other users, rating systems, reviews and viral content, which fundamentally transforms the architecture of market relations. Social networks act as generators of current consumer trends and determine behavioural patterns, forcing business structures to adapt to evolving market dynamics. The study of cognitive distortions and personalisation through algorithms, together with emotional and psychological factors, is becoming methodologically important for understanding the evolution of consumer practices in the era of digitalisation of the economy and for creating valid predictive models.

The growing importance of digital technologies and social networks in the daily lives of consumers has stimulated scientific research in this critically important area by leading experts. A. Asanova *et al.* (2022), having studied the modification of mechanisms influencing consumer behaviour and the development of new marketing strategies in the digital space, formulated a well-founded conclusion that modern business models based on digital technologies not only revolutionise methods of communication with customers, but also determine the prospects for the formation of long-term competitive positions of companies in the global economy. Among the key strategic advantages of social media marketing, researchers Y. Dwivedi *et al.* (2021) pointed to such critically important elements as: content personalisation; expansion of analytical tools and interactive functions; targeted and remarketing technologies. The study by S. Shantatula *et al.* (2024) proves the significant impact of UGC (user-generated content) and strategic partnerships with influencers on the effectiveness of marketing communications. These tools enable businesses to optimise the effectiveness of communication processes and improve marketing approaches in a comprehensive manner. In addition to the

above, the potential for instant interaction, viral characteristics of content, the creation of online communities, and accurate metric assessment of the effectiveness of digital marketing initiatives should be taken into account, which opens up new horizons for economic development.

As for neuromarketing studies, the research by I. Ponomarenko *et al.* (2021) empirically verified the fundamental proposition that the dominant share of consumer choices is made at the subconscious level under the influence of sensory and cognitive stimuli, which is of fundamental importance for understanding market behaviour patterns. For example, research by P.D. Balki *et al.* (2025) proved that colour choices, the temporality of information presentation, and the sound design of advertising materials directly influence the emotional perception of a brand before a rational assessment of product attributes takes place, which correlates with the principles of behavioural economic theory. K. Cherry (2023) emphasised that the analysis of cognitive distortions, in particular the anchoring effect – a phenomenon where a person relies too much on initial information (anchor) when making decisions, regardless of its relevance or randomness, which directly correlates with market pricing mechanisms. R. Fernandes (2023) emphasised in his works the significant economic impact of confirmation bias on consumers – the tendency to prefer information that confirms existing beliefs, while systematically ignoring or rejecting conflicting facts, which generates information asymmetries in the market environment. Research by L. McLaughlin (2024) demonstrated the growing relevance of the social proof effect – a phenomenon where individuals interpret the behaviour or decisions of those around them as socially correct and use them as a guide for their own actions, which provokes cascading effects in consumer practices.

Contemporary researchers are particularly interested in analysing the phenomenon of FoMO (fear of missing out) – the psychological "fear of missing out on an opportunity". A study by T.C.T. Dinh & Y. Lee (2025) proved that FoMO intensifies the influence of social platforms on user behaviour patterns and stimulates spontaneous purchases. A significant number of scientific works also emphasise the economic value of influencers and user-generated content (UGC), which, as shown by L. Romero-Rodriguez & B. Castillo-Abdul (2023), enjoys greater consumer trust than traditional advertising and contributes to increased conversion while reducing transaction costs. In this context, FoMO acts as a factor that encourages consumers to actively engage with UGC, creating a self-reinforcing engagement effect.

Thus, existing scientific research reveals the multifactorial and systemic nature of the influence of social networks and psychological mechanisms on consumer practices, which highlights the critical need for further interdisciplinary study of these processes in the modern digital context, especially given the exponential dynamics of technological development and the growing role of social platforms in everyday consumer life and the formation of market structures. The aim of the study was to determine the systemic impact of social networks and psychological mechanisms on the processes of economic choice of consumers in the context of digital transformation, as well as to outline strategic prospects and potential threats to business development in the context of fundamental changes in consumer behaviour and the formation of a new paradigm of the digital economy.

MATERIALS AND METHODS

The methodological framework of the study was based on an interdisciplinary approach that synthesises the conceptual foundations of marketing, consumer psychology, neuroeconomics, and digital analytics. The main theoretical constructs are "consumer behaviour", "social networks", "neuromarketing", "cognitive biases", "FoMO" (Fear of Missing Out), and "algorithmic personalisation," which are conceptualised as fundamental determinants of the digital transformation of the consumer market in a globalised economy.

The empirical basis of the study is built on the systematisation of open statistical data from leading international analytical and marketing agencies: Statista (n.d.), Grand View Research (n.d.), Maximize Market Research (n.d.). For the Ukrainian economic system, data from the Digital 2025: Ukraine report (Kemp, 2025) was analysed. The analysis covers actual

indicators for the period 2022-2024 and forecast indicators for the period 2025-2030, which allows to identify and extrapolate current trends in the influence of social networks on consumer patterns. In addition, a body of contemporary scientific research in the field of behavioural economics and neuromarketing for the period 2020-2025 was reviewed. The study was based on the works of foreign and Ukrainian scientists, in particular H. Pane *et al*. (2024), I. Ponomarenko *et al*. (2024), R. Gupta (2025).

An integrated methodology combining quantitative and qualitative analytical approaches was used to collect and process empirical data, in particular: content analysis of scientific and practice-oriented sources in the field of digital marketing and behavioural psychology; statistical analysis, which included a study of the dynamics of digitalisation processes and a comparative assessment of the pace of development of advertising markets in different national economies; comparative analysis of the specific characteristics of the influence of leading social platforms (Facebook, Instagram, TikTok) on the formation of consumer preferences and purchasing decisions. The study also introduced the case method as a tool for qualitative analysis of business practices. The experience of leading international companies, in particular McDonald's (n.d.), Starbucks (n.d.), Netflix (n.d.), Spotify (n.d.) and Nike (n.d.), which actively implement algorithmic personalisation, FoMO strategies and gamification elements, which allowed for a deeper understanding of the specifics of the impact of digital technologies on consumer patterns. The analysis of their experience provided an opportunity to trace the relationships between theoretical models and practical results, as well as to identify the factors of success and determinants of failure in the implementation of innovative marketing tools.

The study provides a theoretical generalisation of the results of neuromarketing approaches (eye-tracking, associative tests, cognitive biases), which made it possible to interpret the mechanisms of influence of sensory and cognitive stimuli without their direct use as primary data collection tools. To improve the structure and systematisation of the results obtained, the main digital and psychological tools of influence were summarised in tabular format, which made it possible to clearly outline their content, potential for business application and identify associated risks. The comparative advantage of the chosen methodology is the synergistic combination of quantitative and qualitative approaches, which provides a comprehensive and systematic analysis of the phenomena under study. Methodological limitations associated with the use of secondary data were compensated for by involving multiple independent sources and cross-validating the results to increase the reliability of the analytical conclusions. Despite the lack of opportunities to conduct own neuromarketing experiments, the applied methodological framework allows to form a systematic understanding of the transformational processes of consumer behaviour under the influence of social networks and psychological mechanisms, as well as to generate relevant conclusions for the Ukrainian business environment.

RESULTS AND DISCUSSION

The modern global web marketing market shows clear signs of exponential growth, reflecting fundamental changes in consumer behaviour and the technological landscape. According to Maximize Market Research (n.d.), in 2024, the market capitalisation of this segment reached USD 462.14 billion, which is only the starting point of a rapid development trajectory. Forecast models indicate the possibility of reaching a market volume of USD 1,404.88 billion by 2032, corresponding to an average annual growth rate of 14.91% over the forecast period. This dynamic is particularly relevant in the context of the rapid digital transformation of the consumer experience and the evolution of communication technologies. It is worth noting that the most dynamic development is observed in the social media advertising segment, which is due to the convergence of several key factors: exponential growth in the number of Internet users on a global scale, revolutionary improvements in algorithmic targeting mechanisms, and a dramatic increase in the strategic importance of online interaction for brands seeking to build deeper and more personalised connections with their target audiences.

Analytical forecasts presented by the leading research organisation Statista (n.d.) indicate

that spending on social media advertising will reach USD 275.98 billion in 2025. Moreover, the average annual growth rate for the period 2025-2030 is expected to be 11.71%, allowing the global market volume to expand to USD 480.07 billion by the end of the decade. In geographical terms, the United States remains the leader, with more than USD 103 billion in advertising investment projected for 2025. This dominance reflects not only the scale of the American consumer market, but also its technological advantage in digital platforms and innovative advertising solutions. Particularly significant is the fact that 82.9% of these expenditures, according to Statista (n.d.) forecasts, will be generated through mobile devices, confirming the irreversibility of the conceptual shift towards a mobile-oriented user experience. This trend reflects a fundamental transformation in consumer behaviour, where smartphones and tablets have become the main points of contact between brands and their audiences.

Modern advertising in the digital environment is characterised by the increasingly intensive use of advanced algorithmic systems and machine learning technologies for audience targeting. This technological evolution leads to a significant increase in the effectiveness of advertising campaigns and a qualitative improvement in the level of interaction with target consumer segments. In this context, social networks function as a powerful multiplier tool for business structures of various sizes, providing the opportunity to simultaneously reach potential customers and maintain the loyalty of the existing customer base. According to Maximize Market Research (n.d.), the average American adult spends more than two hours a day interacting with social media content, and over 70% of users report a positive experience interacting with brands in the digital space, which plays a strategic role in stimulating e-commerce and online sales.

Leading social platforms, including Facebook, Instagram, Pinterest, TikTok, Twitter, and other mega-platforms with billion-strong audiences, demonstrate a unique ability to instantly and scalably disseminate information among segmented target audiences. Statistics from the Maximize Market Research portal (n.d.) on the American market illustrate the depth of these platforms' penetration into marketing strategies: 99% of digital marketers actively use Facebook to promote their brands and products, 97% use Twitter, 69% integrate Pinterest into their campaigns, and 59% actively work with Instagram as their primary communication channel. The chart in Figure 1 illustrates the penetration level of leading social platforms in marketing strategies in 2025. The indicators reflect the share of each platform's use in marketing activities, allowing to assess their popularity and strategic value in the modern digital environment. The global reach of users aged 18 and older by social media advertising, according to Cropink (2025), is shown in Figure 1. The figures reflect the global significance of the leading platforms and show how brands allocate their advertising budgets according to the size of their audience. Facebook, YouTube and Instagram remain the global leaders.

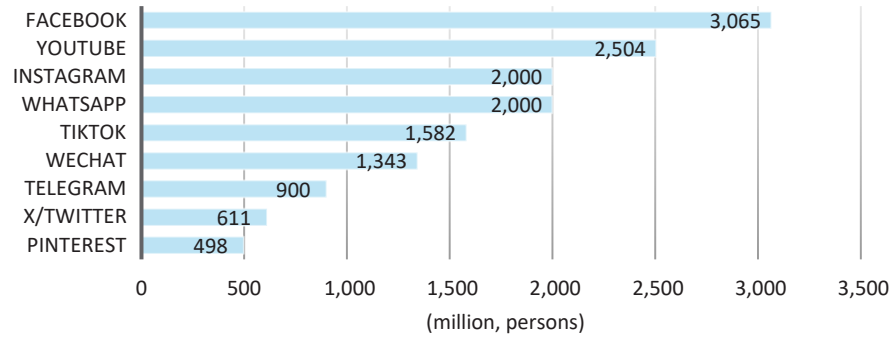

Figure 1. Number of active users reached by advertising on social media worldwide
Source: compiled by the authors based on Cropink (2025)

These indicators reflect not only the technical capabilities of platforms, but also the evolution of consumer expectations for personalised and contextually relevant content. At the same time, the total number of social media users involved in the advertising ecosystem is expected to reach 6.61 billion, representing an unprecedented scale of global digital audience (Statista, n.d.). An analysis of Ukraine's national digital space also demonstrates an extremely high level of technological and social adaptation to digital communication technologies. According to the international analytical resource DataReportal, as of early 2025, the digital space in Ukraine is characterised by almost total coverage of the population: 82.4% of the population, or approximately 31.5 million citizens, actively use Internet technologies. This indicator shows that the critical mass of digital engagement necessary for the effective functioning of a modern market economy has been achieved. The phenomenon of excessive mobile connectivity is particularly indicative: the number of active mobile connections reaches 56.4 million, which is 147% of the country's total population. This indicator reflects the widespread practice of using multiple SIM cards and devices simultaneously, which indicates a high degree of integration of mobile technologies into the daily lives of Ukrainian consumers and the formation of a complex multi-platform ecosystem of digital interaction (Kemp, 2025).

Social networks in the Ukrainian context have evolved from a simple means of communication to a fundamental element of the social architecture of society. Statistics from the report "Digital 2025: Ukraine" (Kemp, 2025) indicate that more than half of the Ukrainian population (21.6 million active accounts) systematically use social platforms, and among Internet users, this figure reaches almost 70%, demonstrating a high conversion rate from general online access to active participation in social networks. An analysis of platform diversification reveals an interesting picture of consumer preferences: YouTube maintains its undisputed leadership with a reach of 68.5% of the adult population, sharing the top spot with TikTok at 53.6%, reflecting a shift towards visually-oriented and short-form content. Facebook maintains a stable position with 44.1%, demonstrating the resilience of traditional social platforms, while Instagram attracts 38% of users, confirming the importance of aesthetically-oriented content in the modern media landscape (Fig. 2)

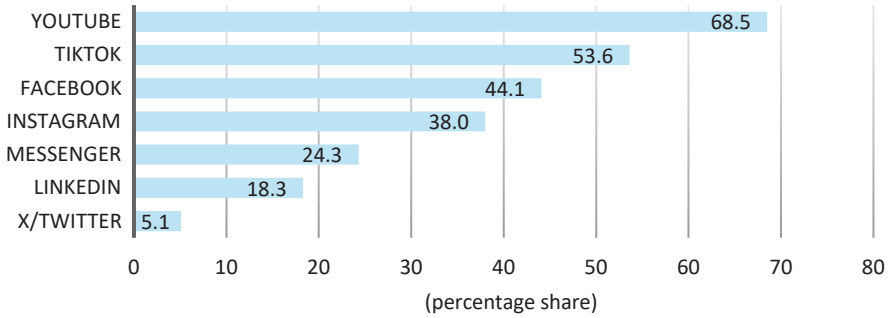

Figure 2. Share of users aged 18 and older exposed to advertising on social media in Ukraine

Source: compiled by the authors based on S. Kemp (2025)

The empirical data presented allows to ascertain the depth of penetration of digitalisation processes into the daily lives of Ukrainian consumers and to identify social networks as a key determinant of contemporary consumer behaviour. Table 1 shows the key similarities and differences in the influence of YouTube, TikTok, Facebook, and Instagram on the formation of consumer preferences and purchasing behaviour, which allows to assess their marketing potential and the specifics of their interaction with the Ukrainian audience.

Table 1. Comparative analysis of the influence of YouTube, TikTok, Facebook, and Instagram on consumer preferences and purchasing decisions

Platform	Nature of content	Features of influence on consumers	Influence on purchasing decisions	Notes
YouTube	Long-form videos, reviews, educational and entertainment content	Facilitates deep immersion in the product and the formation of well-grounded consumer preferences through detailed video content	Increases the likelihood of rational purchasing, especially after viewing reviews and comparisons	A powerful platform for video marketing and brand positioning; effective for informing and educating consumers
Facebook	Text, images, videos, links to articles	Builds stable and long-term consumer preferences through regular content and group-based communication	Encourages informed purchasing decisions and supports conversion through brand pages and advertising campaigns	A resilient traditional platform, effective for broad target audiences
TikTok	Short videos, music-based and interactive content	Shapes spontaneous and rapid consumer preferences and stimulates participation in trends	Highly effective for impulsive purchases, with the viral nature of content increasing conversion rates	A leader in reach and engagement; the FoMO effect and UGC significantly enhance purchasing activity
Instagram	Visual content, photo and video materials, Stories and Reels	Stimulates aesthetic and image-based preferences and influences brand perception through visual cues	Encourages impulsive and emotional purchases and supports the promotion of lifestyle products	Particularly effective for younger audiences and segments with high sensitivity to aesthetics

Source: compiled by the authors based on S. Kemp (2025), Cropink (2025) Maximize Market Research (n.d.)

Thus, a comparative analysis shows that Facebook, Instagram, and TikTok have different effects on consumer preferences and purchasing behaviour: YouTube promotes deep immersion in the product and informed consumer decisions through detailed reviews and educational content; Facebook shapes stable and long-lasting preferences; Instagram focuses on aesthetics and impulse purchases, while TikTok stimulates quick, trendy decisions through viral content. Modern consumer behaviour theory is based on the understanding that the decision-making process is a complex interaction between rational cognitive processes and subconscious affective mechanisms. On the one hand, consumers systematically analyse the functional characteristics of a product, conduct a comparative assessment of pricing, and perform a comparative analysis of alternative options. On the other hand, there is a powerful subconscious reaction to sensory stimuli, including visual elements of presentation, the emotional tone of the communicative message, and social signals transmitted through reference groups. Revolutionary research in the field of neuromarketing, conducted by SIS Survey and disclosed by L. Hunter (2024), shows that up to 90% of consumer decisions are made on a subconscious level. This is consistent with the results of this study, which also confirm the dominance of emotional and sensory triggers in the digital environment: the high level of interaction with visual content on social media correlates with the intensity of consumers' subconscious reactions. These signals include a wide range of stimuli: from the colour palette and rhythmic structure of information presentation to the musical accompaniment in advertising messages. This dominance of unconscious processes radically rethinks traditional approaches to understanding consumer rationality and brings to the fore the importance of neuropsychological methods of market research.

A methodological breakthrough in the field of neuromarketing has been eye-tracking technology, a high-precision tool for tracking eye activity that allows for unprecedented detail in analysing patterns of consumer visual attention. According to research by J. Novak *et al.* (2024), eye-tracking technology allows to identify the visual elements that first attract attention and stimulate quick impulsive reactions. Empirical

research on the use of eye-tracking technologies by J. Novak *et al*. (2024) has shown that warm colour schemes (red, orange, yellow shades) can induce a psychological state of urgency and stimulate impulsive purchasing decisions, while cool and neutral tones (blue, green, grey) are associated in the consumer psyche with concepts of reliability, stability and customer care. These visual and auditory elements form the initial emotional perception even before the activation of rational cognitive processes of product evaluation, thus creating a powerful multiplier effect for advertising messages and providing a psychological basis for accelerated purchasing decisions (Spytska, 2024).

The methodological arsenal of modern neuromarketing is significantly complemented by associative tests – a psychodiagnostic tool that allows to identify latent consumer attitudes and subconscious emotional reactions. This technique is based on the principle of rapid response by participants to verbal or visual stimuli associated with a specific brand or product category. The kinetic parameters of reactions (response speed) and their qualitative nature serve as indicators of hidden emotional associations and attitudes that are often not realised by respondents or articulated in direct responses to traditional surveys. The results of associative testing are used to gain an in-depth understanding of consumer attitudes towards a brand, systematically identify the strengths and weaknesses of advertising messages, and develop more precise and effective marketing communication strategies. The use of these tests makes it possible to predict the reaction of target audiences to innovative products, optimise the visual and verbal components of advertising content, and create brand images that correlate as closely as possible with the emotional expectations and subconscious needs of consumers (Gupta, 2025). An example of the use of neuromarketing, including associative tests, is McDonald's (n.d.). The company uses associative methods to identify hidden emotional attitudes in consumers and consciously uses a yellow and red colour combination in its brand design, which is subconsciously associated with energy, speed and appetite, stimulating purchasing decisions. By integrating these advanced methodological approaches, marketers gain a unique opportunity not only to assess consumers' rational judgements, but also to systematically take into account their hidden psychological attitudes and unconscious motivational drivers, which play a decisive role in shaping final purchasing decisions.

A fundamental understanding of consumer psychology is impossible without a thorough analysis of cognitive biases – systematic deviations in decision-making that arise as a result of evolutionarily formed mental heuristics. These psychological phenomena play a role as powerful determinants of consumer behaviour, often undermining traditional economic models of rational choice. Among the most influential cognitive mechanisms, it is worth highlighting confirmation bias – the tendency to selectively search for, interpret and remember information that correlates with an individual's pre-formed beliefs. This mechanism causes consumers to actively seek data that confirms their existing preferences, while ignoring contradictory or alternative information (Fernandes, 2023). Equally significant is anchoring bias, which manifests itself in an excessive dependence on the first information received when forming a judgement. In the context of consumer behaviour, this mechanism leads to the initial price, product characteristics or recommendation creating a psychological reference point that significantly influences all subsequent evaluations of alternatives (Spytska, 2024). Another powerful determinant of consumer decisions is the phenomenon of social proof, which is the psychological tendency to imitate the behaviour of the majority in situations of uncertainty. When a product accumulates thousands of positive reviews or receives active approval from influential bloggers and opinion leaders, consumers tend to perceive it as a high-quality and socially sanctioned choice, regardless of their own previous experience with this product category (Farooq & Maqbool, 2024).

R. Fernandes (2023), L. Spytska (2024) and S. Farooq & A. Maqbool (2024) emphasise the significant impact of the confirmation effect and social proof on brand perception on social media. The results described above confirm this trend: about 80% of users make decisions under the influence of UGC, and high social support

for the product remains a key factor in trust. Accordingly, the conclusions of the aforementioned authors largely coincide, demonstrating the systemic effect of cognitive biases in the digital environment and reinforcing the general concept of consumer behavioural non-linearity.

Social networks function as powerful amplifiers of cognitive biases, creating an environment where countless consumer decisions are formed and implemented every day. Each platform has developed unique mechanisms of psychological influence, adapted to the specifics of user interaction and content format. Instagram stimulates impulsive purchasing decisions through highly aesthetic visual content and strategic advertising integrations with influencers, creating the illusion of authentic recommendations from trusted sources. The platform effectively uses the psychology of visual consumption, where aesthetically appealing product images are associated with a desirable lifestyle and social status. TikTok generates virality through algorithmically optimised short content, where trending products or services gain popularity through rapid dissemination in the form of short videos. The platform uses the psychological principles of micro-gratification and constant stimulation with novelty, creating a state of heightened receptivity to advertising messages. Facebook functions as a social platform for multilateral discussion and exchange of experience, where user comments and recommendations play a critical role, creating an effect of social confirmation through horizontal communication between equal community members (Eg, 2024). All of these platforms integrate complex machine learning algorithms for content personalisation, which systematically analyse user behaviour patterns and show them content with the highest probability of generating engagement and positive reactions.

The hyper-personalisation of algorithmic content generates a complex set of unpredictable socio-cognitive consequences, the most problematic of which is the phenomenon of "filter bubbles". This effect arises because recommendation system algorithms gradually limit users' exposure to content that confirms their previous preferences, ideological beliefs, or consumer interests. Such algorithmic curation leads to the formation of cognitively isolated information environments where consumers are less likely to encounter alternative opinions, competing offers, or critical assessments of products. This significantly narrows the opportunities for critical analysis and comparative evaluation of market alternatives (Yang, 2023; Rodilosso, 2024). Empirical research by J. Azer & M. Alexander (2023) has shown that such recommendation systems create a psychologically comfortable information ecosystem, characterised, however, by extremely low permeability to content diversity and alternative perspectives (Bingbing *et al.,* 2023). In the long term, this phenomenon can provoke cognitive closure, reduce consumers' ability to think critically and sceptically evaluate advertising messages, which poses a strategic challenge for marketing strategies aimed at building sustainable brand loyalty. Researchers E. Rodilosso (2024) and X. Yang *et al.* (2023) confirmed that algorithmic social media systems form "information bubbles" that limit users to content that matches their previous interests. These results confirm the findings of J. Azer & M. Alexander (2023) and T. Bingbing *et al.* (2023), further demonstrating the psychological "closedness" of the information environment – a phenomenon that was also observed in the analysis of Ukrainian users' behaviour on social networks.

One of the most effective psychological mechanisms systematically exploited on social networks is the FoMO (Fear of Missing Out) phenomenon – an anxious feeling of possibly missing out on important social events, information or lucrative opportunities. In the context of digital marketing, this phenomenon manifests itself as a user's permanent anxiety that other participants in the social network may receive exclusive experiences, privileged information or commercial advantages to which they do not have access (Morsi *et al*., 2025). FoMO functions not simply as an information channel, but as a powerful emotional catalyst that psychologically prompts immediate action by creating an artificial sense of temporal urgency and uniqueness of a commercial offer. Research by H. Pane *et al.* (2024) provides compelling empirical evidence that FoMO as a marketing tool statistically significantly increases the likelihood of impul-

sive purchasing decisions while reducing the duration of cognitive analysis and comparative evaluation of alternatives. The most effective marketing campaigns are those that strategically combine temporal constraints (e.g., messages such as "this offer is only valid for the next 2 hours") with social proof ("more than 5,000 users have already taken advantage of this offer in the last 24 hours"). This convergence of psychological triggers creates multiplicative emotional pressure and stimulates consumers to make quick, often irrational decisions.

A striking example of the successful implementation of FoMO strategies in combination with celebrity collaboration marketing is McDonald's "Travis Scott Meal" campaign, launched in September 2020. This limited-time commercial offer instantly went viral on Twitter, and related videos on TikTok accumulated tens of millions of views within days of launch. The phenomenal popularity of the campaign led to an unforeseen shortage of key ingredients in restaurants across the United States. The strategic combination of limited temporal availability, the high social status of the celebrity ambassador, and algorithmically stimulated virality on social media created powerful psychological pressure on consumers, generating massive impulsive purchasing decisions. This campaign was a striking example of the effectiveness of FoMO strategies in the digital marketing environment, demonstrating how cognitive biases can be systematically exploited to achieve commercial goals (Schick, 2024).

Contemporary studies by T. Kumar *et al.* (2025), I. Ponomarenko *et al.* (2024), and M. Shevchenko (2024) emphasise that personalisation algorithms have evolved into the most powerful tool for attracting users and stimulating their purchasing decisions in the digital space. These complex computing systems systematically collect and analyse multimodal user data, including behavioural patterns, content preferences, search queries, and interaction activity with advertising messages, in order to build highly accurate individual recommendation profiles. Thanks to this technological advancement, each user receives a hyper-personalised content experience that correlates as closely as possible with their unique interests and consumer preferences. Such adaptation significantly reduces the likelihood of missing relevant products and services, while providing brands with unprecedented opportunities to effectively influence consumer decisions and significantly increase the likelihood of successful conversion.

The most striking example of successful implementation of algorithmic personalisation is Netflix's strategy (n.d.), which uses advanced machine learning technologies to comprehensively analyse user behaviour and create individualised content recommendation systems. The platform uses a multi-level filtering system that takes into account viewing history, content viewing time, user ratings, and demographic characteristics to create a unique, personalised user experience. Spotify (n.d.) demonstrates a similar strategic practice, implementing complex algorithmic systems to create personalised music playlists. The platform conducts in-depth analysis of users' musical preferences, temporal listening patterns, and emotional contexts of audio content consumption, creating a powerful emotional connection between the listener and the digital ecosystem (TPMUNN, 2025).

Within the contemporary digital marketing landscape, influencers play a particularly important role. These are individuals with high social capital and the ability to shape public opinion, who have the trust of their target audiences and can exert a significant influence on consumer choices. These opinion leaders strategically use complex psychological triggers, including the artificial scarcity effect (when a product is positioned as unique or time-limited) and the principle of social belonging (when a purchase is associated with a desired lifestyle or social status), to create highly effective advertising campaigns (Cuevas, 2023). Research by the American company Sociallyin (n.d.) confirms that 69% of consumers trust the recommendations of influencers rather than direct messages from brands, which contrasts sharply with the decline in the effectiveness of traditional advertising. Campaigns based on UGC (User-Generated Content) – content created directly by consumers – have become a particularly revolutionary innovation in modern digital marketing. This content includes spontaneously generated videos,

photos, text posts, and reviews that appear organically after using a product or service. The fundamental difference between UGC and traditional branded messages is its increased credibility, as it comes from authentic consumers rather than corporate marketing departments (Romero-Rodriguez & Castillo-Abdul, 2023).

According to leading international research organisation Grand View Research (n.d.), the market capitalisation of the UGC segment in 2022 was USD 4.4 billion. Forecast models indicate that the market volume will reach USD 32.6 billion by 2030, corresponding to a phenomenal compound annual growth rate of 29.4% over the forecast period 2023-2030. Geographically, North America holds a dominant position in the global user-generated content platform market, with a 34.1% share in 2022. However, analytical forecasts indicate that the Asia-Pacific region will show the highest average annual growth rate over the next decade, reflecting the rapid digitalisation and growth in purchasing power in the region. The exponential growth in the use of user-generated content for advertising and marketing purposes is driven by the convergence of several factors: the expansion of online shopping, growing consumer aversion to traditional intrusive marketing methods, and brands' search for more authentic ways to communicate with customers. User-generated content distributed through social networks has significantly greater persuasive power and influence than traditional sources because it is transmitted through trusted personal networks of consumers embedded in their social ecosystems (Grand View Research, n.d.).

Comprehensive studies conducted by leading marketing agencies CrowdRiff (2024) and Grand View Research (n.d.) provide compelling empirical evidence of the effectiveness of UGC strategies. Statistical analysis shows that approximately 80% of consumers make purchasing decisions under the direct influence of user-generated content, confirming its critical importance in the consumer choice process for goods and services. The use of UGC strategies provides a statistically significant 20% increase in audience engagement and increases online conversion rates by nearly 29%, indicating a significant positive impact on booking and direct purchase metrics. Critically, more than half of users (55%) perceive UGC as authentic and trust it significantly more than traditional corporate advertising, while the level of trust in brands that actively use UGC strategies reaches 79%. Behavioural analysis shows that the average user spends up to four hours a day viewing user-generated content, which correlates with a 20% increase in repeat visitors. The results for video content are particularly telling: UGC videos receive almost a third more views (28%) compared to other formats, highlighting the powerful potential of this type of content in modern digital communication strategies.

Parallel to the growing role of user-generated content and interactive formats in the digital marketing landscape, there is an intensification of the gamification trend – the strategic desire of brands to transform consumer interaction into a gaming experience. This phenomenon has a complex dualistic impact on consumer behaviour, requiring careful analysis of both its positive and potentially problematic consequences. The most successful implementations of gamification include loyalty programmes that effectively motivate regular and systematic consumer interaction with the brand through point systems, achievement levels and material rewards. An example of such a strategy is the Starbucks Rewards loyalty programme, which demonstrates the exceptionally successful use of game mechanics to significantly increase customer loyalty. Under this system, customers accumulate 'stars' for every dollar spent, with the number of points earned differentiated based on the payment method, creating additional incentives to use the company's payment solutions. A critical indicator of the effectiveness of this strategy is the customer retention rate of 44%, which is statistically significantly higher than the industry average of 25% (Mohammad, 2025).

At the same time, there are documented cases of problematic use of gamification strategies, leading to unpredictable negative consequences for consumer welfare. A notable example is the Nike Run Club mobile app, which integrated leaderboards and competitive systems between users but subsequently received a wave of criticism from consumer organisations and

the academic community. The problem arose after a significant portion of users developed a pathological dependence on daily "challenges" and achievements in the app. More than 10% of active users of the app reported losing their internal motivation to exercise without constant external stimulation from the platform, which paradoxically reduced their long-term interest in a healthy lifestyle and even led to physical overload due to a compulsive desire to achieve virtual goals (Rodrigues *et al.*, 2021). This case illustrates a critically important principle: excessive or unskilled use of game mechanics can have serious unpredictable consequences, potentially transforming healthy consumer interaction with a brand into a form of behavioural addiction or compulsive behaviour.

Thus, the synergistic convergence of global digital marketing trends, national market specifications, revolutionary advances in neuropsychological research, a deep understanding of cognitive biases, and innovative algorithmic personalisation technologies is shaping a fundamentally new paradigm of marketing communications. In this paradigm, digital platforms function as intelligent multi-level ecosystems that integrate big data analytics, neuropsychological targeting, algorithmic personalisation, exploitation of cognitive biases, user content and interactive communication into a single strategic architecture of post-industrial digital business. To systematise and comparatively analyse the advantages and risks of using digital marketing, Table 2 presents a structured overview of key psychological influence tools, their operational content, strategic opportunities, and potential risks for business organisations in the context of forming and implementing new-generation marketing strategies.

Table 2. Digital and psychological tools for shaping consumer behaviour

Tool of influence	Content and mechanism of action	Benefits for business	Potential risks and threats
Neuropsychological technologies of influence			
Eye-tracking analysis (Neuromarketing)	High-precision tracking of consumers' visual attention patterns to optimise advertising visuals and product design	▪ Precise optimisation of advertising design ▪ Increase in conversion rates of up to 25% ▪ Reduction in spending on ineffective visual elements ▪ Objective data on consumer attention	▪ High costs of technological equipment ▪ Ethical issues related to privacy ▪ Limited representativeness of the sample ▪ Complexity of result interpretation
Associative tests (Psychodiagnostics)	Identification of consumers' subconscious emotional associations with a brand through reaction speed to stimuli	▪ Identification of hidden consumer attitudes ▪ Forecasting reactions to new products ▪ Development of precise communication strategies ▪ Identification of brand weaknesses	▪ Subjectivity of interpretation ▪ Cultural and demographic limitations ▪ Potential for manipulative use ▪ Difficulty in standardising the methodology
Exploitation of cognitive biases			
Confirmation bias (Cognitive psychology)	Leveraging consumers' tendency to seek information that confirms their existing beliefs and preferences	▪ Increased trust in the brand ▪ Strengthening loyalty among existing customers ▪ Effectiveness of personalised content ▪ ▪ Reduced resistance to new offerings	▪ Limited reach of new segments ▪ Creation of "information bubbles" ▪ Reduction of consumers' critical thinking ▪ Ethical issues of manipulation
Exploitation of cognitive biases			
Social proof (Social psychology)	Leveraging people's tendency to follow the behaviour of the majority through reviews, ratings, and recommendations	▪ Rapid trust-building among new customers ▪ Lower decision-making barriers ▪ High effectiveness with minimal costs ▪ Viral dissemination effect	• Vulnerability to negative reviews • Possibility of review manipulation • Dependence on external opinions • Risk of reputational crises

Table 2, Continued

Tool of influence	Content and mechanism of action	Benefits for business	Potential risks and threats
Exploitation of cognitive biases			
FoMO marketing (Behavioural economics)	Creating artificial scarcity and urgency to stimulate impulsive purchasing decisions	■ Significant increase in impulsive purchases ■ Acceleration of the decision-making cycle ■ High effectiveness in e-commerce ■ High conversion rates	■ Deterioration of long-term customer relationships ■ Increased product return rates ■ Ethical issues of manipulation ■ Possible legal restrictions
Algorithmic personalisation technologies			
Machine learning personalisation (AI technologies)	Using machine learning algorithms to generate personalised recommendations based on behavioural data	■ Increased content relevance by up to 70% ■ Automation of personalisation ■ Continuous self-improvement of the system ■ Increased time spent interacting with the platform	■ High technological investments ■ Need for large volumes of data ■ Risks of privacy violations ■ Complexity of technical maintenance
Predictive analytics (Big Data)	Predicting consumer behaviour and needs on the basis of historical data and behavioural patterns	■ Optimisation of inventory and logistics ■ Forecasting trends and demand ■ Improved effectiveness of marketing campaigns ■ Reduced operational costs	■ Possibility of inaccurate forecasts ■ Excessive dependence on data ■ Ethical issues related to the use of personal data ■ Difficulty in adapting to new conditions
Content and social strategies			
User-Generated Content (UGC) (Social Media)	Using content created by consumers themselves to enhance brand authenticity and trust	■ Increased trust of up to 79% ■ Growth in conversion rates of up to 30% ■ Reduced content creation costs ■ Authenticity and credibility	■ Loss of control over brand-related content ■ Possibility of negative user-generated content ■ Legal issues concerning content usage ■ Difficulty in controlling large volumes of information
Influencer marketing (Social marketing)	Collaborating with opinion leaders to influence target audiences through the influencer's trust and authority	■ High audience trust levels (69%) ■ Precise interest-based targeting ■ Rapid dissemination of information ■ Increased brand awareness	■ High costs of top-tier influencers ■ Reputational risks arising from scandals ■ Difficulty in measuring ROI ■ Dependence on the influencer's personality
Gamification (Behavioural psychology)	Integrating game mechanics into marketing strategies to increase consumer engagement and loyalty	■ Improved customer retention of up to 45% ■ Increased frequency of interactions ■ Formation of consumption habits ■ Differentiation from competitors	■ Risk of developing consumer dependency ■ Decrease in intrinsic motivation ■ Ethical issues of behavioural manipulation ■ Rapid loss of interest if implemented incorrectly
Innovative technological solutions			
AR/VR technologies (Immersive technologies)	Using augmented and virtual reality to create immersive consumer experiences	■ Innovative product interaction experience ■ Reduced barriers to online purchasing ■ Brand differentiation ■ Increased time spent engaging with the brand	■ High development and implementation costs ■ Limited accessibility of the technology for users ■ Technical issues and instability ■ Rapid obsolescence of technological solutions

Table 2, Continued

Tool of influence	Content and mechanism of action	Benefits for business	Potential risks and threats
Innovative technological solutions			
Chatbots and AI assistants (Artificial intelligence)	Automated communication systems for personalised customer support and product recommendations	■ 24/7 service availability ■ Reduced staffing costs ■ Faster query processing ■ Collection and analysis of customer needs data	■ Limited capacity to resolve complex issues ■ Possible errors in query recognition ■ Loss of the human element in service delivery ■ Negative reactions to overly "robotic" communication

Source: created by the authors based on I. Ponomarenko (2021), S. Farooq & A. Maqbool (2024), T.C.T. Dinh & Y. Lee (2025), R. Gupta (2025), O. Morhulets (2025)

Thus, analysis of current trends convincingly shows that modern consumers demonstrate a marked preference for personalised and authentic content on social media, which generates a critical need for corporate brands to develop transparent, ethically sound and trust-oriented marketing strategies. This fundamental shift in consumer expectations reflects broader socio-cultural transformations, where authenticity and corporate integrity are becoming key determinants of competitiveness. At the same time, there has been an intensification of the importance of corporate social responsibility (CSR) – a strategic shift in focus towards sustainable development principles and active integration with local social communities has evolved from simple PR activities to key factors that directly influence consumer decisions and determine the long-term market competitiveness of brands in the digital business environment. In this context, modern companies have to perform a complex strategic balancing act between maximising the commercial potential of social platforms to stimulate sales and actively managing potential reputational, operational and ethical risks by developing adaptive strategies to respond flexibly to rapidly changing consumer preferences and market conditions.

CONCLUSIONS

A comprehensive analysis of the empirical data presented allows to conclude that social networks have radically transformed the fundamental mechanisms of consumer behaviour, turning the process of making purchasing decisions into a more emotionally charged, socially determined and algorithmically controlled phenomenon. In particular, it has been established that user content influences an average of 80% of consumer decisions, and its use can increase conversion rates by up to 30%, while the use of neuromarketing tools, such as eye-tracking, increases the effectiveness of advertising communications by increasing conversion rates by up to 25%. These trends demonstrate that digital platforms are creating new opportunities for content personalisation and individual influence on users, while making it more difficult to predict behavioural responses.

In the contemporary digital landscape, it is critical for companies to be able to continuously analyse user behaviour dynamics, track new trends and adapt marketing strategies to changing consumer sentiment. The continued growth of algorithmic personalisation, which can be up to 70% effective in increasing content relevance, as well as the development of AR/VR technologies and intelligent predictive analytics systems, will significantly strengthen the influence of digital platforms on consumer choice. Accordingly, companies will have to go beyond traditional models of interaction and form unique emotional ecosystems capable of maintaining lasting trust and loyalty.

A favourable macroeconomic context, a high level of digital infrastructure, and the spread of digital marketing expertise are increasing the effectiveness of personalised advertising solutions and consumer engagement. At the same time, the progressive development of digital technologies and the spread of professional competencies in digital marketing significantly increase

the effectiveness of advertising campaigns. Global trends in sustainable development and corporate social responsibility are prompting organisations to adopt more ethical and socially responsible advertising practices, which correlates positively with increased consumer confidence and creates a positive resonance among conscious and socially active consumer segments. Companies that can successfully meet rapidly changing consumer expectations will not only retain existing customers, but also activate the formation of brand-loyal communities with a high level of emotional loyalty. In the era of artificial intelligence, algorithmic personalisation and information hypermobility, the ability to engage in authentic, ethically sound marketing is transforming from a temporary trend into a fundamental business norm that will determine consumer trust and long-term loyalty. Future research should focus on a deeper study of the relationship between brand authenticity and consumer trust in the digital environment, developing quantitative tools to assess the effectiveness of personalised and ethical marketing strategies, and integrating psychological and cognitive approaches to more accurately predict user behaviour in the digital era.

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Вплив соціальних мереж та психологічних механізмів на поведінку споживачів в епоху цифровізації

Анотація. Соціальні медіаплатформи у цифрову епоху стали основним інструментом впливу на споживчу поведінку, інтегруючи інформаційні, емоційні та соціальні впливи, що трансформують процес ухвалення рішень через психологічні механізми. Актуальність аналізу цих процесів зростає в умовах гіперконкурентного середовища та прискореної цифровізації. Метою цього дослідження було виявлення системних закономірностей взаємодії між соціальними мережами та психологічними тригерами, що детермінують динаміку споживчого вибору, а також визначення стратегічних маркетингових можливостей і потенційних ризиків, які постають у результаті фундаментальної цифрової трансформації бізнес-екосистем. У роботі застосовано міждисциплінарний методологічний підхід, що синергетично поєднує контент-аналіз наукових джерел, статистичні дані провідних міжнародних маркетингових агентств, методи компаративного аналізу, систематизації й теоретичного узагальнення, що дозволило комплексно розглянути феномен впливу соціальних мереж на споживчу поведінку. Результати дослідження продемонстрували, що сучасна поведінка користувачів значною мірою формується алгоритмічною персоналізацією контенту (підвищує релевантність до 70 %) та когнітивними упередженнями (90 % споживчих рішень приймаються під впливом сенсорних і когнітивних тригерів). Понад 70 % користувачів позитивно сприймають бренди в соцмережах. Користувацький контент впливає на 80 % споживчих рішень і збільшує конверсію на 29 %, а інфлюенсери зміцнюють довіру до брендів у 69 % споживачів. Однак замкнене інформаційне середовище знижує критичність сприйняття. Також виявлено суперечливі наслідки: зростання імпульсивності покупок поряд із підвищенням репутаційних ризиків. Соціальні мережі функціонують як багатофункціональний екосистемний простір, де синергетично поєднуються маркетингові практики, комунікаційні стратегії й психологічний вплив на підсвідомому рівні. Для бізнес-структур це відкриває стратегічні перспективи імплементації персоналізованих маркетингових стратегій, проте потребує системного управління ризиками й збалансованого підходу між алгоритмічною ефективністю і прозорістю взаємодії зі споживачами. Доведено, що конкурентні переваги здобудуть бренди, які стратегічно інтегрують технологічні інновації з автентичністю та соціальною відповідальністю. Практична значущість статті полягає у можливості використання результатів дослідження для розробки науково обґрунтованих

маркетингових стратегій із урахуванням психологічних механізмів впливу соціальних мереж та прогнозування поведінкових трендів у цифровому споживчому просторі

Ключові слова: цифровий маркетинг; нейромаркетинг; персоналізація; когнітивні упередження; гейміфікація; інфлюенсери

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Mechanisms for managing the financing of energy-efficient solutions in agricultural enterprises

Abstract. The purpose of this study was to establish approaches to the rational use of financial resources for the introduction of energy-saving technologies in agricultural production considering the operational characteristics of agricultural enterprises. In the course of the study, a comprehensive theoretical and analytical analysis of the mechanisms for financing energy-efficient measures was carried out, the availability of various types of financial support and criteria for the effectiveness of financial management were evaluated. Special attention was paid to the analysis of the state programme "Affordable loans 5-7-9%", under which in 2024 agricultural enterprises received UAH 46.9 billion in loans, attracting 8,750 participants, and the total volume of bank lending to the agricultural sector amounted to more than UAH 104.5 billion. The role of international donors and grant programmes was also investigated, including support from the Food and Agriculture Organization in partnership with the European Union, the United States Agency for International Development, and the Ukraine – Local Empowerment, Accountability and Development programme, which contributed to the development of energy-efficient projects in the agricultural sector. The practical part of the study was based on the analysis of financial mechanisms and management decisions of the agricultural holding Myronivskyi Hlibproduct, in particular on the implementation of biogas complexes Biogas Ladyzhyn and Oril-Lider, which enabled a comprehensive assessment of the current financing models. The

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24 MW Biogas Ladyzhyn complex provided electricity to more than 35,000 households annually, meeting about 40% of the needs of the agroindustrial cluster, while the payback period of the project was 7-8 years. The results showed that the combination of domestic resources, bank loans, state support, and international assistance created effective conditions for the modernisation of production and the introduction of innovative technologies. The practical significance of the study lied in the possibility of using its results to improve the system of financing energy-efficient projects, improve the efficiency of resource management, and support the sustainable development of the agricultural sector in the future

Keywords: investment; biogas; credit; resource; modernisation

INTRODUCTION

Current challenges caused by rising energy costs, climate change, geopolitical instability, and the need to adapt to sustainable development standards require a rethink of approaches to energy consumption in the agricultural sector. Agricultural enterprises, as energy-intensive business entities, are forced to implement solutions that promote energy efficiency to optimise costs, reduce dependence on fossil fuels, and reduce the environmental impact. However, the implementation of such solutions involves significant investment, which is especially difficult in conditions of economic instability and limited access to financial resources.

Inefficiency of management decisions on the introduction of energy-saving technologies in innovation-oriented structures reduces their competitiveness and environmental compliance. This topic was studied by S.M. Lutkovska *et al.* (2024), who justified the importance of digitalisation of energy management, implementation of Smart Grid, and development of managerial competencies. They stressed the need to integrate technological solutions with the management system to achieve energy efficiency. However, the mechanisms for financing energy efficiency at the level of agricultural enterprises remain insufficiently studied, which requires further research on adapting management models to the specifics of agriculture.

Low financial stability of enterprises, concentration of assets in large companies, and limited investment hinder the modernisation of energy infrastructure. This issue was investigated by R. Kostyrko *et al.* (2021), who proved that the liberalisation of the electricity market contributed to lower prices, increased competition and innovation. However, generation remains profitable, while distribution shows financial instability. Despite the active investment, there is a lack of transparent financing mechanisms for small and medium-sized enterprises, which requires further research on the effectiveness of financial instruments and the role of integrated reporting. Imperfect financial instruments and uneven access to resources hinder the implementation of energy-efficient solutions in Ukraine. A.V. Litvinenko (2021) analysed the effectiveness of the green tariff, loans, grants, ESCO agreements (energy service company agreements) and the prospect of introducing green bonds. The researcher showed the positive impact of these instruments on energy savings and emissions reduction, but pointed out the risks of financial instability and bank congestion. Balancing funding and support for small initiatives require further study.

Financing renewable energy in conditions of limited resources and destroyed infrastructure remains a critical challenge for ensuring Ukraine's energy security. Y. Petlenko (2024) explored the possibilities of government subsidies, private capital, international programmes, and innovative mechanisms, such as guarantees of green loans. The researcher proved that the successful implementation of projects depends on a combination of political will, transparent rules, and external support. However, approaches to harmonisation with EU requirements, assessment of the effectiveness of financing in crisis conditions, and prevention of non-ecological investments need to be clarified. Current conditions for energy development require increased investment in renewable energy sources, which was studied by H.O. Pudycheva (2020), analysing the effect of green tariffs, tax incentives, network

connection mechanisms, bank loans, and international grants. The researcher stressed the importance of harmonising legislation, reducing risks for investors, and expanding community participation. Simultaneously, the issues of access to long-term financing, lack of coordination between market participants and adaptation of support tools to the stages of technology development remain unresolved.

Financial instability of the agricultural sector and limited long-term investment hinder the sustainable development of enterprises. This was investigated by S. Boiko *et al.* (2020), who evaluated the structure of financial resources of agricultural enterprises of Ukraine for 2010-2018, identifying three periods with different trends in the share of equity, credit burden, and payment discipline. The researchers proved that equity remains the main source of financing, but since 2015, the role of current liabilities has been increasing against the background of a decrease in long-term investments. The lack of an effective mechanism for long-term lending, insufficient risk assessment by banks, and exchange rate fluctuations remain unresolved issues that require additional analysis and systematic reform.

The unstable economic environment and weak investment climate make it difficult to finance innovative projects in agriculture. R. Myniv & R. Batyuk (2023) analysed the main sources of investment (self-financing, loans, leasing, project financing), identified external and internal risks, and proposed a system of principles of the investment and innovation mechanism. They also developed an approach to evaluating the effectiveness of innovations by type of effect. But the tools for adapting these mechanisms to crisis conditions and attracting foreign capital remain rather neglected. Low efficiency of energy use in industrial enterprises leads to overspending and an increase in the cost of production. This issue was investigated by T. Livoshko (2022), who justified the organisational and economic mechanism of energy saving, identified groups of measures (organisational, technological, investment), and emphasised the role of personnel motivation. The proposed solutions help to reduce costs and improve energy efficiency. However, the criteria for evaluating the effectiveness of measures have not been specified, and there is no mechanism for monitoring and considering regional specifics, which requires further analysis.

The purpose of this study was to develop effective approaches for optimal management of financial resources for the introduction of energy-saving technologies in the agricultural sector considering the specifics of the activities of agricultural enterprises. Within the framework of the study, the following tasks were set: to analyse the available sources of financing used for the implementation of energy-efficient measures in agricultural enterprises; to determine the criteria for the effectiveness of financing management.

MATERIALS AND METHODS

The research was conducted within the framework of applied economics and management in the period 2020-2024, using a comprehensive theoretical, analytical, and applied approach to studying the mechanisms of managing the financing of energy-efficient solutions in agricultural enterprises. The theoretical basis was formed using fundamental studies by contemporary researchers, in particular M. Mahmood *et al.* (2024), G.N. Yuan *et al.* (2022) and M. Adamowicz (2022). These studies were selected because of their significant contribution to the development of conceptual models for integrating environmental responsibility into financial management, and through the development of innovative strategies for improving energy efficiency in the agricultural sector, which corresponded to the topic and specifics of this study. The application of their approaches has provided a methodological basis for assessing financial processes in the context of current challenges to sustainable development. The analytical block included research on modern digital monitoring platforms, such as EOSDA Crop Monitoring (n.d.), Climate FieldView (n.d.), and Wexus Energy Management (n.d.). The choice of these platforms was conditioned by their wide functionality, ability to integrate various types of data, and application in the practice of agricultural production, which ensured the reliability and complexity of the analysis of energy consumption and the state of agricultural production.

As part of the organisational and economic analysis, the state programme "Affordable loans 5-7-9%" was studied (PrivatBank, n.d.), which was a key instrument of concessional lending to agricultural enterprises in 2024-2025. The study analysed statistical data on the number of attracted loans and financial activity of the agricultural sector in the context of this programme. Special attention was paid to the investigation of the role of international donors and grant programmes, including the Food and Agriculture Organization (FAO) in partnership with the European Union (State Agricultural Register, 2025), the United States Agency for International Development (USAID) (ACREC, n.d.), and the programme Ukraine – Local Empowerment, Accountability and Development "U-LEAD" (Decentralisation, 2024). The inclusion of these international initiatives allowed for a comprehensive approach to financing energy efficiency projects, covering both state and donor support, creating favourable conditions for the implementation of innovative technologies. Special attention was paid to the use of digital systems for monitoring financial flows and reporting, which contributed to increasing transparency and optimising management processes (Ministry of Education and Science of Ukraine, 2024). The practical aspect of the study was based on a comprehensive analysis of financial mechanisms and management decisions of agricultural enterprises on the example of the agricultural holding Myronivskyi Hlibproduct (MHP). Research of MHP activities, in particular the implementation of biogas complexes Biogas Ladyzhyn (Ecobusiness, 2021) and Oril-Lider" (Ukrainian Energy, 2021; MHP, n.d.a), provided an opportunity to comprehensively assess the existing mechanisms for financing energy-efficient projects.

RESULTS AND DISCUSSION

Theoretical and methodological foundations of financing management for energy-efficient solutions

Energy-efficient technologies in agriculture play a key role in reducing energy consumption, increasing productivity, and minimising negative environmental impacts. Their implementation is a response to contemporary challenges related to energy security, rising energy prices, and the need for sustainable development of agricultural production. In general terms, energy-efficient technologies are a set of technical, organisational, and managerial decisions aimed at reducing energy costs without lowering production volumes or deterioration of product quality. Their application in agriculture covers a wide range of processes – from soil preparation to storage and processing of agricultural products (Fu & Niu, 2023).

In the practice of agricultural enterprises, energy-efficient technologies are classified according to several criteria. According to their functional purpose, technologies are distinguished that ensure efficient use of energy in the processes of tillage, sowing, irrigation, harvesting, transportation, drying, cooling, lighting, and heating of livestock premises. According to the sources of energy saving, technologies are divided into passive and active. Passive technologies include solutions that reduce energy losses – thermal insulation of warehouses, ventilation systems with heat recovery, and the use of natural light. Active technologies replace conventional energy sources with alternative ones or optimise consumption: installation of solar panels, biogas plants, wind turbines, and the introduction of intelligent energy management systems (smart metering, FMS systems) (Yuan *et al*., 2022).

According to the energy source, technologies are divided into those that run on fossil fuels with high efficiency factor, and those that use renewable sources. The use of the latter is especially relevant for farms and enterprises that have their own raw materials for energy production – for example, organic waste that is processed into biogas. In the context of digitalisation, energy efficiency information technologies are distinguished separately – monitoring platforms, sensor systems, automated solutions based on artificial intelligence (AI), which allow predicting energy costs and optimising equipment operation modes. Examples of such solutions are EOSDA Crop Monitoring (n.d.), which allows tracking the state of crops on satellite images, determine vegetation indices (Normalised Difference Vegetation Index (NDVI), Modified Soil-Adjusted Vegetation Index (MSAVI)), predicting yields, and estimating the need for resources for each site. This helps to reduce the cost

of fertilisers, plant protection products and fuel, and improve the accuracy of agricultural production solutions. Internet of Things (IoT)-platforms like Climate FieldView (n.d.) combine data from field sensors, tractors, combine harvesters, weather stations, and satellites. Due to this, farmers receive an adaptive tool for managing sowing, fertilising, irrigation, and harvesting. In particular, PJSC Zernoprodukt MHP (MHP, n.d.b) began implementing Climate FieldView as part of the MHP Digital Farming project. During the training organised by the platform's specialists, agronomists, engineers, and combine harvesters were demonstrated the possibilities of crop mapping and field analysis. Based on the results of working with the programme, it was noted that accurate identification of problem areas, regulation of the technology of sowing, fertilisation, and harvesting allows minimising crop losses, increasing labour productivity and profitability of the farm. The use of this platform also helps to optimise fuel costs, reduce unproductive processing and form an effective economic strategy of the enterprise (AgroTimes, 2022). Another example is Wexus Energy Management (n.d.) – a service for monitoring electricity consumption on farms in real time. The system allows detecting inefficient use of equipment, manage energy loads, and optimise costs. According to the developers, its use in medium-sized farms allows achieving annual savings of 20-30% of the cost of electricity. The introduction of such technologies allows agricultural enterprises to make informed financial decisions regarding the modernisation of equipment and reduction of energy costs. A significant advantage of introducing energy-efficient technologies in agriculture is not only saving energy resources, but also reducing the cost of production, increasing competitiveness and compliance with environmental standards, which opens up access to new markets (Mahmood *et al*., 2024).

Managing financial resources in a transition to sustainable development involves a strategic rethinking of traditional financial models considering environmental, social, and economic challenges. At the centre of theoretical approaches is the concept of Sustainable Development, which provides for meeting the needs of the modern generation without compromising the opportunities of the future. With this in mind, the financial policy of an agricultural enterprise should be aimed not only at maximising profits, but also at minimising environmental impact, conserving resources, and improving energy efficiency. Contemporary scientific approaches require the inclusion of elements such as environmental budgeting, integrated risk management, long-term forecasting and cost assessment of energy innovations (Viles *et al*., 2022).

One of the key theoretical provisions is the introduction of the principles of the green economy, according to which investments are directed to projects with high energy-saving potential, the development of renewable energy sources, and the modernisation of fixed assets. Examples of such projects are the construction of biogas plants at agricultural enterprises, the installation of solar panels on farms (for example, Solar Farm Solectra (n.d. in the Vinnytsia Oblast), modernisation of irrigation systems using energy-efficient pumps, and the introduction of energy-saving drying complexes in the grain processing industry. In particular, biogas plants allowed agricultural producers to dispose of organic waste and obtain biogas for generating electricity and heat, reducing the consumption of conventional resources such as gas or coal. The introduction of such technologies has reduced CO_2 emissions by thousands of tonnes annually, increasing the energy autonomy of enterprises. The Dobrivlyany photovoltaic power plant (PVPP) has a capacity of 7 MW, covers an area of 9 hectares, and has over 16,000 solar modules, with a total investment of UAH 158 million (Samosvat, 2019). As of the beginning of 2022, the total installed capacity of solar power plants in Ukraine exceeded 6.4 GW, and the share of domestic power plants – more than 1.2 GW, which provided approximately 1.4 billion kWh of green electricity per year and covered the needs of 460 thousand households. This has helped to reduce the burden on the centralised energy system, increase the stability of energy supply for agricultural enterprises, and reduce dependence on unstable supplies of conventional resources (Chayka, 2023). Despite the significant potential, the amount of budget financing through the Decarbonisation

Fund of Ukraine in 2024 amounted to only about UAH 1.4 billion, which is insufficient for a complete transformation of the industry, while the total investment potential of the energy efficiency sector was estimated at more than EUR 50 billion (Ukranian Energy, 2024). Such initiatives not only contribute to reducing the consumption of traditional energy resources, but also ensure the stability of production in the face of rising tariffs and environmental challenges. In this context, management decisions should be based on the principles of environmental feasibility and economic efficiency. The theory of sustainable finance also emphasises the importance of considering external effects – both positive and negative – when assessing the feasibility of certain expenditures. This requires advanced financial analysis that goes beyond conventional profitability indicators and covers the impact on the environment, employee health, local communities, etc. (Adamowicz, 2022).

A special place in the theory is occupied by the concept of ESG factors (Environmental, Social, Governance), which is increasingly being implemented in the practice of strategic planning. These factors allow building the financial model of an enterprise in such a way that it is attractive to investors who focus on social responsibility and long-term sustainability. In agriculture, where a significant part of the costs is related to energy needs, financing should also consider the possibility of attracting green loans, participation in energy modernisation programmes, climate grants, and tax benefits for the use of energy-saving technologies. In addition, theoretical models focus on the need to create an adaptive financial management system that can quickly respond to changes in the regulatory field, energy prices, climatic conditions, or geopolitical situation. In particular, the concept of financial stability provides for the availability of reserve funds, access to insurance instruments, and a dynamic cost structure, which allows the enterprise to maintain economic balance even in conditions of instability (Huang, 2024).

The methodology for assessing the financial effectiveness of implementing green solutions involves combining conventional financial instruments considering the social and environmental consequences of projects. Unlike conventional investments, eco-oriented initiatives require an integrated approach to valuation, where long-term effects on society and the environment play an important role along with profitability. The methodology is based on formal financial indicators, such as net present value (NPV), which allows estimating the total benefit of a project based on the cost of money over time. This criterion is the basic one for determining the economic feasibility of environmental investments. Another key indicator is the internal rate of return (IRR), which shows the level of return on investment regardless of the cost of capital. It is especially important in the case of green projects, because such investments often have a high initial cost threshold, but simultaneously generate long-term benefits. The benefit-cost ratio (BCR) is also used, which allows comparing the presented benefits with expenses, the discounted payback period (DPP) to consider the time factor of return on funds, the return on investment index (RI), and the simple payback period (PP), which allows estimating the rate of return on invested funds. In addition, the methodology takes into consideration the efficiency of using the financial resources of the enterprise implementing the project. These indicators include the return on capital, assets, and sales, which allows assessing how effectively the company generates profit in the context of attracted resources. Liquidity and solvency are also considered, which indicate the company's ability to meet its financial obligations in the short and long term. The equity concentration coefficient, in turn, allows assessing the financial stability of the enterprise. An important component is the assessment of economic, social, and environmental consequences. Energy savings, reduction of harmful emissions, positive impact on public health and possible growth in employment are considered. It also analyses the impact of project implementation on the value of assets and changes in market conditions. The methodology provides for the inclusion of informal criteria such as the country's investment attractiveness, the level of competence of management personnel, and the availability of the necessary infrastructure (Olayinka, 2022). All cash flows are brought to the present value, which ensures an adequate

reflection of the opportunity cost of capital. A mandatory step is to analyse the risks that may affect financial results, and assess the effect of the project for interested parties – the community, employees, and authorities. Based on this integrated approach, the methodology allows not only measuring profitability, but also assessing the project's compliance with the principles of sustainable development.

Instead, research by P.D. Long *et al.* (2024) covered a broader context and proposed six groups of financial mechanisms, including public, private, market and innovation financing, risk reduction tools, and institutional support. The researchers showed how these tools were applied at different stages of the energy transition – from initiation to a sustainable future. In contrast, this study did not form a step-by-step model, but focused on applied aspects and identifying barriers to financing in the agricultural sector. C. Herce *et al.* (2024a) analysed financial incentives in terms of their integration into European sustainable development policies, which included evaluating the effectiveness of tax incentives and regulatory practices at the macro level. In contrast to this systematic approach, the current study focused on the micro level – the problems of access to finance for small and medium-sized agricultural enterprises in Ukraine. Despite this, both studies suggested that financial support is a key condition for a successful energy transition.

The study by T.A. Jensen *et al.* (2024) proposed an analytical model for optimising energy consumption based on digital platforms and geographic information systems. It also provided an assessment of the socio-economic impact of such measures in agriculture. But the current study focused on practical problems of lending, state support, and other sources of financing that are relevant for Ukrainian farmers. Although both approaches differ in methodology, they equally emphasise the role of financial factors in ensuring energy efficiency. Comparing this paper with the study by A. Ur Rehman *et al.* (2024), both noted the importance of energy efficiency for the agricultural sector and the presence of financial barriers. The study by A. Ur Rehman focused on technical solutions and sources of energy consumption on farms in South Asia, while the current study focused on financial mechanisms for supporting energy efficiency in the Ukrainian agricultural sector. Thus, both approaches complement each other-technical and managerial.

The introduction of energy-efficient technologies in agriculture is an important tool for improving the resource and financial stability of agricultural enterprises. This allows not only reducing energy costs and production costs, but also adapting to modern challenges of sustainable development and climate change. A comprehensive financial assessment of such projects should include both economic and socio-environmental aspects, which ensures informed management decision-making. Thus, energy efficiency combined with innovative financial approaches is a key factor in the modernisation of the agricultural sector.

Organisational and economic aspects of managing the financing of energy efficient measures

The structure and sources of financing of energy-efficient solutions at agricultural enterprises in Ukraine is a multicomponent system based on a combination of domestic resources, bank lending, state support, and international technical assistance. Agricultural enterprises are increasingly investing in the modernisation of production facilities, the introduction of green technologies, renewable energy sources, and digital monitoring systems, which reduces energy costs, increases competitiveness, and meets the requirements of sustainable development. The main external source of financing for farmers remains bank lending. Agricultural enterprises received significant support under the programme "Affordable loans 5-7-9%" (PrivatBank, n.d.), which provides for preferential conditions. In 2024, 8,750 agricultural enterprises attracted UAH 46.9 billion under this programme. In total, in 2024, 13,088 agricultural farms used bank loans totalling UAH 104.5 billion, which indicates a high activity of the agricultural sector in the credit market (Ministry of Agricultural Policy and Food of Ukraine, 2024).

During 2025, more than 3,251 agricultural enterprises have already attracted UAH 19.1 billion, which confirms the growing demand for

affordable financing of modernisation projects. Agricultural enterprises also actively use their own funds to upgrade their technical fleet, purchase generators, solar panels, heat pumps, etc. In 2025, more than UAH 18 billion was provided for state support programmes for the agricultural sector, of which a significant part was allocated to compensate for interest rates on loans. In addition, the government has expanded the programme "Affordable loans 5-7-9%" to finance the purchase of energy generation systems from renewable sources. The amount of such a loan can reach up to UAH 150 million with a term of up to 10 years (Pavlenko, 2025). International organisations actively finance projects in the field of energy efficiency in the agricultural sector, providing both grant and technical support, in particular through targeted programmes. The most significant ones are shown in Table 1.

Table 1. Main international donors and areas of financing energy-efficient projects in the agricultural sector of Ukraine for 2024

Organisation	Amount of grants / support	Main areas of financing
FAO + EU	USD 2.8 million	Green technologies, infrastructure
USAID	USD 37 million	Biofuels, energy efficiency
GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit), U-LEAD programme	USD 40 million	Energy efficiency in communities
EU	up to EUR 1.5 million	RES, technical and economic feasibility studies

Source: compiled by authors based on Decentralisation (2024), Sluga narodu (2025), State Agricultural Register (2025)

FAO has already provided support to 237 agricultural producers in Western Ukraine, which has contributed to the introduction of energy-saving technologies. USAID (ACREC, n.d.) and GIZ also implement a number of programmes that include the purchase of energy-efficient equipment, infrastructure development, and support for local communities. In particular, GIZ has a Power Up! project, which provides grants to Ukrainian enterprises for the purchase of energy-efficient equipment. Priority is given to enterprises affected by the war in Sumy, Kharkiv, and Chernihiv oblasts starting in 2023 (East Europe Foundation, 2023). Simultaneously, USAID (Energy Security Project) ESP organises training events and provides cogeneration plants to heating companies in 19 cities of Ukraine, which will provide heat to more than 600 thousand residents. The programme also contributes to improving the legal and regulatory framework for the effective use of such installations (Murdza, 2025). For the period 2021-2024, the volume of investments in renewable energy (solar panels, bioenergy, wind generators) in the agricultural sector amounted to approximately EUR 200-400 million (State Agricultural Register, 2025). In particular, in 2022-2023, more than 650 MW of new capacities were commissioned in Ukraine, of which 371 MW were solar power plants, 227 MW were wind power, and 50 MW were bioenergy. This indicates a high rate of attracting investment, despite military and economic risks. Investments in solar power plants for farmers range from EUR 800-1,000 per 1 kW, and projects for 1 MW cost approximately EUR 700 thousand – 1 million. The cost of wind farms is EUR 1.2-1.5 million per 1 MW, and large projects can exceed EUR 75 million. The payback period for such projects is on average 5-10 years. The schedule of financing dynamics under the programme "Affordable loans 5-7-9%" shows a reduction in the volume of financing in 2024-2025 compared to the peak of 2022, but the number of attracted agricultural enterprises remains significant, which indicates the continued demand for soft loans even in times of crisis (Order of the Cabinet of Ministers of Ukraine No. 761-r, 2024).

Thus, the structure of financing energy-efficient solutions in the agricultural sector of Ukraine is formed based on a combination of domestic funds, bank loans, and international

support. The state programme "Affordable loans 5-7-9%" plays a key role in farmers' access to financing, in particular, in the field of energy efficiency. The FAO, USAID, and GIZ donor programmes also play a significant role, which help to reduce financial barriers for small and medium-sized farms. In particular, the FAO, in partnership with the European Union, implements a programme to support agricultural producers in the Western regions of Ukraine, which provides funding for the purchase of energy-efficient equipment, infrastructure modernisation, and the development of value chains. The USAID "Agro" programme provides technical and financial support to agricultural enterprises in implementing bioenergy solutions, implementing sustainable production standards, and improving market access. GIZ, within the framework of the "U-LEAD with Europe" initiative, finances projects to improve energy efficiency in communities, including the creation of municipal energy plans, the installation of solar panels for agricultural enterprises and the implementation of educational activities on energy management. Based on such programmes, farmers get the opportunity to modernise their production facilities with less financial risks. The increase in investment in renewable energy sources (RES) indicates a change in the paradigm of agricultural sector development towards sustainability, energy independence, and economic adaptability to new challenges.

Financial flow management in the implementation of green technologies in the agricultural sector of Ukraine is based on the integration of advanced information systems, international accounting standards, and cost efficiency monitoring tools. Enterprise Resource Planning (ERP) and Customer Relationship Management (CRM) systems provide automation of accounting and management accounting, increasing the transparency of financial statements, and making informed investment decisions. The most common ERP system among agricultural enterprises is 1C due to its wide functionality and availability. Integrated ERP systems, CRM, and accounting according to International Financial Reporting Standards (IFRS) are actively used mainly among medium and large agricultural enterprises (15-25% of the total number), which allows effectively managing business processes, in particular, in terms of energy-efficient projects (Ministry of Education and Science of Ukraine, 2024).

Integration of ERP and CRM systems with the requirements of International Financial Reporting Standards (IFRS) is accompanied by a number of challenges, in particular, the need to adapt software to reporting standards, provide qualified personnel, and technical integration with other management platforms. The implementation of such systems helps to improve accounting accuracy, reduce the level of financial risks, and also provides the basis for strategic planning and reporting on sustainable development. The level of transparency of reporting in the use of energy-efficient budgets in the agricultural sector is gradually increasing, but it remains insufficiently detailed. Companies covered by the Law of Ukraine No. 2258-VIII (2017) are required to provide open reporting, including on environmental initiatives. However, the detail of data on spending on green projects differs significantly depending on the size of the enterprise, industry, and domestic policy. Elements of non-financial reporting, including energy efficiency indicators, are gradually being integrated into the internal documentation of enterprises, although systematic monitoring and public disclosure of such data is a common practice. Stimulating factors are International Reporting Standards (IFRS, Global Reporting Initiative (GRI)), investor requirements, and government initiatives to achieve the sustainable development goals (Transparency Report..., 2024). In 2021-2024, agricultural enterprises actively implemented energy-efficient solutions with the support of international donors, which contributed to the modernisation of production (Ukrinform, 2024). Significant investment in renewable energy has been combined with digitalisation of accounting and management. Enterprises have implemented ERP, CRM, and IFRS, gradually integrating non-financial reporting, in particular energy efficiency indicators. This formed the basis for increasing the transparency and sustainability of the agricultural sector.

The level of transparency of reporting directly affected the effectiveness of implementing energy-efficient initiatives in the agricultural sector. Clear cost accounting, monitoring

of results and compliance with international standards ensured the trust of donors and investors. It was due to well-established reporting systems that enterprises more effectively attracted financing and implemented advanced technologies. This has become an important factor in the successful modernisation of agricultural production in conditions of limited resources. The actual costs of implementing energy-saving projects in the agricultural sector often differ from the planned ones by 10-20%, which is conditioned by the seasonality of agricultural work, fluctuations in prices for agricultural equipment, the need to adapt technical solutions to rural conditions, and the cost of additional work. In complex projects, such as the construction of biogas complexes or the installation of energy monitoring systems, cost deviations can reach 25%. The duration of the budget cycle for the implementation of energy-efficient initiatives at agricultural enterprises includes several stages: approval of funds lasts from 1 to 3 months, transfer – from 1 to 2 months after approval, and direct development – from 6 to 12 months, depending on the scale and seasonality of work. Thus, the full implementation cycle of an energy-saving project lasts on average from 8 months to a year (Resolution of the Cabinet of Ministers of Ukraine No. 485, 2025). Since 2024, there has been an updated procedure for using Decarbonisation Fund resources, which provides more transparent and standardised procedures, but there is still a risk of delays due to bureaucratic restrictions, tender requirements, and technical complexity of implementation. Centralised financing mechanisms, in particular, the Energy Efficiency Fund and the Decarbonisation Fund, provide 70-80% of the volume of state funding (Strategy of the state Institution..., 2023). Decentralised mechanisms (territorial communities, agricultural clusters, associations) implement 20-30% of funding, mainly through grant programmes, local initiatives, and co-financing. Their role is growing against the backdrop of increased international technical assistance and private capital participation (Energy transition, 2025).

S.T. Ijaz & S. Chughtai (2022) focused on the need to transform green economy policies, particularly in the context of Pakistan. Both papers emphasised the key role of the state in overcoming financial barriers and creating a favourable environment for implementing energy-efficient solutions. However, if S.T. Ijaz & S. Chughtai focused on the institutional and political plane, this study focused on direct instruments – financial programmes, grants, and loans, considering the local specifics of the agricultural sector in Ukraine. The study by E. Szafranko (2021) proposed a multidimensional analysis of energy efficiency financing systems, emphasising the relationship between institutional quality, public policy, and economic security. These elements were also partially present in this study. However, in contrast to the analytical and evaluation approach by E. Szafranko, the use of country ranking models was dominated by practical analysis – focused on barriers to access to finance and the search for applied solutions for the agricultural sector.

X. Liu *et al.* (2023) paid special attention to the potential of digital technologies to improve energy efficiency, including Big Data and artificial intelligence tools. Common to this study was an understanding of the importance of financial support and institutional stability. However, X. Liu *et al.* placed the emphasis on technological transformation as a driver of efficiency, while this study considered financial accessibility as a priority condition for change, focusing on the problems of small enterprises in the agricultural sector. In the publication by J. Chen *et al.* (2024), the main subject of the analysis was the impact of energy efficiency on access to finance among small and medium-sized enterprises in the UK. The study combined empirical data with analysis of the green bond market and ESG financial standards. Although both studies focused on the relationship between energy efficiency and funding, J. Chen *et al.* highlighted credit capacity of enterprises and institutional trust, while this study was dominated by the analysis of systemic barriers to financing the Ukrainian agricultural sector.

Financing of energy-efficient solutions in the agricultural sector of Ukraine is characterised by multicomponent nature, combining bank loans, enterprises' own funds, state support, and international technical assistance. The "Affordable loans 5-7-9%" programme remains a key tool for raising funds, especially for the

modernisation of production and the introduction of renewable energy sources. Simultaneously, the role of ERP, CRM systems, and IFRS in increasing the transparency of financial flow management is growing. In general, there is a change in the paradigm of agricultural production towards sustainability, energy independence and digital transformation.

Practical aspects of applying financial mechanisms and management decisions

Myronivskyi Hlibproduct agro-industrial holding actively implements energy-efficient technologies in its production activities, combining economic feasibility with environmental responsibility. One of the most ambitious examples is the biogas complex Biogas Ladyzhyn (Ecobusiness, 2019), located in the Vinnytsia region. The project was implemented in two stages, each of which had a capacity of 12 MW (MHP, n.d.a). The first stage, launched in December 2019, allowed providing electricity to more than 35,000 households annually and covered approximately 40% of the energy consumption needs of the MHP agroindustrial cluster. The construction costs of the complex were financed by equity, bank loans, and international technical assistance, in particular, through grant programmes to support green energy (Ekonomichna pravda, 2019).

From the standpoint of economic efficiency, the return on investment primarily in the biogas complex was approximately 7-8 years. This was due to revenues from the sale of electricity at the "green tariff" (0.15 EUR/kWh) and savings on external energy purchases. In addition, due to the processing of waste into biogas and the production of organic fertilisers, the company receives additional benefits, reducing the cost of mineral fertilisers. Its own fertiliser production allowed the company to increase the agrochemical efficiency of soils, and reduce its dependence on fluctuations in prices for imported raw materials. Environmental safety was ensured through a closed cycle of waste use, which significantly reduced the anthropogenic burden on the environment (Ukranian Energy, 2025).

The second Oril-Lider biogas complex, launched in 2013 in the Dnipropetrovsk region, has a capacity of 5 MW. Its operation ensured stable energy supply to production facilities and reduced energy costs by more than 30%. Due to stable electricity production, the company can also avoid peak tariffs for external consumption, which improves the overall cost balance and ensures predictability of energy costs (Ukrainian Energy, 2021). Both complexes together allow reducing CO_2 emissions by more than 100 thousand tonnes annually, which contributes to the achievement of the company's climate goals, and meets the requirements of ESG strategies and sustainable development standards (Ekonomichna pravda, 2019).

Cost-effectiveness management for implementing energy-efficient solutions is carried out using ERP systems, which allow monitoring costs in real time, generating analytical reports, and evaluating the economic feasibility of solutions. The introduction of digital resource accounting allows identifying energy losses in a timely manner and predicting the need for equipment modernisation. MHP also applies an internal approach to estimating the IRR (Internal Rate of Return), which in the case of bioenergy projects ranges from 14-17% over the horizon of 10 years. The cost of implementing such technologies, according to the company, has an average return on investment (ROI) of more than 12%, which is a high indicator for the agricultural sector, where typical investments have a lower margin (Pikalo, 2025).

In addition to power generating facilities, MHP invests in energy monitoring systems, lighting modernisation, and engine and pump upgrades at its enterprises. For example, the company's enterprises are switching to Light Emitting Diode (LED) lighting, which has reduced energy consumption for lighting by more than 60%. The installation of frequency converters on pumps and fans provided additional energy savings. All projects are subject to a preliminary feasibility study with determination of the level of energy saving and return on investment, which ensures transparency of the investment process and allows management to make informed decisions (MHP – Hromadi, n.d.).

In order to reduce the financial burden, MHP attracts external sources of support. The company cooperates with international partners, such as the European Bank for Reconstruction and Development (EBRD), and also uses state support

tools within the framework of programmes that encourage the introduction of green technologies. In 2023, MHP became one of the recipients of grant funding for the development of the biomethane sector, including the production of compressed biomethane for domestic needs and for export. According to the company, further expansion of bioenergy projects will allow MHP not only to reduce its dependence on traditional energy sources, but also to export excess energy to EU countries, which opens up new markets and sources of income (Pikalo, 2025).

Thus, the MHP example demonstrates an integrated approach to the introduction of energy – efficient technologies, where costs are carefully planned, calculated using advanced financial methods, and the achieved effect is measured not only through resource savings, but also through environmental benefits. Integration of digital management systems, accurate calculation of return on investment, and attraction of grant and credit resources form a management model that is appropriate for scaling in the agricultural sector of Ukraine. This experience shows the possibility of combining profitability with social and environmental responsibility, which meets requirements for sustainable development.

In the current conditions of energy uncertainty and rising cost of resources, agricultural enterprises should implement systematic approaches to improving energy efficiency. Despite the significant achievements of MHP agricultural holding in the field of energy-saving technologies, further improvement of management and investment in this area is necessary to achieve long-term economic and environmental sustainability. Key areas of improvement include four components: financial management, investment planning, digital technology adoption, and integrating sustainability into the company's strategy. It is advisable to expand the practice of independent energy audit with the subsequent development of a map of energy losses of the enterprise. This will allow distributing investments more efficiently, focusing them on areas with the highest savings potential. It is necessary to actively use green financing mechanisms, in particular international assistance programmes, issuing green bonds, and attracting concessional lending for renewable energy projects. Digitalisation of energy monitoring processes is an important area. Installation of intelligent sensor systems, integration of Supervisory Control and Data Acquisition (SCADA) solutions and automated energy management systems based on ERP will allow real-time detection of irrational energy use. Additionally, it is recommended to develop internal analytical expertise to assess IRR, NPV, and other project performance indicators, which will improve the quality of decision-making. Table 2 provides specific recommendations for improving the efficiency of implementing energy-efficient technologies in the activities of agricultural enterprises.

Table 2. Recommendations for improving the efficiency of implementing energy-efficient technologies in agricultural enterprises

Area	Recommendation	Expected result
Financial management	Introduction of an independent energy audit with a frequency of once every 3 years	Detection of areas of excessive power consumption
Investment planning	Development of domestic green investment policy; use of green bonds	Diversification of funding sources
Technological update	Installation of intelligent energy metering systems, modernisation of LED lighting	Reduction of energy costs by up to 25%
Analytics and performance evaluation	Internal calculation of ROI, NPV, IRR for each project	Making informed investment decisions
State interaction	Increased participation in the programmes "Affordable loans 5-7-9%", FAO, USAID, EU grants	Increase in external financing
Educational initiatives	Advanced training of energy managers and economists of the enterprise	Strengthening of energy management competencies
ESG integration	Inclusion of sustainability indicators in corporate reporting	Improving of reputation and access to international investment

Source: compiled by the authors based on Ekonomichna pravda (2019), State Agricultural Register (2025), MHP – Hromadi (n.d.)

The application of the proposed solutions will not only increase the energy efficiency of the enterprise, but also reduce CO_2 emissions, optimise the cost structure, and ensure greater resistance to external risks – economic, energy, regulatory. The expansion of the portfolio of energy-saving projects at MHP should be accompanied by transparent monitoring of the results achieved, which meets international management standards. Thus, the energy efficiency management system should be considered as a strategic asset of the enterprise and the basis for long-term growth.

Comparing this study with paper by A. Chughtai *et al.* (2024), a general recognition of the role of financial instruments and institutional support in improving energy efficiency in developing countries can be noted. Both studies highlighted the importance of concessional lending, partnerships, and a strategic approach to investment. A. Chughtai *et al.* considered this issue in the global context of sustainable development and green financing, while this study focused on applied barriers and financial mechanisms of the agricultural sector of Ukraine.

In the case of A. Kerstens & A. Greco (2023), a general understanding of the importance of funding to support energy efficiency was observed, but the difference was in application levels: A. Kerstens & A. Greco investigated urban areas and communities, and this study considered individual agricultural enterprises. They focused on socio-organisational barriers and the need for political change, while here the main focus was on practical financial difficulties and ways to overcome them. Both approaches complemented each other, combining the system and practical levels. M. Economidou *et al.* (2024) highlighted the role of financing energy-efficient projects in regional initiatives in Europe, especially in the field of buildings, with a focus on local authorities and European foundations. The current study focused on the agricultural sector of Ukraine and relevant national loan programmes and grants. While both approaches recognised the need to overcome financial and technical barriers, the scope and scale were different. Thus, M. Economidou *et al*. provided a systematic review of EU policies, and this study represented a practical analysis of local challenges and mechanisms.

Comparison with B. Wepner *et al.* (2025) found that both studies recognised the importance of stakeholder engagement and an integrated approach to sustainable agricultural development. However, B. Wepner *et al.* paid more attention to the technological, cultural, and political aspects of digital transformation of sustainable agri-food systems, while the current study focused on financial barriers and practical solutions to improve energy efficiency. Such approaches complemented each other, revealing both technological and financial aspects. Compared to C. Herce *et al.* (2024b), both studies recognised the importance of energy consumption analysis for developing effective policies. C. Herce *et al.* focused on methodologies for data collection and correction for SMEs in different EU countries, while this study focused on local financial mechanisms and support programmes in the agricultural sector of Ukraine. Thus, C. Negse *et al.* proposed a scientific and methodological basis, and this research is a practical tool for implementing energy efficiency.

The introduction of energy-efficient technologies has helped to lower energy consumption, reduce costs, and improve environmental safety. The use of advanced bioenergy complexes, digital monitoring, and automation systems allowed increasing the productivity and efficiency of energy resource management. Effective financing and attracting state and international support played a key role in the implementation of such projects. In general, the integration of economic feasibility and environmental responsibility became the basis for sustainable development of the agricultural sector.

CONCLUSIONS

This study showed that the introduction of energy-efficient technologies at agricultural enterprises in Ukraine is an important factor in improving competitiveness, environmental safety, and sustainable development of the agricultural sector. Analysis of financial mechanisms has shown that the structure of financing energy-saving measures is formed by combining internal resources of enterprises, bank loans, state support, and international technical assistance. In particular, the state programme "Affordable loans 5-7-9%" plays a key role in ensuring farmers'

access to concessional financing, because in 2024 this program attracted UAH 46.9 billion of loans to 8,750 enterprises, and the total amount of bank lending to the agricultural sector amounted to more than UAH 104.5 billion. This indicates a high level of activity of farmers in the credit market, despite economic challenges.

International donors, including FAO, USAID, GIZ, and the EU, have provided significant support in the form of grants and technical assistance worth tens of millions of USD aimed at developing green technologies and renewable energy. As a result, during the period 2021-2024, investments in renewable energy sources in the agricultural sector reached EUR 200-400 million, and the commissioned capacities in 2022-2023 amounted to more than 650 MW, including 371 MW of solar power plants, 227 MW of wind, and 50 MW of bioenergy complexes. This indicates a gradual change in the paradigm of agricultural production towards sustainability and energy independence.

Using the example of MHP agricultural holding, the effectiveness of an integrated approach to energy efficiency is demonstrated, which combines its own investments, bank lending, and international support. The Biogas Ladyzhyn complex with a capacity of 24 MW annually provides electricity to more than 35,000 households, covering about 40% of the needs of the agroindustrial cluster, and the payback period of the project is estimated at 7-8 years. The use of digital monitoring systems, ERP, and CRM increases the transparency of financial flow management and allows optimising costs. In addition, the introduction of LED lighting and frequency converters has reduced energy consumption by more than 60%, which significantly reduces operating costs.

It is important to note that effective financial management in the field of energy efficiency requires not only raising funds, but also developing a domestic green investment policy, regular energy audits, analytical assessment of project profitability (ROI, IRR, NPV), and integrating ESG factors into the corporate strategy. The implementation of these recommendations will help to increase the financial stability of enterprises, diversify sources of financing, and reduce the environmental burden. A limitation of this study is to focus mainly on the financial mechanisms and practices of the agricultural sector of Ukraine without an in-depth analysis of the technical aspects of implementing energy-efficient technologies. The prospect of future research is a comprehensive study of the impact of digital technologies and artificial intelligence on improving energy efficiency and integrating innovative financial instruments to support the sustainable development of the agricultural sector.

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Механізми управління фінансуванням енергоефективних рішень на аграрних підприємствах

Анотація. Метою даного дослідження було встановити підходи до раціонального використання фінансових ресурсів для впровадження енергоощадних технологій в аграрному виробництві з урахуванням особливостей функціонування підприємств у сільському господарстві. У ході дослідження було проведено комплексний теоретичний і аналітичний аналіз механізмів фінансування енергоефективних заходів, оцінено доступність різних видів фінансової підтримки та критерії ефективності управління фінансами. Особливу увагу приділено аналізу державної програми «Доступні кредити 5-7-9 %», за якою у 2024 році аграрні підприємства отримали 46,9 млрд грн кредитів, залучивши 8 750 учасників, а загальний обсяг банківського кредитування агросектору склав понад 104,5 млрд грн. Вивчено також роль міжнародних донорів і грантових програм, зокрема підтримку від Food and Agriculture Organization у партнерстві з Європейським Союзом, United States Agency for International Development, та програму Ukraine – Local Empowerment, Accountability and Development, які сприяли розвитку енергоефективних проєктів у агросекторі. Практична частина дослідження базувалася на аналізі фінансових механізмів і управлінських рішень агрохолдингу «Миронівський хлібопродукт», зокрема щодо реалізації біогазових комплексів «Біогаз Ладижин» та «Оріль-Лідер», що дозволило всебічно оцінити діючі моделі фінансування. Біогазовий комплекс «Біогаз Ладижин» потужністю 24 МВт забезпечував електроенергією понад 35 000 домогосподарств щороку, задовольняючи близько 40 % потреб агроіндустріального кластера, при цьому термін окупності проєкту становив 7-8 років. Отримані результати засвідчили, що поєднання внутрішніх ресурсів, банківських кредитів, державної підтримки та міжнародної допомоги створює ефективні умови для модернізації виробництва і впровадження інноваційних технологій. Практичне значення дослідження полягає у можливості використання його результатів для вдосконалення системи фінансування енергоефективних проєктів, підвищення ефективності управління ресурсами та підтримки сталого розвитку аграрного сектору в майбутньому

Ключові слова: інвестиції; біогаз; кредит; ресурс; модернізація

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Methods and approaches of financial controlling for the prevention of fraud in small and medium-sized businesses of Kyrgyzstan

Abstract. The purpose of the study was to examine methods and instruments of financial controlling that ensure the detection and prevention of fraudulent activities in the small and medium-sized business (SME) sector of Kyrgyzstan. The research methods included theoretical-analytical, comparative-analytical, comparative-legal, and structural-functional approaches, as well as the content analysis method, which ensured a comprehensive assessment of the institutional, legal, and managerial aspects of financial controlling. As a result of the conducted study, it was established that financial controlling constitutes an integrated system of management accounting, analysis, and control aimed at ensuring the financial sustainability of an SME enterprise. It was determined that the implementation of the controlling cycle "plan – actual – adjustment" makes it possible to increase the accuracy of budget planning and to reduce time lags between the emergence and elimination of financial deviations. It was revealed that the structuring of controlling functions – monitoring, forecasting, analysis, and risk prevention – contributes to an increase in the transparency of financial flows and reduces the likelihood of fraudulent operations in small and medium-sized businesses. It was established that financial fraud in the SME sector of the Kyrgyz Republic has a systemic nature and manifests itself in the forms of manipulation of financial statements, cash and payment fraud, and tax schemes. A low level of implementation of internal control mechanisms was quantitatively confirmed. It was established that only 13.3% of small and medium-sized enterprises with access to bank financing apply institutionalised internal control mechanisms, which indicates a low level of maturity of managerial procedures. The main institutional factors of SMEs' vulnerability to financial abuses were identified. The key factors are: a high share of cash transactions, low financial literacy (11.6 out of 21 points according to the methodology of the Organisation for Economic Co-operation and Development/National Bank of the Kyrgyz Republic), limited use of banking financing instruments, and high perceived corruption (146th place in the Corruption Perceptions Index-2024). As a result of the study, an approach to the implementation of financial controlling in small and medium-sized businesses of the Kyrgyz

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Republic was developed, based on the integration of organisational, analytical, and technological methods. The practical significance of the results lies in the possibility of applying the proposed comprehensive controlling model to reduce the frequency of financial violations and to optimise managerial decision-making in SME enterprises

Keywords: preventive measures; risk sources; manipulation of financial statements; cash and payment fraud; tax schemes

INTRODUCTION

The economy of Kyrgyzstan during the period 2015-2025 is characterised by a high share of small and medium-sized businesses (SMEs), which serve as a factor of employment and a source of tax revenues. However, this sector is particularly vulnerable to financial risks and fraudulent schemes, which leads to a decline in investor confidence, loss of enterprise liquidity, and a reduction in business activity. Under conditions of insufficient institutional control, imperfections in internal audit systems, and limited access to qualified management accounting specialists, the problem of detecting and preventing financial fraud becomes one of the most acute issues for the sustainable development of SMEs in Kyrgyzstan. Traditional mechanisms of accounting and tax control, such as desk and on-site inspections, comparison of tax declarations and primary documentation, and formal analysis of balance sheets and financial statements, are of a formal nature and do not ensure systematic monitoring of deviations in financial flows. At the same time, internal audit methods applied in small and medium-sized enterprises are limited to reactive detection of violations rather than their prevention. The absence of a strategic approach to financial controlling, which integrates the functions of analysis, planning, and monitoring, creates significant gaps in risk management and hinders the formation of a culture of transparency and accountability.

In academic discourse, the issue of fraud prevention in small and medium-sized businesses is examined through the prism of the effectiveness of internal control systems, the development of analytical instruments, and digital technologies. The findings of A.F. Azizan & M.M. Ali (2024) confirm the importance of improving internal control mechanisms in SMEs. In the course of the study, the authors demonstrated that a transparent system of responsibility allocation and dual authorisation of financial transactions makes it possible to reduce the number of abuses by 30-35% while simultaneously increasing the level of investor confidence in enterprises. Contemporary researchers also pay attention to digital solutions for analytical monitoring. M. Duan *et al.* (2024) proposed a Dynamic Grouping Aggregation Graph Neural Network model, which ensures fraud detection accuracy of more than 90% through the integration of data from various sources of financial information. This approach confirms the effectiveness of using intelligent algorithms in the controlling of financial flows. In the study by R.P. Igbojioyibo (2024), it was substantiated that strengthening internal control systems increases the reliability of financial reporting and the protection of assets in small enterprises. The author recorded a reduction in the frequency of erroneous financial reports by 25% following the implementation of standardised internal audit procedures, which confirms the necessity of regulated approaches in controlling. A contribution to the development of the topic was made by M.Z. Hossain (2025), who empirically examined the effectiveness of internal control systems in preventing financial fraud in small and medium-sized enterprises. Based on a sample of 214 companies, the author established that the introduction of multi-level transaction approval procedures, internal audit, and electronic transaction logs reduces the probability of fraudulent actions by 32-37%. The study also revealed a positive relationship between the maturity of the internal control system and the stability of enterprises' financial indicators.

The work of C. Free (2020) develops the theory of the "fraud triangle", emphasising the significance of socio-ethical and psychological factors in the formation of fraud prevention systems. The author notes that even in the presence of

formal control procedures, a high level of tolerance for violations within an organisation significantly increases the risk of fraudulent actions. The study by I.F. Prasetia & H.F. Rabbani (2025) shows that an effective strategy for early detection of violations and the implementation of anti-fraud practices makes it possible to reduce companies' average financial losses by almost 40%. The authors emphasised the role of the level of managerial authority within the control system as a determining factor in the effectiveness of fraud counteraction. In the work of G. Pu *et al.* (2021), the role of innovative financial instruments and technological adaptation in ensuring the resilience of SMEs during periods of crisis phenomena is examined. The authors demonstrated that state support acts as a mediator between the level of business digitalisation and its ability to avoid financial risks, which creates a basis for the formation of new risk-oriented approaches to financial controlling. P. Rao *et al.* (2023) developed a conceptual model of sustainable business practices for SMEs that integrates the principles of ethical governance, transparency, and social responsibility. The authors demonstrated that business sustainability is impossible without effective financial control that ensures a balance between profitability and ethical standards of activity. Finally, the bibliometric study by U. Rashid *et al.* (2024) identified the main scientific trends in the study of SME financial insolvency. The results showed that most studies focus on macroeconomic determinants of bankruptcy, while issues of internal controls and preventive mechanisms remain insufficiently developed, which constitutes the key research gap that this study seeks to address. Thus, the synthesis of contemporary academic findings indicates that the prevention of financial abuses in SMEs requires not only the formalisation of audit procedures, but also the development of comprehensive controlling systems that combine organisational, analytical, and technological elements and foster a culture of ethical responsibility in the business environment.

The aim of the study was to analyse the methods and instruments of financial controlling aimed at detecting and preventing fraudulent activities in the SME sector of Kyrgyzstan. The objectives of the study were to examine the theoretical foundations of financial controlling and to identify its key functions within the management system of SMEs; to systematise the main types of financial fraud and assess their potential economic consequences; and to develop a conceptual approach to the implementation of a controlling system in SMEs in Kyrgyzstan.

MATERIALS AND METHODS

The study covered an analysis of financial and economic data and institutional indicators of SMEs in the Kyrgyz Republic for the period 2021-2024, which provided an empirical basis for examining risk dynamics and assessing the effectiveness of internal control procedures. On this basis, the study of the theoretical foundations of financial controlling within the management system of small and medium-sized businesses in the Kyrgyz Republic relied on a set of interdisciplinary methods of economic analysis, including the comparative-legal method and structural-functional analysis. Structural-functional analysis was used to construct a systemic model of interrelated controlling functions (planning, monitoring, deviation analysis, information and analytical support, and risk prevention). This method made it possible to determine the managerial orientation of each function and its contribution to improving the efficiency of financial processes. The comparative-legal method was applied to compare the provisions of the Law of the Kyrgyz Republic No. 76 (2002), the Law of the Kyrgyz Republic No. 72 (2007), as well as the Resolution of the Cabinet of Ministers of the Kyrgyz Republic No. 505 (2024), with the norms of the international standard International Financial Reporting Standard for Small and Medium-Sized Entities (n.d.). This approach made it possible to identify the degree of harmonisation of the national regulatory framework with international principles of transparency and accountability in financial reporting, as well as to determine institutional gaps in the practice of implementing financial controlling.

Within the empirical part of the study, the classification of forms of financial fraud in SMEs was developed using content analysis of analytical publications, including data from World Bank (2025) and Transparency International (2024). To compare different SME segments –

micro-services, trade, and small-scale manufacturing – the comparative-analytical method was applied, aimed at identifying differences in the structure of financial operations, the level of organisational formalisation, the nature of budget deviations, and the degree of digitalisation of accounting procedures. Since official statistics on risk parameters (the share of cash transactions, the frequency of cash-related violations, and the number of reporting adjustments) are not available disaggregated by types of enterprises, the comparative analysis was based on qualitative and conditionally quantitative benchmarks reconstructed on the basis of World Bank data.

To identify systemic vulnerability factors and their impact on fraud risk, the system-structural analysis method was applied. Its application relied on materials containing complementary information on enterprise behaviour and the institutional environment. Micro-level characteristics of SMEs – the structure of payment operations, features of accounting procedures, and the degree of process automation – were identified on the basis of data from the National Bank of the Kyrgyz Republic (2024; 2025). Macroeconomic indicators of the business environment, including the level of financial literacy and the intensity of the use of cashless instruments, were additionally analysed based on materials from World Bank (2024) and Transparency International (2024). To substantiate the financial controlling model, the theoretical-analytical method was applied. The materials included studies on risk-oriented control and integrated management systems presented in the works of S.F. Zainal *et al.* (2021) and E.O. Adeboye (2024).

RESULTS

Theoretical foundations of financial controlling in the SME management system

In enterprise management theory, financial controlling is considered not as a component of accounting or financial accounting that records past transactions, but as an integrated system of management accounting, analysis, and control oriented towards ensuring the financial sustainability of an enterprise (He, 2023). Financial controlling, in accordance with the approach of E. Nkwinika & S. Akinola (2023), is understood as a set of procedures and instruments covering the planning of financial flows, monitoring of revenues and expenditures, identification and analysis of deviations, assessment of financial risks, and the adoption of managerial decisions with the aim of optimising the use of financial resources and increasing the efficiency of enterprise operations. An important characteristic of financial controlling is its distinction from traditional accounting and financial accounting (Olinmah *et al.*, 2024). Traditional accounting is oriented towards the registration, classification, and reporting of already completed economic transactions, often with the purpose of fulfilling regulatory, tax, or external information requirements. Controlling has a preventive nature: it is aimed at answering the questions "what may happen?" and "what needs to be done to influence future outcomes?", rather than merely recording what has already occurred. In this sense, controlling becomes an instrument of early warning of deviations and a set of measures for correcting processes before they develop into serious problems. Moreover, financial controlling functions as an instrument of strategic management, providing an informational basis for managerial decision-making. It supplies management with timely and relevant information on key financial indicators, risks, and trends, which makes it possible to formulate strategy, adjust budgets, introduce control procedures, and minimise the likelihood of financial failures and fraud. Thus, the controlling system is integrated into the overall enterprise management system, becoming an element of economic security and long-term sustainability.

If controlling is considered as a dynamic managerial instrument, key importance is attached not so much to the very fact of control as to the mechanism of its functioning – namely, which processes are monitored, how analytical data are generated, and how they are transformed into managerial decisions. In this context, the functions of financial controlling act as interrelated elements of a unified system that ensures not only the recording of the financial condition, but also an active influence on the results of enterprise activity (Free, 2020). Their implementation covers the entire management cycle – from planning and forecasting to monitoring, analysis, and adjustment of financial

indicators. A structural representation of these functions is presented in Table 1, which outlines the main directions of their impact on business efficiency and sustainability.

Table 1. Functions of financial controlling and their managerial orientation

Function of controlling	Content	Managerial outcome
Monitoring and analysis of financial flows	Systematic monitoring of revenues, expenditures, and cash flows	Improvement of liquidity and financial transparency
Planning and forecasting	Preparation of budgets, scenario modelling, and risk assessment	Increase in the accuracy of financial planning
Control and assessment of deviations	Comparison of planned and actual indicators	Adjustment of strategic decisions and reduction of losses
Information and analytical support	Preparation of managerial reports and data visualisation	Improvement in the quality of managerial decision-making
Prevention of risks and fraud	Identification of anomalies and transaction control	Minimisation of financial violations and abuses

Source: compiled by the author based on A.E. Adegboyegun *et al.* (2020), J.E. Ziorklui *et al.* (2024)

Thus, the functions of financial controlling form an interconnected system that encompasses both current and strategic aspects of management. Their implementation contributes to increased transparency of financial processes, a reduction in fraud risks, and optimisation of the enterprise's resource potential. Empirical studies confirm the effectiveness of such mechanisms: in particular, based on a sample of 347 manufacturing enterprises, it was statistically established that the implementation of controlling positively correlates with a higher level of return on sales (Potkány *et al.*, 2022). In small and medium-sized businesses, controlling does not function as an auxiliary "superstructure" over accounting, but as a mechanism for rationalising financial processes under conditions of strict resource constraints. Its key managerial value lies in the fact that it integrates budgeting, liquidity monitoring, and scenario forecasting into a single closed-loop system "plan – actual – adjustment", reducing information lags and transforming financial management from a reactive into a proactive format. Under the unified closed-loop system "plan – actual – adjustment", R.Q. Majumder (2025) understands a closed managerial cycle in which planning processes, operational monitoring, and corrective actions function not in isolation, but as interrelated elements of a unified financial architecture of the enterprise. At the first stage, a plan is formed – target indicators for revenues, expenditures, liquidity, cash flows, and acceptable risk levels. Next, actual monitoring is carried out, including regular collection of financial data, their aggregation, comparison with planned parameters, and automated identification of deviations. At the final stage, the adjustment loop is activated: identified deviations are interpreted in terms of their causes, their impact on overall financial sustainability is assessed, and on this basis corrective managerial decisions are taken in near real-time mode – reallocation of resources, budget updates, revision of forecasts, and adjustment of limits and scenarios. In particular, according to the results of A. Martins *et al.* (2023), companies applying closed loops of planning, monitoring, and corrective actions demonstrate higher budgetary discipline, a lower frequency of cash gaps, and more stable fulfilment of financial plans.

The second strategic role of controlling is the institutionalisation of transparency and accountability in financial management. Controlling establishes standardised, comparable, and verifiable managerial reporting, reducing information asymmetry between owners, management, and external stakeholders (banks, investors, donors). At the firm level, this manifests itself in regular panels of Key Performance Indicators, cash flow dashboards, and regulated deviation reports; at the level of the business environment, it results in more predictable corporate behaviour, reduced opportunism, and strengthened business integrity. Regional studies for Eastern Europe and Central Asia confirm that practices of business integrity and internal control (including control procedures,

compliance, and transaction monitoring) improve the quality of corporate governance and reduce the risks of abuse through transparency mechanisms operationalised by controlling (Organisation for Economic Co-operation and Development, 2022). For SMEs, this also has a direct financial effect: the higher the quality of managerial reporting and the "transparency" of budgets, the lower the cost of borrowed capital and the greater the willingness of creditors to accept risk, which is particularly important in markets with limited long-term funding. In the context of the Kyrgyz Republic, this is confirmed by recent assessments of SME access to finance: despite a high degree of "banking inclusion" of accounts, the share of bank financing in investment remains low, and the development of a sustainable SME financing market is directly linked to the strengthening of internal planning and risk management practices within companies (World Bank, 2024).

Finally, controlling performs the function of early identification of signs of financial distress and optimisation of cash flows. In the work by S.R. Sethi & D.A. Mahadik (2025), it is emphasised that modern early warning systems are based on multi-component analysis, including regular assessment of key profitability ratios (margins, return on assets and equity), liquidity (current, quick, absolute), and solvency (share of borrowed capital, interest coverage, debt burden). In this context, not only the static level of indicators is important, but also the dynamics of their change over time, the identification of deterioration trends, and the acceleration of negative shifts. Such early warning systems are naturally "embedded" in the controlling loop and guide managers towards timely budget adjustments, revision of payment schedules, and reconfiguration of working capital. In the sphere of abuse prevention, controlling relies on the design and testing of internal control procedures (segregation of duties, verification of primary documents, triggers for atypical transactions). Accumulated empirical evidence for SMEs confirms that internal control systems reduce the likelihood of fraudulent actions and improve companies' operational performance. In the study by P. Santosuosso (2025), it is emphasised that enterprises that implemented formalised transaction controls and regular data reconciliation procedures demonstrated a lower frequency of anomalies in settlements with suppliers and personnel. For example, in one of the cases analysed by the author, a small manufacturing enterprise, following the introduction of segregation of duties (separation of procurement, accounting, and payment functions), as well as monthly variance analysis of cash flows, recorded a reduction in the number of erroneous and potentially fraudulent transactions and, simultaneously, an increase in the stability of the operating margin. As noted by the author, it was precisely the formalisation of control procedures and their regular repetition that enabled the company not only to eliminate cash leakages, but also to align operational processes, which was directly reflected in financial results.

The legal regulation of financial controlling in the Kyrgyz Republic is formed on the basis of a set of legislative and subordinate regulatory acts defining requirements for accounting, internal control, and transparency of financial reporting by business entities. The key document is the Law of the Kyrgyz Republic No. 76 (2002), which establishes methodological principles for accounting and financial reporting in accordance with international standards, namely the International Financial Reporting Standard for Small and Medium-Sized Entities (n.d.). The law mandates that all economic entities implement an internal control system ensuring data reliability and the prevention of abuses, thereby creating a regulatory foundation for the development of financial controlling as an element of the enterprise's managerial architecture. For the SME sector, specialised provisions apply, established by the Resolution of the Cabinet of Ministers of the Kyrgyz Republic No. 505 (2024). This document adapts accounting and managerial accounting requirements to the limited resources of SMEs, introducing the obligation to adopt accounting policies, document transactions, conduct internal data reconciliation, and apply digital financial control instruments, including electronic signatures and reporting through national online platforms.

Institutional aspects of state and internal control are additionally regulated by the Law of the Kyrgyz Republic No. 72 (2007), which

establishes the principles of risk-oriented supervision. In accordance with this law, unplanned inspections are permitted only in the presence of substantiated suspicions of violations, while risk assessment and the application of checklists become mandatory elements of control. This makes it possible to combine the preventive functions of state supervision with the strengthening of enterprises' internal responsibility. Taken together, these regulatory acts form a multi-level system for regulating financial controlling, encompassing state accounting standards, internal audit mechanisms, and risk-oriented supervision. Despite the formal consolidation of the regulatory framework, institutional challenges remain, including fragmentation of controlling implementation practices, insufficient qualification of accounting personnel, and limitations of digital infrastructure, which necessitates further improvement of the regulatory environment and the unification of financial management standards in the SME sector of the Kyrgyz Republic.

The presented theoretical and applied provisions make it possible to consider financial controlling as a comprehensive concept that integrates the functions of accounting, analysis, planning, monitoring, and risk management into a unified system of enterprise financial management. In small and medium-sized businesses, it forms the basis for improving the efficiency of resource utilisation, ensures a balance between short-term liquidity and long-term sustainability, and contributes to the formation of an institutional culture of transparency and accountability. Taken together, these effects make controlling a key element of the managerial architecture of SMEs in the Kyrgyz Republic.

Types of financial fraud in small and medium-sized businesses of Kyrgyzstan

For the Kyrgyz Republic, the problem of financial fraud becomes particularly relevant due to the high share of the shadow economy, the prevalence of informal financial practices, and the low level of digitalisation of accounting and financial reporting. According to World Bank (2025), only 13.3% of small and medium-sized enterprises with access to bank financing use institutionalised internal control mechanisms, which indicates limited maturity of managerial procedures and an increased risk of financial violations. In addition, the Transparency International (2024) notes that Kyrgyzstan continues to face problems related to the transparency of business practices, low levels of trust in financial institutions, and weak implementation of compliance control mechanisms, which makes the SME sector vulnerable to various forms of financial fraud. Under these conditions, structuring the forms and manifestations of fraud characteristic of SMEs becomes particularly important, as it makes it possible to identify vulnerable points in the management system, develop preventive financial controlling mechanisms, and increase the transparency of business processes (Table 2).

Table 2. Classification of financial fraud in SMEs of Kyrgyzstan

Type of fraud	Characteristic	Notes for SMEs of the Kyrgyz Republic	Examples
Manipulation of financial statements	Deliberate distortion of data in order to conceal losses, understate the tax base, or obtain credit (fictitious assets, "dual" reporting)	Occurs in small enterprises with limited managerial control	Recognition of fictitious accounts receivable in order to increase the volume of assets prior to submitting a loan application
Cash and payment fraud	Unauthorised cash withdrawals and transfers, creation of "dead" accounts	Enterprises with cash revenues and weak automation of reporting are particularly vulnerable	Regular cash write-offs recorded as travel expenses without supporting documentation
Abuses in procurement and contracting	Fictitious tenders, overpricing by suppliers, kickback schemes	Relevant for enterprises engaged in procurement and interaction with public contracts	Conclusion of a contract with a supplier at a price above the market level in exchange for a kickback to the responsible manager

Table 2, Continued

Type of fraud	Characteristic	Notes for SMEs of the Kyrgyz Republic	Examples
Tax schemes	Use of shell companies, false invoices, and fictitious value-added tax transactions	Widespread among SMEs seeking to minimise the tax burden	Recording the purchase of services from shell companies in order to artificially increase the tax credit
Loan and credit fraud	Falsification of financial statements for the purpose of obtaining bank financing	Risk increases under conditions of limited resources and insufficient business transparency	Overstatement of sales volumes in financial reporting for the last two quarters prior to applying to a bank for working capital financing
Internal staff abuses	Misappropriation of funds, "cleaning" of cash vouchers, violation of the segregatXion of duties principle	Occurs in enterprises with centralised management and weak segregation of functions	The cashier and the accountant combine functions, concealing daily "micro-withdrawals" of cash through adjustment of cash vouchers

Source: compiled by the author based on Transparency International (2024), World Bank (2025)

The presented classification demonstrates the systemic nature of financial fraud in small and medium-sized businesses of the Kyrgyz Republic, where each category reflects a specific level of vulnerability of financial processes and the institutional environment. The obtained empirical generalisations confirm that the dominant risk factors are weak automation of accounting procedures, a high share of cash transactions, insufficient segregation of managerial functions, and limited implementation of digital internal control instruments. Such conditions contribute not only to the distortion of financial reporting, but also to the formation of persistent corrupt practices in the spheres of procurement and taxation. Consequently, the development and implementation of a structured financial controlling system integrating analytical monitoring, risk-oriented inspections, and independent internal audit appears not merely as a managerial recommendation, but as a strategic direction for strengthening financial transparency and trust in the SME sector of Kyrgyzstan.

Taking into account the identified features, a comparison of the most common types of SMEs – micro-services, trading enterprises, and small manufacturing firms – by key financial risk indicators for the period 2021-2024 is of particular interest (Table 3). Since official statistics on such parameters as the share of cash transactions, the frequency of budget deviations, the number of cash-related violations, and reporting adjustments are not published disaggregated by the specified categories of business, the analysis is based on conditionally quantitative benchmarks and qualitative characteristics reflecting actual enterprise practices during the specified period.

Table 3. Comparative analysis of three types of SMEs in the Kyrgyz Republic by financial risk indicators (qualitative assessment, 2021-2024)

Type of SME	Share of cash transactions (trends)	Budget deviations (nature)	Cash-related violations (frequency)	Level of risk	Dominant abuse schemes
Micro-services	High; cash predominates	Frequent minor deviations due to informal accounting	Regular violations: undocumented disbursements, absence of daily reports	High	Understatement of revenue, cash fraud, off-the-books payments

Table 3, Continued

Type of SME	Share of cash transactions (trends)	Budget deviations (nature)	Cash-related violations (frequency)	Level of risk	Dominant abuse schemes
Trade (retail and small-scale wholesale)	Medium; a downward trend due to digitalisation	Significant deviations associated with changes in procurement prices	Cases of discrepancies during inventory counts, shortages	Above average	Manipulation of inventory balances, double write-offs, overstatement of procurement prices
Small manufacturing	Low; the majority of payments are cashless	Deviations arising from fluctuations in raw material costs	Rare cash-related violations	Medium	Overstatement of procurement costs, manipulation of cost calculations

Source: compiled by the author based on World Bank (2025)

The comparative analysis of three types of SMEs in the Kyrgyz Republic makes it possible to conclude that their financial risks are differentiated due to the structure of operational activities and the degree of formalisation of accounting procedures. Micro-services prove to be the most vulnerable, where the predominance of cash settlements, the minimal use of digital instruments, and the prevalence of "manual" accounting create a high probability of cash-related violations and systematic understatement of revenue. The trade sector demonstrates a more complex risk profile, primarily associated with instability of procurement prices, frequent discrepancies during inventory counts, and manipulation of inventory balances, which is reflected in an increased frequency of budget deviations. Small manufacturing enterprises are characterised by a lower share of cash transactions and rare cash incidents; however, they remain vulnerable in the areas of procurement and cost calculation, where typical schemes of overstating material costs and distorting production expenses are observed.

The identified micro-level risks are amplified by the characteristics of the national payment infrastructure and the level of financial literacy of economic entities. According to the assessment of the National Bank of the Kyrgyz Republic (2024), despite the expansion of cashless payment infrastructure (more than 38.9 thousand unified QR codes were installed in 2024), cash remains the primary instrument of retail payments, which objectively weakens transaction traceability and increases the risk of false entries, "cash-out" operations, and other cash and payment schemes. At the same time, the official financial literacy benchmark published by the National Bank of the Kyrgyz Republic (11.6 out of 21 points according to the methodology of the Organisation for Economic Co-operation and Development in the baseline measurement of 2021; target – to exceed 12) confirms a low level of competencies among a significant share of economic entities and their employees (National Bank of the Kyrgyz Republic, 2025). This exacerbates accounting errors, weak configuration of internal procedures, and vulnerability to fraudulent practices.

From the perspective of the formalisation of financial flows, it is indicative that, according to World Bank (2024) data, despite the universal availability of bank accounts, only 13.3% of companies used banks to finance investments. This gap between the "availability of formal financial instruments" and the actual practice of their use indirectly reflects the low level of institutionalisation of financial procedures and the propensity of enterprises to resort to informal settlement and funding schemes. Such structural imbalance fully corresponds to the risks previously identified in SME segments: the dominance of cash transactions in micro-services, instability of procurement flows in trade, and weak formalisation of internal procedures in small manufacturing. At the macroeconomic level, this manifests itself in the form of systemic vulnerability factors that create a favourable environment for the widespread

abuse schemes, ranging from cash-related fraud to manipulation of costs and reporting.

Finally, macro-level indicators of business environment transparency confirm the intensification of these structural risks. In the Corruption Perceptions Index (CPI-2024), Kyrgyzstan scored 25 points out of 100 and ranked 146th among 180 countries, which indicates widespread practices of non-transparent payments, "fictitious" expenses, and conflicts of interest that strengthen behavioural incentives to circumvent formal regulatory procedures (Transparency International, 2024). This directly correlates with the identified characteristics of SME vulnerability, as the high share of cash settlements, limited use of banking instruments, and low level of financial literacy among personnel create preconditions for the reproduction of the forms of abuse highlighted in the comparative analysis. Taken together, these macro- and micro-level preconditions are reflected in Table 4, which systematises the key indicators of SME vulnerability to financial abuses in Kyrgyzstan and demonstrates their interconnection with the dominant risk behaviour schemes.

Table 4. Indicators of SME vulnerability to financial abuses in Kyrgyzstan (2023-2025)

Indicator	Current value	Interpretation for risk
Dominance of cash in retail transactions	Cash remains the primary instrument; more than 38.9 thousand QR codes were implemented in 2024	A high share of cash transactions reduces the traceability of financial operations and creates conditions for manipulation of cash and payment flows
Financial literacy (methodology of the Organisation for Economic Co-operation and Development/ National Bank of the Kyrgyz Republic)	11.6/21 (baseline measurement; target benchmark >12)	Low staff competencies increase the risk of accounting errors and susceptibility to fraud
Use of banks for investment financing	13.3% of firms	Low "institutionalisation" of finance and reliance on informal practices
Macro-level transparency (CPI-2024)	146th place out of 180	High perceived corruption strengthens behavioural incentives to circumvent rules

Source: compiled by the author based on Transparency International (2024), National Bank of the Kyrgyz Republic (2024; 2025), World Bank (2025)

The presented set of indicators demonstrates that the key factors of SME vulnerability to financial abuses in Kyrgyzstan are of an institutional and behavioural nature: structural dependence on cash turnover, insufficient financial literacy, limited depth of formal financing channels, and weak overall transparency of the business environment. Even against the background of active policies aimed at developing cashless payments and updating national risk assessments, enterprises lack systematic compliance policies and regular internal audit, which is reflected in indirect indicators (low levels of bank-mediated investment financing and persistently low CPI scores). In this configuration, abuses remain latent (do not reach official registration) due to fears of reputational losses and the transaction costs associated with reporting. This is indirectly indicated both by the structure of payment instruments itself and by the conclusions of the national risk assessment regarding the need to expand reporting on suspicious transactions and to improve the quality of compliance among financial market participants.

Approaches to the implementation of a financial controlling system in SMEs of Kyrgyzstan

The theoretical justification of the financial controlling model for the SME sector of the Kyrgyz Republic is based on contemporary concepts of risk-oriented control (Zainal *et al.*, 2021; Adeboye, 2024), practices of managerial analysis and monitoring of financial deviations developed in studies on anti-fraud accounting (Alayli, 2022; Ngan, 2024), as well as empirical findings on the impact of digital internal control systems on reducing accounting errors and the likelihood of abuses (Zgarni, 2021; Doğan & Hamidow, 2023, Sawaya *et al.*, 2025). The model proposed in this study represents an authorial adaptation of

these approaches to the institutional conditions of the Kyrgyz SME sector. In its development, structural features of micro-services, trading enterprises, and small manufacturing firms were taken into account, as well as the nature of the identified financial violations described in the previous sections.

In the context of Kyrgyz SMEs, controlling acquires particular significance due to the combination of institutional fragmentation, the high role of the human factor, limited availability of qualified personnel, and weak digitalisation of financial processes. Under these conditions, financial controlling should perform not only a recording function, but also a preventive one, ensuring early detection of anomalies, risk forecasting, reduction of fraud probability, and improvement of the quality of managerial decision-making. The proposed model includes three interrelated levels – organisational, analytical, and technological – each of which manifests itself differently depending on the type of enterprise. Their structural content is presented in Table 5.

Table 5. Levels of the financial controlling model and their application across different types of SMEs in Kyrgyzstan (qualitative assessment)

Type of SME	Organisational level	Analytical level	Technological level	Expected effect after the implementation of controlling
Micro-services	Segregation of the functions "cash handling – accounting"; introduction of responsibility for operations; restriction of access to monetary resources	Daily reconciliation of revenues; analysis of deviations; recording of "unrecorded" revenue	Online cash registers, mobile accounting, automation of cash operations	Reduction in the number of cash-related incidents; decrease in the volume of manual adjustments; increase in the transparency of cash flows
Trade (retail and small-scale wholesale)	Segregation of procurement, warehouse, and cash functions; control over the movement of goods	Regular comparison of inventory and financial data; analysis of write-offs and shortages	Warehouse ERP modules; barcode scanning; automation of inventory accounting	Reduction of shortages; decrease in discrepancies during inventory counts; increase in the accuracy of inventory accounting
Small manufacturing	Formalisation of procurement and raw material write-off procedures; control of access to production resources	Plan-actual cost control; analysis of abnormally high procurement prices; monitoring of production expenses	ERP systems for raw material accounting; digital recording of material movements	Stabilisation of cost of production; reduction of overstated procurement; decrease in misallocated expenditures

Source: compiled by the author based on S.F. Zainal *et al.* (2021)

The organisational level is aimed at establishing managerial discipline and the allocation of responsibility. In micro-service enterprises, it reduces the risk of cash misappropriation through the segregation of the functions "cash handling – accounting" and the restriction of access to monetary resources. In trading companies, organisational separation between procurement, warehousing, and cash operations makes it possible to prevent manipulation of commodity flows and to reduce discrepancies during inventory counts. In small manufacturing, the formalisation of procurement and raw material write-off procedures renders processes transparent and reduces the likelihood of overstating procurement prices and misallocation of resources. Thus, the organisational level creates a system of mutual constraints, strengthens accountability, and reduces the probability of abuses across each SME segment.

The analytical level ensures continuous tracking of key financial processes and the formation of a basis for early risk warning. In micro-services, it enables daily control of revenues, identification of "unrecorded" receipts, and detection of small but regular deviations characteristic of this segment. In trading enterprises, the analytical block ensures systematic reconciliation of inventory and financial data, analysis of write-offs, and identification of anomalous changes in procurement prices. In small manufacturing, it forms an informational basis for cost

control, allowing for the prompt identification of overstated purchases and errors in cost calculations. In this way, the analytical level transforms fragmented accounting into an instrument for monitoring and adjusting managerial decisions.

The technological level integrates digital accounting tools – ERP systems, online accounting, automated notifications, and visualisation dashboards, which ensures the timeliness, reliability, and traceability of financial data. For micro-services, key instruments include online cash registers and mobile accounting services, which reduce manual adjustments and minimise cash-related incidents. For trade, technological solutions include warehouse ERP modules, automated inventory processes, and scanning of goods movements, which reduces the risk of shortages and manipulation of inventory balances. In small manufacturing, digital recording of raw material movements and production costs ensures calculation accuracy and reduces the likelihood of cost manipulation. Such a technological complex is particularly significant under conditions of limited human resources and low levels of automation characteristic of Kyrgyz SMEs.

The implementation of the financial controlling model in the SME sector of the Kyrgyz Republic requires an institutionally established and normatively integrated approach. Effective implementation is possible only through the phased development of a system based on the standards of the International Financial Reporting Standard for Small and Medium-Sized Entities (n.d.), adapted to the national legal environment. The application of these standards ensures the unification of accounting and managerial reporting, comparability of financial indicators, and the formation of a transparent information base for internal control. The incorporation of the principles of the International Financial Reporting Standard for Small and Medium-Sized Entities into SME practice in Kyrgyzstan may become a key condition for the transition from fragmented accounting to systemic financial controlling, which is consistent with the recommendations of the Organisation for Economic Co-operation and Development (2022) on strengthening business institutional resilience in Central Asian countries.

An element of the implementation concept is staff training, since the effectiveness of financial controlling directly depends on the level of employee competencies. In the context of Kyrgyz SMEs, where a low level of financial literacy is observed, a systematic professional development programme for accountants, auditors, and middle managers is required. Training should include modules on anti-fraud accounting, interpretation of financial indicators, use of digital analytical tools, and the construction of internal reporting. Regular internal audit is of particular importance within the controlling system, performing not only a diagnostic but also a preventive function. Periodic reviews of financial documentation, cash, and settlement operations make it possible to identify and eliminate violations in a timely manner before they develop into systemic abuses. At the same time, it is important that internal audit is not merely formal, but is integrated into enterprise managerial practice through the use of digital audit logs and automated reporting templates. Finally, effective implementation is impossible without integrating controlling with the corporate strategy of the enterprise. Controlling should not exist in isolation as an instrument of accounting oversight, but must support the strategic objectives of the company – profit growth, cash flow sustainability, cost optimisation, and strengthening of counterparty trust. In this context, controlling becomes part of the corporate management architecture, forming the information and analytical basis for strategic planning and decision-making. Thus, the implementation of the financial controlling model in Kyrgyz SMEs should be regarded as a continuous process of organisational and technological development based on comprehensiveness, professionalisation of personnel, regular auditing, and strategic integration.

DISCUSSION

The results obtained in the course of the study are consistent with a number of academic works devoted to the examination of the role of financial controlling and internal control in ensuring the sustainability and transparency of SME operations. In particular, the conclusion regarding the strategic nature of controlling, which

integrates the functions of planning, analysis, monitoring, and risk prevention, is confirmed by the research of N.J. Isibor *et al.* (2022). The scholars developed a financial control and managerial model for SMEs, demonstrating that the systematic use of budgeting, forecasting, and deviation analysis instruments makes it possible to increase enterprise profitability by an average of 18% while simultaneously reducing the risk of liquidity deficits. These findings correlate with the results presented in the present study, according to which the implementation of the "plan – actual – adjustment" cycle improves the accuracy of financial planning and enhances the structure of resource utilisation.

On the other hand, the work of S.E. Okeke *et al.* (2021) revealed that the introduction of internal control procedures and controlling-based monitoring in small businesses in Nigeria contributes to a reduction in cases of professional misconduct and fraudulent actions by 27%. This empirical result supports the position advanced in the present study that controlling functions as an instrument of preventive management and early detection of signs of financial distress. However, the authors note that the effectiveness of internal control decreases in the absence of formalised reporting standards, whereas in the context of Kyrgyz enterprises this issue is addressed through the institutionalisation of transparent managerial reporting procedures, which makes it possible to minimise information asymmetry among business participants.

The findings of the study also align with the conclusions of S. Bhat (2023), according to whom the quality of the internal control system has a direct impact on the level of financial violations and overall business sustainability. The author demonstrated that in organisations where transaction monitoring mechanisms and verification of the reliability of financial data are implemented, the frequency of financial abuses decreases by an average of 30%. A similar pattern is observed in the context of Kyrgyz SMEs, where the application of controlling instruments for early deviation analysis and verification of primary documents strengthens financial discipline and contributes to increased trust among investors and creditors. In the study by K.G. Al-Hashedi & P. Magalingam (2021), it was noted that a high level of SME vulnerability to financial abuses is associated with limited application of analytical monitoring instruments and weak integration of digital technologies into internal control systems. The authors emphasised that in countries with developing economies, a low level of automation of accounting processes facilitates the spread of schemes involving reporting distortions and payment manipulations.

At the same time, the work of A.M. Al-Zoubi (2021) proposes a conceptual model for the classification of preventive anti-fraud measures based on the principle of aligning control procedures with sources of risk. The author highlights that for small enterprises the priority lies precisely in the development of preventive instruments, including compliance control, internal audit, and segregation of duties. This position corresponds to the conclusions of the present study, according to which the absence of institutionalised compliance mechanisms and regular inspections constitutes one of the key reasons for the systemic nature of financial fraud in the Kyrgyz SME sector. Thus, the classification of types of fraud proposed in this study may be regarded as a practical implementation of the structural-functional approach described by A.M. Al-Zoubi. The study by Z.Z. Mthiyane *et al.* (2022) develops the idea of institutional risk governance in SMEs and indicates that in developing countries primary attention should be paid not only to control, but also to the formation of an organisational culture of integrity and transparency. The authors argued that weak segregation of managerial functions and limited financial literacy among personnel intensify latent forms of fraud that are not reflected in official statistics. This observation correlates with the problems identified in the Kyrgyz context: a low level of competencies (11.6 points out of 21 according to the methodology of the Organisation for Economic Co-operation and Development/National Bank of the Kyrgyz Republic), limited application of formalised internal audit procedures, and fear of reputational losses that hinder the disclosure of abuses.

The conclusions regarding the need for a comprehensive combination of organisational, analytical, and technological control methods are consistent with the results of the study by

M. Bakar *et al.* (2023), who demonstrated that the key factor in preventing fraud in small and medium-sized enterprises is the combination of effective internal control, an ethical corporate culture, and regular monitoring of financial operations. The authors established that even in the presence of advanced technological instruments, the risk of financial violations remains high in the absence of an organisational culture of accountability and transparency. These observations confirm the findings of the study of Kyrgyz SMEs, where weak managerial discipline and the lack of systematic allocation of functions among employees increase the likelihood of abuses.

The findings of the study also resonate with the results of M. Amin & V. Motta (2021), who, analysing firm-level survey data in developing countries, concluded that high levels of corruption and limited access to formal sources of finance stimulate the spread of informal financial practices in the SME sector. These conditions weaken control over financial flows and create preconditions for institutionalised fraud. A similar pattern is observed in the Kyrgyz context, where low transparency and weak enforcement of financial reporting requirements increase the importance of integrating controlling with corporate strategy and the internal audit system. Thus, the results of the study confirm that financial controlling in Kyrgyzstan should perform not only a managerial, but also an anti-corruption function.

At the same time, a partial divergence is observed with the results presented by K.M. Mang'ana *et al.* (2024). These authors demonstrated, using the example of agrarian SMEs in Tanzania, that technological automation of accounting and digital instruments constitute the main factor in enhancing the effectiveness of financial management. However, the data obtained for the Kyrgyz SME sector show that technological solutions alone are insufficient: without prior formation of an organisational structure and analytical support, controlling instruments do not ensure a sustainable effect. This allows the conclusion that for Kyrgyzstan a comprehensive approach combining institutional and human factors with digital control mechanisms is more relevant. Thus, the results of the study confirm the thesis regarding the necessity of phased implementation of a financial controlling system encompassing organisational, analytical, and technological methods, and emphasise that in the conditions of the Kyrgyz Republic the decisive factor is not the level of digitalisation, but the coherence of managerial and control functions that form a transparent and sustainable financial architecture of enterprises.

CONCLUSIONS

The conducted study made it possible to confirm the systemic nature of financial controlling as an element of the managerial architecture of SMEs and to develop an empirically grounded model for its implementation, adapted to the institutional and resource conditions of the Kyrgyz Republic. The model is based on the standards of the International Financial Reporting Standard for Small and Medium-Sized Entities, the recommendations of the Organisation for Economic Co-operation and Development, and the results of an analysis of national regulatory acts, which ensures its applicability in the context of a developing economy. The analysis demonstrated that the level of financial risks varies across different types of SMEs. Micro-services are characterised by a high share of cash transactions, a high frequency of cash-related violations, and a significant volume of manual accounting adjustments, which forms the most vulnerable risk profile. Trading enterprises demonstrate an increased risk of inventory discrepancies and deviations related to procurement prices, while small manufacturing is distinguished by risks of cost overstatement and manipulation of production costs. The probability of financial abuses is most significantly influenced by such indicators as the structure of payment operations (share of cash), the frequency of budget deviations, the number of cash incidents, the regularity of reporting adjustments, and the level of digitalisation of accounting procedures. This confirms the necessity of an adaptive and differentiated approach to the implementation of controlling depending on the type of enterprise. The institutional context reinforces these risks: the share of companies using formalised internal control mechanisms does not exceed 13.3%, while the financial

literacy indicator according to the methodology of the Organisation for Economic Co-operation and Development/National Bank of the Kyrgyz Republic amounts to 11.6 out of 21 points, indicating a systemic deficit of competencies. At the same time, the Corruption Perceptions Index CPI-2024 (25 points out of 100; 146th place out of 180 countries) reflects a low level of institutional transparency and creates conditions for the spread of informal financial practices.

The practical significance of the obtained results lies in the formation of a step-by-step algorithm for implementing a financial controlling system, which includes: institutional adaptation of the International Financial Reporting Standard for Small and Medium-Sized Entities; development of training programmes for accountants and auditors in anti-fraud accounting; implementation of digital platforms for internal audit and financial monitoring dashboards; and integration of controlling with corporate strategy. The implementation of this model is capable of increasing the transparency of financial flows, reducing the frequency of cash and reporting manipulations, and strengthening creditor confidence in the SME sector. The theoretical conclusions of the study demonstrate that controlling in small business should perform an adaptive and preventive function, transforming financial management from a reactive into a proactive format. The combination of organisational and digital instruments makes it possible not only to record results, but also to generate managerial signals regarding risks in real time. This ensures a transition from formal reporting to managerial accountability and internal compliance.

The limitations of the study are associated with insufficient availability of detailed data on enterprises' internal control systems and the latent nature of fraud cases. Prospects for further research include empirical validation of the proposed model on a sample of enterprises from different industries, assessment of the economic effect of controlling implementation, and the development of a financial management maturity index for SMEs in Kyrgyzstan. Such an instrument would make it possible to integrate controlling into the national system for assessing business transparency and the sustainability of the entrepreneurial sector.

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Методи та підходи фінансового контролінгу для запобігання шахрайству в малому та середньому бізнесі Киргизстану

Анотація. Мета дослідження полягала у вивченні методів та інструментів фінансового контролінгу, що забезпечують виявлення та запобігання шахрайським діям у секторі малого та середнього бізнесу (МСБ) Киргизстану. Методи дослідження включали теоретико-аналітичний, порівняльно-аналітичний, порівняльно-правовий, структурно-функціональний підходи та метод контент-аналізу, що забезпечило комплексну оцінку інституційних, правових та управлінських аспектів фінансового контролінгу. В результаті проведеного дослідження встановлено, що фінансовий контролінг є інтегрованою системою управлінського обліку, аналізу та контролю, спрямованою на забезпечення фінансової стійкості підприємства МСБ. Визначено, що впровадження контролінгового циклу «план – факт – корекція» дозволяє підвищити точність бюджетного планування, скоротити часові лаги між виникненням і усуненням фінансових відхилень. Виявлено, що структурування функцій контролінгу – моніторинг, прогнозування, аналіз і попередження ризиків – сприяє зростанню прозорості фінансових потоків і знижує ймовірність шахрайських операцій у малому та середньому бізнесі. Встановлено, що лише 13,3 % малих і середніх підприємств, які мають доступ до банківського фінансування, застосовують інституціоналізовані механізми внутрішнього контролю, що вказує на низьку зрілість управлінських процедур. Ідентифіковано основні інституційні фактори вразливості МСБ до фінансових зловживань. Ключовими факторами є: висока частка готівкових розрахунків, низька фінансова грамотність (11,6 з 21 бала за методикою Організації економічного співробітництва та розвитку/Національного банку Киргизької Республіки), обмежене використання банківських інструментів фінансування та високий рівень сприйняття корупції (146-те місце в Corruption Perceptions Index-2024). В результаті дослідження розроблено підхід до впровадження фінансового контролінгу в малому та середньому бізнесі Киргизької Республіки, заснований на інтеграції організаційних, аналітичних та технологічних методів. Практична значущість результатів полягає в можливості застосування запропонованої моделі комплексного контролінгу для зниження частоти фінансових порушень та оптимізації управлінських рішень на підприємствах МСБ

Ключові слова: превентивні заходи; джерела ризику; маніпулювання бухгалтерською звітністю; касово-платіжні махінації; податкові схеми

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Assessment of the investment attractiveness of the agricultural sector of Kyiv region in the context of contemporary financial policy

Abstract. This article aimed to evaluate the investment attractiveness of the agricultural complex of the Kyiv region and to analyse the financial policy that contributed to its development. The following

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methods were used to achieve the aim: descriptive statistical analysis, comparative analysis, cluster analysis, SWOT analysis, correlation analysis, and integrated assessment of investment attractiveness. As a result of the analysis of the structure of sown areas, the specialisation of the region was established in the production of cereals, oilseeds and vegetables, which provides food security and stimulates investment in the modernisation of agricultural production. The largest share of investments was directed towards the modernisation of the machine-technical base (40%), infrastructure development (30%) and implementation of agrotechnologies (20%). The profitability of cereal and oilseed production increased from 18% in 2020 to 22% in 2022, which in turn increased the investment attractiveness of the sector. The results of the interregional analysis showed that although Kyiv region ranked second only to two regions in terms of foreign investment in the agro industrial complex, it took the first place in the integrated ranking of investment attractiveness due to the developed infrastructure, economic stability and qualified personnel. The cluster analysis made it possible to establish that the most investment-attractive districts of Kyiv region are Bila Tserkva, Obukhiv and Fastiv. The territories of Bucha and Vyshhorod districts showed the lowest investment attractiveness and need investments in the development of infrastructure and the creation of workplaces. The SWOT analysis revealed a number of strengths, fertile soils, developed infrastructure, and weaknesses, dependence on weather conditions, and high interest rates on loans, for the elimination of which it is necessary to improve the financial policy. The further development of the region's agro-industrial complex is forecasted, provided that the state support will be preserved, investments in progressive agrotechnologies will be attracted, and the infrastructure will continue to develop, which will contribute to the economic growth of Kyiv region. The practical value of the obtained results consists in their applicability in the formation of policies aimed at investment stimulation in the agro-industrial complex, in particular due to tax instruments, subsidies and credit programmes

Keywords: tax incentives; subsidies; credit; sown areas; profitability; development

INTRODUCTION

Agriculture is a significant sector of the economy of Ukraine, which provides food security, creates a certain share of gross domestic product and employs a large portion of the population. The sector also has significant prospects for further growth, because it is the main supplier of raw materials for the food industry, which is only at the stage of formation. At the same time, the agricultural sector has a number of problems that hinder its development, including resource constraints, the need to modernise production capacities, introduce new technologies and weather conditions, which further complicate the activities of agricultural producers. In the context of economic instability, changes in tax policy and against the background of global economic crises, the investment attractiveness of the agricultural sector becomes a topical issue. It directly affects the ability of the sector to attract domestic and foreign investment, which is a necessary condition for sustainable development, innovation and modernisation of infrastructure. It is also important to ensure the efficient use of natural and economic resources and attract capital for the development of agricultural enterprises, which will significantly increase productivity and competitiveness in the world market.

O. Hryvkivska & B. Venta (2025), in their article, examine the investment strategy as an instrument for the recovery and transformation of agricultural enterprises in the conditions of war in Ukraine. The authors investigated the influence of the military situation on the economic activity of agricultural enterprises and proposed investment attraction strategies for the stabilisation and further development of the agricultural sector. Particular attention is paid to the need to adapt to new economic conditions and restore the infrastructure of the agricultural sector. The factors influencing the infrastructure of the agro-industrial complex in the context of European integration were studied by D. Makhyna (2020). The author analysed

the factors contributing to the strengthening of the investment attractiveness of infrastructure and their impact on the competitiveness of the agricultural sector of Ukraine against the background of European integration. Great attention is paid to infrastructure development as a factor in investment attractiveness and adjustment to European standards. A. Bilochenko *et al.* (2021) examined innovations as an important factor in increasing the investment attractiveness of the agro-industrial complex. The authors studied various innovative solutions that can be applied in the agro-industrial complex to improve efficiency and attract investments. The authors considered the influence of innovations on the competitiveness and sustainability of agricultural production.

N. Omurgazieva *et al.* (2024) evaluated the impact of tax policy on the development of agroindustrial complex enterprises. The authors highlighted the role of tax mechanisms in stimulating investments in the agro-industrial complex and expanding the production potential of agro-industrial complex enterprises. The improvement of tax incentives is considered to increase the efficiency of the sector. L. Tang & S. Sun (2022) considered the influence of fiscal incentives and financial support on the agro-industrial complex and on the disparity between urban and rural areas. The authors analysed the effect of state actions on the reduction of income inequality between the urban and rural population by improving financial support for agro-industrial complex entities. The authors stressed the importance of policy directions to support small agro-industrial complex entities and ensure balanced regional development. X. Wu *et al.* (2025) investigated whether fiscal policy facilitates green development in China's agro-industrial complex, especially from the energy and environmental perspective. The study showed the application of fiscal instruments for the sustainable development of the agro-industrial complex, in particular, the improvement of energy efficiency and reduction of environmental impact. The importance of "green" fiscal incentives for the development of the agro-industrial complex is stressed.

W. Lin & J. Huang (2021) studied the impact of agricultural incentives on land rent prices in China with a special focus on recent studies on price formation in the agro-industrial complex. The authors showed how agro-industrial complex incentives affect the structure of the land market and land rent prices, thus contributing to a more efficient use of land resources. The study also offers insights into policies supporting agricultural producers and the impact of incentive programmes on the land market. For example, policies concerning agricultural production and their effect on healthy agricultural products were considered by R. Lencucha *et al.* (2020). The authors considered policies aimed at improving the production of healthy agricultural products and evaluated their impact in the globalisation context. The impact of state policy on improving the quality of agricultural products and enhancing their competitiveness on the international market is assessed. The effect of government subsidies on technological innovations in the agribusiness sector, particularly in China, was investigated by L. Wu *et al.* (2022). The authors considered how subsidies influence innovation processes in the agricultural sector and evaluated the effectiveness of state programmes aimed at promoting the development of new technologies in agriculture. The study highlights the need for state support of technological changes in the agricultural sector. The effectiveness of fiscal incentives for promoting eco-innovation at the enterprise level, particularly in the context of the role of firms' dynamic capabilities, was analysed by S. Long & Z. Liao (2021). The authors considered how fiscal incentives can influence innovation processes, particularly in the context of the development of environmentally friendly products, as well as the role of managers' competencies in innovation processes. The need for appropriate state policy in support of eco-innovation in business is highlighted.

Thus, the investment attractiveness of the agricultural sector depends on a number of factors, including investment strategies, infrastructure potential, tax incentives, and innovation support. The analysis of recent studies confirms the need for a comprehensive approach to investment management in the agricultural economy, which should include fiscal and financial mechanisms and measures to stimulate innovation. This study aimed to assess

the investment attractiveness of the agricultural sector of Kyiv region and identify the main directions for its improvement under the current economic challenges. To achieve this aim, the following objectives were defined: to analyse the key factors influencing the investment attractiveness of the agricultural sector of Kyiv region; to evaluate the role of tax policy and fiscal instruments in forming the investment climate of the agricultural sector; and to identify promising directions for increasing investment attractiveness, particularly in innovation and infrastructure improvement.

MATERIALS AND METHODS

This study was conducted from January to September 2025. It was aimed at evaluating the investment attractiveness of the agricultural sector of the Kyiv region comprehensively. The empirical material of the study was official statistical data from the State Statistics Service of Ukraine (2024), reports, and analytical materials of Ukraine Invest (n.d.) and the Kyiv School of Economics Agrocenter (2023), which were used to analyse the dynamics of investment flows and development of the agricultural sector. The data covered the period from 2020 to 2023, which enabled tracing changes and key trends in the agricultural sector of Kyiv region, such as the structure of sown areas, the volume of investment, and its distribution by directions. The choice of the period from 2020 to 2023 was caused by the following reasons. Firstly, during this period, it is possible to assess the influence of the economic crisis caused by the COVID-19 pandemic and martial law on the agricultural sector and the process of recovery from their consequences. Secondly, in this period, government support programmes for agricultural producers have been actively implemented in Ukraine, such as tax incentives, subsidies, and credit schemes, and it is important to evaluate their impact on the development of the sector. Thirdly, it includes the most recent year for which statistical data are available, which makes it possible to assess the current state of the agricultural sector and to develop forecasts for its further development.

To solve the objectives set, analytical methods were used. Descriptive statistical analysis was used to systematise and describe the data on the structure of sown areas, the volume of investment and its distribution by directions (modernisation of machinery, infrastructure development, and agrotechnologies). This method allowed forming an idea of the general state of the agricultural sector of Kyiv region and identifying the main trends of its development in the context of investment. For a comprehensive comparison of the investment attractiveness of the Kyiv region with other regions of Ukraine, a comparative analysis was carried out with Odesa, Kharkiv, Dnipropetrovsk, and Lviv regions. The choice of these regions is explained by their role in the agricultural complex of Ukraine, the developed infrastructure, and the high level of investment inflows, which allowed comparing the Kyiv region with the most competitive agrarian regions of the country. The integrated indicator of investment attractiveness was calculated as the arithmetic mean of the estimates of five components: economic stability, infrastructure, institutional support, resource potential, and access to finance. The assessment of each component is carried out on a five-point scale. Where one (1) point indicates a very low level of development, significant problems or a lack of conditions for the effective functioning of the component. Two (2) points indicate a low level of development, problems that require significant improvement to improve the investment climate. Three (3) points indicate a moderate level of development, the component is quite important for investments, but there are some problems or limitations that require solving. Four (4) points indicate a high level of development, the component has a rather high positive effect on investment attractiveness, but there are minor drawbacks or areas for improving the situation. Five (5) points indicate a very high level of development, the optimal state of the component for investments, in the absence of significant problems or constraints that could hinder the attraction of investments.

The research also included a comparative analysis of approaches to state support for agricultural producers in Kyiv, Kharkiv, and Lviv regions in 2022, which allowed distinguishing the differences in financial tools between the Kyiv

region and other regions. The choice of these regions for comparison is explained by their role in the agricultural complex of Ukraine, the existence of different support programmes, and the peculiarities of their investment strategies. Kyiv region is noted for its high investment attractiveness and active financing programmes for the agricultural sector; Kharkiv Region is noted for its developed infrastructure and significant production potential; Lviv Region is noted for its support of organic production, which is a promising direction for sustainable development of the agro-industrial complex. The sample for this part of the comparative analysis is smaller than in the case of investment attractiveness in the regions, since the comparison in this case is carried out according to individual components of support for agricultural producers, and an attempt is made to reveal regional disparities in the system of financial instruments and priorities of development. The comparison could involve a larger number of regions, but within the framework of this study, the sample was limited to three regions, which made it possible to take a closer look at each region.

The efficiency of financial policy was evaluated using correlation analysis, which allowed establishing the relationship between the dynamics of investment in small and medium-sized farms and the provision of tax incentives within the framework of the fourth group of the single tax. The calculation was based on data on investment volumes and production volumes for three years (2020-2022), which made it possible to evaluate the effect of the tax incentive on the development of the agro-industrial complex of Kyiv region. The dynamics of profitability of major types of crop production in Kyiv region for 2020-2022 were also analysed, which made it possible to evaluate the efficiency of resource use and the dynamics of growth in the profitability of the agro-industrial complex. To analyse the impact of tax incentives on the investment activity of small and mediumsized farms, in particular in the Kyiv region, two examples were taken: Agro-Kyiv LLC and the farming enterprise Soniachne. These enterprises were selected because they operate within the framework of the fourth group of the single tax, which made it possible to evaluate the direct impact of tax incentives on the development of the business and modernisation of production.

Cluster analysis was performed to find the differences within the region using the example of the districts of Kyiv region (Bila Tserkva, Boryspil, Brovary, Bucha, Vyshhorod, Obukhiv, Fastiv). Clustering was carried out on the basis of such variables as the level of infrastructure development, the unemployment rate, the share of agricultural land, and natural and climatic conditions. Using the nearest neighbour method allowed distinguishing of the districts by the level of investment attractiveness, to form a visual map of investment activity distribution in the region. To perform a detailed analysis of the investment attractiveness of the agricultural sector of the Kyiv region, a SWOT analysis was applied. This method made it possible to systematise the strengths and weaknesses of the region, to identify opportunities and threats in agricultural production development. The method allowed assessing both internal and external factors which may influence the investment attractiveness and to identify the most promising directions for investment. In addition, recommendations were developed to improve financial policy, particularly with regard to stimulating investment in the development of agrotechnologies, infrastructure, and the deep processing of agricultural products. The statistical processing and analysis of the data were carried out using standard software packages: Excel (Microsoft, United States of America) and SPSS (Statistical Package for the Social Sciences) (International Business Machines Corporation, United States of America).

RESULTS

Current state and dynamics of the investment attractiveness of the agricultural sector of the Kyiv region

The structure of the sown areas of the Kyiv region has a significant diversification by districts. For example, in the Bila Tserkva district, the production of cereals prevails, and in the Obukhiv district, the production of vegetables prevails. The diversification of production by districts allows for a rational use of natural and climatic conditions, and ensures the stability of agricultural production (Table 1).

Table 1. Structure of sown areas in Kyiv region (2023)

Crop type	Areas (thousand ha)	Share of total area (%)
Cereals	450	35
Oilseed crops	350	27
Industrial crops	200	16
Vegetables	150	12
Other crops	100	10
Total	1,250	100

Source: compiled by the authors based on the State Statistics Service of Ukraine (2024)

The structure of sown areas of Kyiv region in 2023 was characterised by a significant diversification towards cereals and oilseed crops, the share of which was 35% and 27%, respectively. This indicates the leading role of these crops in production and the potential of the region to ensure food safety at the regional and national levels. Among the crops, the share of industrial crops was 16%, which is an important indicator of the use of agricultural products for industrial purposes, and vegetables were 12%, which is an indicator of the stability of food production for domestic consumption. The share of other crops was 10%, which indicates a diversified agricultural production of the region. In general, the Kyiv region has a high potential for the development of the agricultural sector due to the fertility of soils and favourable climatic conditions. In the first quarter of 2023, the volume of foreign direct investment in the agricultural sector of Ukraine was USD 1,100 million, of which USD 128 million were investments in fixed capital, and the rest were reinvested profit (Ukraine Invest, n.d.) (Table 2).

Table 2. Volume of foreign investment in the agro-industrial complex of Ukraine (2023)

Indicator	Value
Investment volume (million USD)	1,100
Share of total investment (%)	12
Main sources of investment	EU (European Union), USA, Canada, Qatar

Source: compiled by the authors based on Ukraine Invest (n.d.)

The main investors are the European Union countries, the USA, Canada, and Qatar. The interest of these countries in the agricultural sector of Ukraine can be explained as follows: Ukraine has the largest and most fertile lands in the world and is a key player in the production of agricultural products. EU and USA countries are actively investing in innovative agrotechnologies, sustainable development and environmental protection projects in the framework of promoting "green" programmes. Through trade agreements, in particular, with the EU and Canada, Ukraine receives access to new markets, which increases its investment attractiveness. Besides, foreign investments contribute to the development of infrastructure and the modernisation of agribusinesses, which leads to sustainable economic development. Investments in the agricultural sector of Kyiv region are aimed at modernisation of the fleet of agricultural machinery, infrastructure development, introduction of agrotechnologies, and others, such as expanding storage capacities, improving logistics, developing irrigation and water supply systems, investing in energy efficiency, and sustainable development. All this contributes to improving the efficiency of production and enhancing the competitiveness of the agro-industrial complex of the region (Table 3).

Table 3. Distribution of investments by direction in the agro-industrial complex of Kyiv region

Investment direction	Share (%)
Modernisation of machinery	40
Infrastructure development	30

Table 3, Continued

Investment direction	Share (%)
Introduction of agrotechnologies	20
Other	10

Source: compiled by the authors based on Kyiv School of Economics Agrocenter (2023)

Distribution of investments by direction in the agricultural complex of Kyiv region shows that the main emphasis is on the modernisation of the material and technical base and the improvement of logistics. This contributes to the efficiency of the production process and the reduction of production costs, which, in turn, increases the competitiveness of the agricultural complex of the region. An equally important direction of development is the introduction of agrotechnologies, which makes it possible to optimise the process of cultivation and harvesting of products, reduce the negative impact on the environment and increase the crop yields. According to the rating of investment attractiveness of the agro-industrial complex, Kyiv region is ranked third among Ukrainian regions by the volume of foreign investments, which indicates a rather high level of investment attractiveness of the region (Ukraine Invest, n.d.). The basic components of this high rating include: fertile soils, favourable climate, developed infrastructure and the presence of qualified personnel. All these components create the necessary conditions for the development of the agroindustrial complex and attracting investments in this area (Table 4).

Table 4. Assessment of investment attractiveness of the agricultural sector of the Kyiv region

Factor	Score (1-5)
Economic stability	4
Infrastructure	4
Institutional support	3
Resource potential	5
Access to finance	4
Overall score	4.0

Source: compiled by the authors based on Ukraine Invest (n.d.)

As can be seen from the results of the rating of investment attractiveness of the agro-industrial complex of Kyiv region, it has a high level of regional development. The main components that influenced the high rating are economic stability, the level of development of the infrastructure and the availability of resource potential. The institutional support component was estimated at 3 points, which indicates the need for further improvement of the state policy of development of the agroindustrial complex. The overall rating is 4.0 points, which characterises the investment attractiveness of the agro-industrial complex of Kyiv region as high. The analysis of regional disparities of the agro-industrial complex of Ukraine showed that the Kyiv region has a high investment attractiveness. This allows for the projection of further development of the agro-industrial complex of the region, taking into account international experience and available investment opportunities (Table 5).

Table 5. Comparison of the investment attractiveness of the agricultural sector of the Kyiv region with other regions of Ukraine

Region	Score (1-5)
Kyiv region	4.0
Lviv region	3.5
Kharkiv region	3.8
Odesa region	3.9
Dnipropetrovsk region	3.7

Source: compiled by the authors based on K. Huk & A. Zeynalov (2022)

The comparative analysis of the investment attractiveness of the agro-industrial complex of Kyiv region with other regions of Ukraine showed its high competitiveness. Kyiv region has the highest rating among the considered regions, which confirms the prospects of further attracting investments and developing the agro-industrial complex. As a result of the study of the investment attractiveness of the agricultural complex of Kyiv region, a high resource potential of the region was determined due to the presence of fertile soils, as well as favourable climatic conditions. The structure of the sown areas is characterised by specialisation in the production of cereal, oil and vegetable crops, which contributes to ensuring the stability of agricultural production. The dynamics of investments indicate an increase in foreign investment, including in the modernisation of machinetechnical and agrotechnological means. The comprehensive evaluation of the region testifies to its high level of development, while the institutional provision needs to be improved. The comparison of the region with other regions of Ukraine confirms the competitiveness of the Kyiv region and its role in ensuring the development of the agricultural sphere.

The cluster analysis of Kyiv region's districts based on investment attractiveness identified districts with high and medium levels of appeal for investors. The most attractive for investors are districts with a high level of development of the infrastructure, qualified personnel and favourable natural and climatic conditions, in particular: Bila Tserkva, Obukhiv, Fastiv and Brovary districts. Medium attractive for investors are districts with an average level of infrastructure development and higher unemployment, such as Boryspil, Bucha and Vyshhorod districts. To increase the investment attractiveness of the specified districts, it is necessary to attract additional investments for the development of the infrastructure and creation of new workplaces (Table 6).

Table 6. Clustering of districts of Kyiv region by the level of investment attractiveness

District	Investment attractiveness level
Bila Tserkva	High
Obukhiv	High
Fastiv	High
Brovary	High
Boryspil	Medium
Bucha	Medium
Vyshhorod	Medium

Source: compiled by the authors based on the State Statistics Service of Ukraine (2024)

The financial analysis, risk assessment and investment attractiveness of the agricultural sphere of Kyiv region indicate a high potential for attracting investments. The high level of profitability of production, moderate risk level and differentiated investment attractiveness of the districts create favourable conditions for the development of the agrarian sphere. However, for the full realisation of the available potential, it is necessary to pay special attention to the reduction of risks and support for the development of low attractive districts.

The impact of financial policy on the investment climate: Analysis of the effectiveness of instruments

The tax incentives of agricultural enterprises (AEs), in particular, small and medium farms that operate within the framework of the fourth group of the single tax, have been one of the main instruments of stimulating investment activity in the agrarian sphere of Kyiv region. According to the statistics, in 2022, the fourth group of the single tax system united more than 40% of the region's agricultural enterprises, which reduced their tax burden and directed the saved funds for investments in the modernisation of production facilities (State Statistics Service of Ukraine, 2024).

For example, among small enterprises such as Agro-Kyiv LLC and the farming enterprise Soniachne, both operating under the fourth group of the single tax system, production volumes increased by 12-15% due to the reduced tax rate. Due to this, the enterprises directed investments in modern agrotechnologies and

modernisation of equipment. The analysis of these enterprises shows that the application of the tax instrument contributed not only to growth in production efficiency but also to operational efficiency. In particular, investments were directed to the introduction of new technologies for improvement of product quality, reduction of costs and growth of production volumes, which proves the positive effect of tax instruments (State Statistics Service of Ukraine, 2024). Also, these farms showed growth of investments in the construction of storage facilities, purchase of equipment and expansion of production capacities (Table 7).

Table 7. Dynamics of investment in small and medium-sized farms in Kyiv region under the fourth group of the single tax system (2020-2022)

Indicator	2020	2021	2022
Investment volume (million UAH)	215	240	270
Production increase (%)	10	12	15
Share of investment in machinery modernisation (%)	45	48	50

Note: the data in the table relate to all small and medium-sized farms in the Kyiv region operating under the fourth group of the single tax system

Source: compiled by the authors based on the State Statistics Service of Ukraine (2024; 2025)

The system of subsidies and credit support also had a positive influence on the development of the region's agricultural sector, especially among small and medium-sized farms. Thus, in 2022, the general volume of subsidies received by the region's enterprises totalled UAH 1.2 billion, which is 7% more than in the previous year. This allowed for a significant reduction of production costs and an increase of funding for modernisation of equipment and for the purchase of seeds and fertilisers (State Statistics Service of Ukraine, 2024). The analysis of the financial indicators of the agricultural sector of Kyiv region for the period 2020 to 2022 shows positive development dynamics. The profitability of the major agricultural crops (grains and oilseeds) has positive dynamics for the analysed period. The profitability of cereal production increased from 18% in 2020 to 22% in 2022, which points to efficient use of resources and growth of the sector's profitability. Oilseed crops (especially sunflower) retained the level of profitability at 20% to 25% for the same period, which once again proves their investment attractiveness. The profitability of vegetable crops (tomatoes, potatoes) was 15% to 20% in 2020 to 2022, which indicates stable demand and prospects for further investment in this direction (Table 8).

Table 8. Dynamics of profitability of production of main crops in Kyiv region (2020-2022)

Crop type	2020	2021	2022
Cereals	18%	20%	22%
Oilseeds (sunflower)	20%	22%	25%
Vegetables	15%	18%	20%

Source: compiled by the authors based on the State Statistics Service of Ukraine (2024; 2025)

From 2020 to 2022, there was an increase in investment volumes in the agro-industrial complex of the region, which is a consequence of the high investment attractiveness of this economic activity. The estimated rate of return on investment projects in the agro-industrial complex of Kyiv region is 12% to 15% per annum (State Statistics Service of Ukraine, 2024). This makes this type of economic activity attractive to investors, in particular, in connection with the stable demand for agricultural products, state support for the industry and the modernisation of agricultural production.

The study of the availability of credit resources revealed a number of difficulties, in particular, the level of interest rates and the need for collateral. Thus, in 2022, the average interest rate on a loan for a farmer in the Kyiv region was 16.5%, which significantly limits access to credit resources, especially for small farms. Due to the

programme of the Ministry of Agrarian Policy and Food of Ukraine (2024), it was possible to reduce the interest rate to 9%, but only 35% of farmers took advantage of this opportunity due to the imperfection of creditworthiness criteria. An important tool for supporting farmers is subsidies, in particular for the purchase of agricultural machinery, which has become one of the effective levers to reduce the financial burden on enterprises. The data on the dynamics of subsidies received by enterprises of Kyiv region in 2020 to 2022 indicate an increase in the volume of subsidies, in particular, for machinery, which has a positive impact on the modernisation of production capacities (State Statistics Service of Ukraine, 2024; 2025). As can be seen from Table 9, the volume of subsidies for agricultural machinery in 2022 accounted for 40% of the total amount of subsidies.

Table 9. Dynamics of subsidies received by enterprises of Kyiv region (2020-2022)

Indicator	2020	2021	2022
Subsidies volume (UAH)	980 million	1.1 billion	1.2 billion
Year-on-year increase (%)	6	12	7
Share of subsidies for purchase of machinery (%)	30	35	40

Source: compiled by the authors based on the State Statistics Service of Ukraine (2024; 2025)

When comparing the regional support of farmers in the Kyiv region with other regions of Ukraine, some differences in the provision of financial support are noted. Thus, in Kharkiv region, the main support for farmers is the subsidies for technical modernisation, and in Lviv region, the main support is the development of infrastructure and organic farming. At the same time, Kyiv region actively supports farmers by providing tax incentives and credit programmes, which in turn increase the level of investment and contribute to the development of regional agribusiness. In general, the programmes of support in the Kyiv region are mostly carried out at the level of production subsidies, in particular, partial compensation for the purchase of machinery and technical innovations. In the Lviv region, in particular, organic farming is actively supported through grants, due to which farmers switch to more environmentally friendly technologies for growing products. In Kharkiv region, large agribusinesses are supported, in particular, through accessible credit programmes, which increase the efficiency and competitiveness of production (Table 10).

Table 10. Comparison of regional approaches to supporting farmers (2022)

Region	Kyiv region	Kharkiv region	Lviv region
Funding for machinery (million UAH)	520	500	550
Credit programmes (interest rate)	9%	11%	8%
Support for organic farming (%)	5%	2%	10%

Source: compiled by the authors based on the Ministry of Agrarian Policy and Food of Ukraine (2024)

The influence of financial policy on the investment climate in the agrarian sector of Kyiv region is quite significant, in particular, due to tax incentives and the system of subsidies and credit support. A rather high level of subsidies and tax support contributes to an increase in investment activity, although the imperfection of credit support is a rather significant constraint. In comparison with other regions of Ukraine, the Kyiv region has competitive advantages, in particular, due to tax incentives and instruments of financial support, but it is necessary to improve access to credit and the development of organic farming.

Methods for assessing the investment attractiveness of the agrarian sector in the Kyiv region

To carry out a more detailed and reasoned assessment of the investment attractiveness of the agrarian sector in Kyiv region, it is advisable to use a whole range of analytical tools, which take into account all aspects of regional development, economic security and investment potential as

a whole. In particular, one of these tools can be a SWOT analysis, which enables the evaluation of the strengths and weaknesses of the region, and also identifies the opportunities and threats that face the agrarian sector. Conducting a SWOT analysis of the agrarian sector of Kyiv region enables the determination of the main factors that have an impact on the investment attractiveness of the region. The strengths of the Kyiv region are fertile soils and favourable climate conditions, which are the basis for the stable production of agricultural products. The developed infrastructure of the region, in particular, the transport network, decreases the costs of distribution, which increases the competitiveness of the agrarian sector. Tax breaks and subsidies for agricultural enterprises are also strengths that contribute to attracting investments (Kyiv School of Economics Agrocenter, 2023).

However, Kyiv region also faces certain weaknesses. The first and the most significant weakness is the dependence of the sector on weather conditions (drought, flood) that influence the amount of the collected harvest and the financial situation of agricultural producers. High-interest rates on the loan, despite the existing programmes of financing, are also a weakness of the sector, as the small farms cannot afford to get a loan for further development. The opportunities for the agrarian sector of Kyiv region include the production of organic products and the deep processing of agricultural products. First, there is a tendency for growing consumption of organic products in the European Union, which makes this direction of activity rather promising. Second, deep processing of agricultural products increases the value-added and decreases the dependence on the export of raw materials (State Statistics Service of Ukraine, 2024).

However, there are also threats that affect the region's investment appeal. First, the regulatory risk (changes in the tax policy, legislation) influences the investors' activity, as it increases the uncertainty and influences the financial calculations. Second, market risks (fluctuations in the prices for agricultural commodities, changes in demand) influence the income of farmers. One more method for analysing the investment attractiveness is multifactor risk analysis, which enables the systematic analysis of the influence of different factors on the stability and profitability of the agrarian sector. In the Kyiv region, one of the most significant threats to the agrarian sector is weather conditions that can cause 10% to 20% loss in harvest. Moreover, the severe weather events, such as droughts and floods, significantly influence the production capacity. Another significant impact is from the regulatory risks that are associated with the instability of tax policy changes, making it difficult to predict the income and expenses of agricultural enterprises. Market risks that involve fluctuations in prices of the main crops are also capable of leading to unpredictable financial results (Ukraine Invest, n.d.).

An evaluation of these risks allows for the prediction of possible financial losses and taking the relevant measures to reduce them in a timely manner. For example, to reduce the threats associated with weather risks, it is necessary to introduce new agrotechnologies that provide an optimal consumption of water and minimise the dependency on weather conditions. Regulatory risks can be decreased by stabilising the tax policy and the predictability of legislative changes. The market risks can be reduced by developing new sales markets and diversifying production. The application of the above-mentioned assessment methods enables more accurate identification of the investment potential of the agrarian sector of Kyiv region and forms the basis for the elaboration of measures to decrease risks and maximise the potential for the development of the agrarian sector of the region.

Promising investment directions and financial policy improvement recommendations

In 2023, the agrarian sector of Kyiv region retains positive growth dynamics, which testifies to its investment attractiveness (State Statistics Service of Ukraine, 2024). The spheres for targeted investments that are essential for ensuring sustainable development of the region involve deep processing of agricultural products, organic production, agrotechnical innovations, and the development of infrastructure for the storage and transportation of products. The deep processing of agricultural products is one of the most promising investment directions. This includes the production of bioethanol,

organic semi-finished products, and other types of products with high added value. Due to the high demand for bioenergy and other processed products, the agrarian sector of the region can not only add value but also decrease the export of raw agricultural products. The growth of organic farming, first of all, in the sphere of berry and fruit farming, is a highly promising direction for entering the international market. The high demand for organic products in the EU countries makes this direction very attractive for investments (Ukraine Invest, n.d.).

Another promising direction is innovative agrotechnologies and precision farming. Their use can significantly increase the efficiency of production, reduce resource intensity and costs, and increase crop yields. In the Kyiv region, due to the favourable natural and climatic conditions, the use of innovative agrotechnologies can become a driver for the competitiveness of the agrarian sector. No less important is the development of logistics and storage infrastructure, which will ensure the efficient transportation and storage of products. Taking into account that the Kyiv region is a significant agricultural region of Ukraine, the creation of modern logistics infrastructure will reduce the costs of transportation and storage of products, which will positively affect the competitiveness of products in both the domestic and foreign markets (Bilochenko *et al.*, 2021).

Given the above-mentioned promising directions, it is necessary to adjust the financial policy of the region. In order to attract investments in the above-mentioned priority areas, it is advisable to introduce targeted grants or tax benefits for enterprises that implement deep processing of agricultural products and innovative agrotechnologies. Such diversification of state support will give an impetus for investments in these priority areas. The expansion of lending programmes is also a necessary measure to stimulate the development of the agrarian sector. The mechanism of credit guarantee significantly reduces the level of collateral and interest rates, which makes the loan more accessible for small and medium-sized agricultural enterprises (Ministry of Agrarian Policy and Food of Ukraine, 2024). This will provide additional financial resources for the introduction of innovations, renewal of the material and technical base, and development of the necessary infrastructure.

Meanwhile, it is also necessary to create specific programmes to support agrarian districts, which are less developed, for example, Tarashcha and Makariv. The provision of subsidies for the development of infrastructure, grants for the creation of new jobs and the retraining of local staff will increase the investment attractiveness of the mentioned districts. The involvement of external investors is the next direction for the development of the agrarian complex of Kyiv region. One approach could be the creation of a specific investment profile for the agrarian sector, within the framework of which the most promising projects and investment opportunities will be presented to international investors (State Statistics Service of Ukraine, 2024; Ukraine Invest, n.d.). Foreign investments are an important component in the modernisation of the agrarian sector and the introduction of new technologies (Table 11).

Table 11. Ranking of promising investment directions in the agrarian sector of Kyiv region

Investment direction	Prospect level	Key development factors
Deep processing	High	High added value, demand for bioenergy
Organic and niche farming	Medium	Growing demand for organic products
Agrotechnology and precision farming	High	Increased efficiency, environmental sustainability
Logistics and storage facilities	High	Infrastructure development, reduced transport costs

Source: compiled by the authors based on an analysis of current trends in the agrarian sector, State Statistics Service of Ukraine (2024), Ukraine Invest (n.d.)

As a result, in order to ensure sustainable development of the agrarian complex of Kyiv region, investments should be directed to priority areas, such as deep processing, organic production and agrotechnical innovations. The attraction of investments can also be stimulated

through special support programmes, the development of infrastructure and the creation of favourable conditions for foreign investors.

DISCUSSION

The results of this study on the investment attractiveness of the agrarian complex of Kyiv region can be compared with the results of other studies in this area. Firstly, this is the financial stability of agrarian enterprises, the study of which was carried out by M. Hernandez-Romero & G. Coenders (2025), who analysed the impact of the Russian-Ukrainian war on the financial stability of agricultural enterprises in Spain. Similarly, with the presented study, the results show that external economic factors, in particular the COVID-19 pandemic and martial law, affect the investment climate in the agrarian complex. However, unlike in Spain, investments in the agrarian complex of Kyiv region are actively supported by the state through tax incentives and subsidies, which reduce the negative consequences of external crises. A. Kurdyś-Kujawska *et al.* (2025) also studied the role of financial innovations in increasing the resistance of the agrarian sector, in particular, the use of blended finance in Poland. In this context, the present study emphasises the need to implement innovations to attract investments in the agrarian sector. The same upward trend in investments in modernisation of equipment and agrotechnologies can be traced in the case of Kyiv region, as it is represented by the structure of allocated investments, as shown in the given article. However, it is necessary to further improve the financial instruments for financing small and medium-sized agrarian enterprises in the region.

The efficiency of financial management and international support of the agrarian sector, which allows making a comparison of Ukraine's investment policy with the world experience, was studied by H. Mazur *et al.* (2025). The results of the study indicate the positive effect of international cooperation on the stimulation of investments in the agrarian sector. The same situation can be observed in Ukraine, where the major share of investments is provided by the EU, the USA, Canada, and Qatar. The need to expand public investments in research and development for preservation of the rate of agricultural production in the USA was investigated by A. Ortiz-Bobea *et al.* (2024). The same tendency can be traced in Ukraine, where the growth of public investments in the agrarian sector is seen in the policy of support for agrarian enterprises and agronomic innovations. E. Gyamfi *et al.* (2024) paid attention to technological solutions in the field of "smart" agriculture, which is an important component in the development of Ukraine's agrarian sector. Modern agrotechnologies are being actively introduced to increase productivity and reduce the negative environmental effects. This factor has a strong influence on the further development of the agrarian sector of Kyiv region, for which innovations are the main component of investment attractiveness.

The interdependence of credit, land prices, and low-interest-rate policies was considered by T. Hirano & J. Stiglitz (2025). A similar situation can be seen in Ukraine, where high interest rates on credit for agrarian enterprises make it difficult to obtain credit resources. This is confirmed by the results of statistical analysis of the agrarian sector of Kyiv region, comparative regional analysis, and analysis of the influence of tax incentives, subsidies, and credit on investment activity. The results of the analysis showed that support through tax incentives and subsidies contributes to the growth of investments, while differentiation of regions in terms of credit conditions affects the development of the agrarian sector. The authors T. Kreitman & N. Kauffman (2025) studied the conditions for investing in the production and distribution of food products in the USA, based on the results of an economic forum. As in the case of the Kyiv region, this research noted that changes in the economic situation and state policy are important for investing in the agrarian sector, but these researchers paid more attention to the influence of economic risks on investment processes. In the Kyiv region, the economic situation is also important as a factor of investment attractiveness of the agrarian sector. The authors studied the financial stability of the agrarian sector in Ethiopia through the provision of financial assistance from international organisations, such as UNDP (2025). In the Kyiv region, state and international financial assistance, including subsidies, are used as instruments to increase the

investment attractiveness of the agrarian sector. But in Ukraine, more attention is paid to domestic financial instruments, for example, tax instruments, subsidies and financial support for agricultural enterprises.

J. Bai *et al.* (2022) investigated the influence of agrarian subsidies on the sustainable development of agriculture in China in the conditions of big agricultural data. The influence of such subsidies on the development of the agrarian sector is also an important issue in the Kyiv region, but mainly in the context of stimulating innovative activity and the development of ecologically clean production. But in the region, there is also a need to increase the efficiency of the use of subsidies for the sustainable development of the agrarian infrastructure. The researchers Z. Zhang *et al.* (2023) investigated whether the provision of subsidies for agricultural credit could influence carbon emissions at the county level in China. The same interest for the agrarian sector of Kyiv region is the analysis of the availability of credit and the participation in state support programmes as an important factor for investment attractiveness and fostering the adoption of advanced technologies. These researchers found that the mechanism of credit subsidies has a dual nature, contributing to both economic growth and environmental protection. The impact of fiscal support to the agrarian sector and its role in the integration of the three main industries in rural China was studied by J. Li *et al.* (2024). In the Kyiv region, such measures are also implemented to develop integrated agrarian value chains, through the state support of innovations in the agricultural sphere, in particular, in the form of investments of the state in the development of technologies and infrastructure. The effect of farmer subsidy on the global agricultural productivity was investigated by A. Mamun (2024). In the Kyiv region, a direct relationship is also registered between the subsidy and productivity growth of the agrarian sector, since state support acts as the main stimulus for modernisation and introduction of new agrotechnologies.

The influence of subsidies on financial risks and resilience of farms in Hungary was analysed by P. Szálteleki *et al.* (2024). A similar effect of subsidies on the financial stability of agrarian enterprises in the Kyiv region was registered in the results of this research. However, in the region under investigation, it is necessary to take into account the specifics of the market and a higher dependence of agrarian enterprises on state subsidies due to limited access to financial resources and high interest rates of lending. The impact of fiscal expenditures on agriculture and their mechanism of promoting the sustainable economic development of the agrarian sector was analysed by S. Zhang & X. Zhang (2024). Their research notes the role of fiscal expenditures in ensuring sustainable development, which is consistent with the results in the Kyiv region, where state financial instruments (subsidies and tax incentives) increase the investment attractiveness. However, unlike the situation in China, the Ukrainian agrarian sector needs more profound financial instruments to overcome the domestic economic problems, such as high interest rates and limited access to credit. The effect of subsidy reform on income and technical efficiency of smallholder farmers was studied by A. Alawode (2025). This research highlights how the reform of the subsidy policy can contribute to increasing the efficiency of small agrarian enterprises and influence their income. It corresponds to the conditions of the Kyiv region, where subsidies are an effective mechanism of state support for small and medium-sized agrarian enterprises. However, in the region under research, it is necessary to pay attention to the improvement of mechanisms of subsidy support in order to expand access to financial resources for small farms.

The impact of fiscal and tax policies on the development of agribusiness in China was investigated by L. Zhang *et al.* (2025). This research is aimed at revealing the influence of tax incentives and fiscal policy instruments on the development of agribusiness. The results of the research can be compared with the Ukrainian realities, as in the Kyiv region, there is also an active use of tax incentives and other financial mechanisms to attract investments into the agrarian sector. However, in contrast to Chinese regions, in the Kyiv region, it is necessary to improve fiscal policy mechanisms in order to expand access to financial resources and introduce innovations in the agrarian sector. Summarising

the results of the research, it should be pointed out that they testify to the great importance of state support, in particular, by means of fiscal expenditures and tax incentives for ensuring sustainable development of the agrarian sector. These mechanisms promote the increase of investment attractiveness and stabilisation of agricultural production in the Kyiv region, but to achieve greater efficiency, it is necessary to improve the mechanisms of state support for small and medium-sized agrarian enterprises and reduce barriers in accessing financial resources.

CONCLUSIONS

The article analyses the investment attractiveness of the agrarian sector of Kyiv region and reveals the impact of the main factors (natural and climatic conditions, infrastructure, and availability of qualified workforce) on the development of this sector. The structure of sown areas of the region testifies to the high specialisation in the cultivation of cereal and oilseed crops, which provides the stability of agricultural production. In particular, the high level of investment attractiveness of the region is proved by the dynamics of foreign investments, which are directed to the modernisation of the material and technical base, development of infrastructure and introduction of progressive agricultural technologies. The analysis of financial efficiency has shown positive dynamics of profitability of the main cultivated crops, in particular, cereals and oilseeds, which testifies to the effective use of resources and growth of profitability of the agrarian sector. Profitability of growing cereals increased from 18% in 2020 to 22% in 2022, which proves the efficiency of land and labour use in the industry. The profitability of growing oilseeds (sunflowers) is 20-25%, which proves the demand for this type of crop and the attractiveness for investments. The profitability of growing vegetables (tomatoes, potatoes) varied from 15-18% in the period 2020-2022, which proves the demand for these types of products and opportunities for investment development of the segment.

The potential return on investment projects in the agro-industrial complex of Kyiv region were found 12-15% per annum, which increases the interest of investors in the region, first of all, due to the demand for agricultural products and the state support policy. It is an important factor in the development of the agrarian sector of the region, which has great investment potential. Compared to other regions of Ukraine, the Kyiv region has competitive advantages, but to preserve this competitive level, it is necessary to strengthen institutional support, in particular, through tax incentives and subsidies to small and medium farms, as well as the expansion of access to finance, which will allow for increased investment inflows. The results of the cluster analysis of the districts of the region by investment attractiveness show that the most investment attractive districts are Bila Tserkva, Obukhiv, Fastiv, with a high level of infrastructure development, availability of qualified personnel and favourable natural and climatic conditions. The districts with the lower investment attractiveness are Boryspil, Bucha, Vyshhorod, and Brovary, which need additional investments into the development of infrastructure and creation of new jobs to improve the investment attractiveness. For further development of the agrarian sector of Kyiv region, it is necessary to introduce advanced technologies in agricultural production and improve regulatory policy to ensure investors' stability. It is also necessary to develop international investment cooperation and create an investment passport for the agrarian sector, which will contribute to attracting foreign investors and modernising production.

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Оцінка інвестиційної привабливості аграрного сектору Київської області в контексті сучасної фінансової політики

Анотація. Метою роботи було оцінити інвестиційну привабливість аграрного сектору Київської області та проаналізувати фінансову політику, що сприяла його розвитку. Для досягнення поставленої мети були використані такі методи: дескриптивний статистичний аналіз, порівняльний аналіз, метод кластеризації, SWOT-аналіз, кореляційний аналіз та інтегральна оцінка інвестиційної привабливості. Було проведено аналіз структури посівних площ, що показав спеціалізацію області на вирощуванні зернових, олійних та овочевих культур, що забезпечує продовольчі потреби та сприяє залученню інвестицій у модернізацію виробництва. Найбільші інвестиції спрямовувалися на модернізацію техніки (40 %), розвиток інфраструктури (30 %) та впровадження агротехнологій (20 %). Рентабельність виробництва в зернових та олійних культурах зросла з 18 % у 2020 році до 22 % у 2022 році, що підвищило привабливість сектору для інвесторів. Результати міжрегіонального аналізу показали, що,

хоча за обсягом іноземних інвестицій в аграрний сектор Київська область поступалася лише двом областям, за інтегральною оцінкою інвестиційної привабливості вона посіла перше місце завдяки розвиненій інфраструктурі, економічній стабільності та кваліфікованій робочій силі. Кластеризація показала, що найбільш інвестиційно привабливими районами Київщини були Білоцерківський, Обухівський та Фастівський. Території Бучанського та Вишгородського районів мали меншу привабливість, потребуючи інвестицій у розвиток інфраструктури та створення робочих місць. SWOT-аналіз показав сильні сторони, такі як родючі ґрунти та розвинена інфраструктура, а також слабкі сторони, зокрема залежність від погодних умов та високі відсоткові ставки за кредитами, що вимагають вдосконалення фінансової політики. Прогнозується подальший розвиток аграрного сектору області за умови підтримки держави, залучення інвестицій у новітні агротехнології та розширення інфраструктури, що сприятиме економічному зростанню Київщини. Практична значимість результатів полягає в тому, що вони можуть бути використані для розробки політик, спрямованих на стимулювання інвестицій в аграрний сектор, зокрема через податкові пільги, субсидії та програми кредитування

Ключові слова: податкові пільги; субсидії; кредити; посівні площі; рентабельність; розвиток

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Impact of human capital on the efficiency of resource management and production processes in agricultural enterprises

Abstract. The study aimed to determine the effect of human potential on management decisions and production. The methodological foundation of the study was an empirical approach, incorporating descriptive, dynamic, structural and comparative analysis of official statistics, analysis of relative labour market indicators, case studies and analysis of human capital management practices of leading agricultural enterprises. Based on the results of 2020 and mid-2025, the number of employees in the agriculture sector increased by 3.5%, while average monthly nominal wage increased from UAH 9,737 in 2020 to over UAH 21,413 in the first quarter of 2025, exceeding UAH 25,000 for certain roles. Given the labour shortage, the increase in labour costs has strengthened the role of staff quality in resource management. The study established that staff qualifications, investment, and motivation improved labour productivity by 5-15% and enterprise profitability by 10-20%, while results-oriented remuneration systems increased the performed volume of work by 20-25%. The share of agriculture in Ukrainian GDP reached approximately 17% in 2024, reflecting structural transformations in the labour force. Human capital management practices analysed using the examples of Myronivsky Hliboproduct, Kernel and Astarta-Kyiv showed a 15-20% reduction in staff turnover, a 10-30% increase in labour productivity, and an 85-95% increase in the efficiency of material and technical resources, which reduced operating losses by 15-25%. The practical significance of the study is determined by the possibility of using the results obtained by agricultural enterprises to improve the efficiency of personnel and resource management

Keywords: unemployment; productivity; competencies; qualifications; wages; motivation

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INTRODUCTION

The development of the agricultural sector is progressing amid increased market volatility, rising production costs, more complex technological operations, and limited resources. In such circumstances, the performance of agricultural enterprises is increasingly determined not only by the volume of material and financial resources involved, but also by the ability of personnel to ensure their rational combination, the coordination of production operations and the adaptation of technological solutions to specific economic conditions (Bilichenko, 2015). In the functioning of agricultural production, there is a mismatch between the qualitative characteristics of labour resources and the growing complexity of managing resource flows and production operations, which limits the ability of enterprises to adapt to structural changes and recovery processes. These issues were addressed by A.O. Kalynovskyi *et al.* (2024) in an analysis of models of human capital development through educational, socio-institutional and economic mechanisms. The results showed that the level of education, professional training, and the ability of personnel to acquire new competencies form the prerequisites for increasing productivity, technological renewal and the sustainability of economic systems during periods of transformation. O.V. Ptashchenko & O.M. Shersheniuk (2024) emphasised the development of human capital in the context of digital transformations, revealing the role of continuous learning, digital literacy, management innovations and motivational mechanisms in improving the performance of enterprises. The conclusions demonstrated that the adaptation of personnel to the digital economy creates the conditions for growth in productivity, sustainability, and competitiveness of agricultural enterprises.

The development of the agricultural economy insufficiently analysed innovative production modernisation and existing approaches to the formation and use of human resources, which limit productivity growth. O. Radchenko (2025) addressed the strategic principles of human capital development, highlighting the factors of its formation and substantiating the role of qualitative characteristics of personnel in the implementation of innovations. The results of the study substantiate that the level of education, professional training, motivation and institutional support determines the ability of agricultural production to implement technological innovations, reduce dependence on extensive factors and ensure long-term competitiveness. Y. Yuhnovska *et al.* (2024) highlighted the essence of human capital, its structure, types and role in the enterprise management system. The study proved that the development of staff competencies, knowledge and skills creates the preconditions for increasing productivity, competitiveness and consistency of management processes.

Human Resource Management (HRM) is considerably more complex than the management of other resources. Firstly, people are intellectually capable, and their response to management is emotional, thoughtful, and not mechanical, which implies a two-way process. Therefore, HRM requires specific approaches and methods. While the management of material, immaterial, and financial resources does not lead to a conscious response from the managed system to the manager, when influencing human resources, the manager may receive an inadequate and unexpected response. Secondly, due to human consciousness, the possibility of self-development and self-organisation, the expected results and consequences of management may be inadequate, ranging from dynamic growth to complete destruction of the enterprise. Thirdly, it is necessary to address those human resources are used to manage other resources, i.e., there is a synergistic effect that can significantly increase or decrease the effectiveness of managing other resources. Fourthly, human resources can participate in the enterprise on a long-term basis, since a person's professional life can span several decades. Fifthly, employees join the organisation consciously, with certain goals and motives, sometimes contrary to the goals of the enterprise's development, and their goals and motives inevitably change over time (Bolshaia & Bilyk, 2022).

In business management practice, there is still insufficient coordination between the use of digital tools and the systematic development of human capital, which limits the potential for improving the effectiveness of management

decisions. O. Grishnova (2025) developed a comprehensive model of human capital management based on digital technologies, covering strategic, structural, technological, optimisation and evaluation-performance blocks. The study also developed a system of quantitative indicators for assessing the effectiveness of personnel utilisation and the level of automation of HRM processes, which can be used to compare the state of human capital over time and between companies. M. Kozik (2025) substantiated human resource potential as a multi-component system covering quantitative, qualitative, organisational, socio-psychological and innovative characteristics of personnel, and proposed a model of the relationship between "strategy – tools – indicators – results". The results showed that systematic personnel development contributes to increased labour productivity, reduced staff turnover, the formation of a personnel reserve and increased adaptability of enterprises to technological changes.

With the spread of digital solutions and changes in social and labour relations, there is a growing complexity in the requirements for the quality of human capital and the mechanisms for its involvement in economic activity, which directly affects the organisation of production and the use of resources. I. Krysovatyy (2025) combined digitalisation and an inclusive approach to human capital development, justifying changes in the content of employment, the transformation of competency requirements, and the expansion of the participation of various social groups in production processes. The results of the study showed that digital tools increase the flexibility of management decisions, while inclusive mechanisms contribute to the expansion of human resources and the sustainability of economic systems. In the activities of agricultural enterprises, the role of intangible factors, in particular knowledge, staff competencies and organisational practices, which determine the effectiveness of production and management decisions, is growing. Ye. Pyrohov *et al.* (2025) considered intellectual capital as an integrated system of human, structural and relational components, and approaches to assessing its contribution to the economic performance of enterprises are proposed. The results obtained showed that the development of human capital and related organisational elements contributes to increased labour productivity, innovative activity and adaptability of enterprises.

At the same time, existing studies predominantly focus on strategic and conceptual approaches, while the impact of human capital on resource management efficiency and the organisation of production processes at the level of agricultural enterprises remains insufficiently formalised and empirically substantiated. This study aimed to analyse the impact of human capital on the effectiveness of resource management and the organisation of production processes in agricultural enterprises. To achieve this goal, the following tasks were set: to identify the key components of human capital that influence the effectiveness of resource management and production processes in agricultural enterprises; to analyse the relationship between human capital development and the performance indicators of agricultural enterprises based on statistical and analytical data; to summarise human capital management practices in the activities of leading agricultural enterprises in Ukraine.

MATERIALS AND METHODS

The study was empirical in nature and covered the period from 2020 to mid-2025, which was due to the need to analyse the transformations of Ukraine's agricultural sector in the context of the pandemic crisis, military shocks and subsequent adaptation processes. The theoretical basis of the study was the human capital theory developed by Gary Becker and Theodore Schultz, which was used as a conceptual framework for analysing management processes in agrarian business based on scientific sources by T.W. Schultz (1960) and G.S. Becker (1962). To clarify the analytical boundaries of the study, a comparative characterisation of approaches to human capital theory was performed using comparative analysis and generalisation of theoretical provisions based on following criteria: interpretation of investments in human capital, the level and economic content of their profitability, the scope of application of the theory, and the key differences between micro- and macroeconomic interpretations, which ensured the formation

of a comprehensive conceptual framework for the study. To identify the factors that influence the effectiveness of personnel, the study analysed and summarised the results of scientific publications and industry analytical materials by I. Dvornyk (2021), Ye. Lanchenko (2023) and O. Khadzhinova & A. Hryshyn (2025), which systematised the impact of remuneration systems, motivational mechanisms and digital competencies on productivity and resource efficiency.

The study analysed the impact of human capital on the efficiency of resource and production process management, in particular by examining the dynamics of average annual nominal wages in Ukrainian agriculture for 2020-2025. A dynamic analysis of changes in the cost of labour resources and their impact on management decisions in agricultural enterprises was conducted based on official statistical data from Minfin (n.d.a), which tracked changes in wage indicators over time in 2020-2025. A comparison of annual wage indicators revealed trends in nominal wage growth and assessed the increasing role of qualitative characteristics of personnel in the context of a reduction in the number of employees, based on the official Minfin source. To assess the macroeconomic context of human capital utilisation, the dynamics of gross added value in Ukrainian agriculture were examined based on statistical data from various sources, using structural analysis to determine the role of the agricultural sector in gross domestic product formation and the relationship between production efficiency and labour resource quality. At the same time, the age structure of those employed in agriculture was analysed using descriptive statistical analysis to assess the demographic constraints on human capital development and their impact on the implementation of managerial and digital innovations based on a source from the Razumkov Centre (2024). The analysis of unemployment dynamics in Ukraine in 2020-2024, based on statistical data from O. Bilous (2025) and Minfin (n.d.b), using dynamic analysis and analysis of relative indicators by comparing the number of unemployed to the total population to characterise changes in the overall labour potential and conditions for the formation of human capital for the agricultural sector.

Case study methodology was used to analyse practices and directions for improving the efficiency of agricultural enterprise management based on human capital development, using MHP (n.d.a), Kernel (n.d.) and Astarta-Kyiv (2025a; 2025b), which were selected due to their system-forming role in the agricultural sector, the scale of their activities and the existence of formalised approaches to personnel management. For MHP (n.d.b), an analysis of internal educational and motivational personnel management practices was conducted using the method of structural analysis of corporate materials, which was used to assess the integration of professional training, digital competencies and incentive systems with production process management (Major agricultural producer..., 2021). The analysis covered the use of digital management tools, in particular Systems, Applications and Products in Data Processing (SAP) and Power Platform, as components of the development of personnel management competencies. For Kernel, within the framework of descriptive analysis of corporate materials, a systematic approach to human capital management was considered, including the use of internal digital training and communication tools, in particular LMS Collaborator (n.d.) and Kernel HUB (n.d.). The use of Microsoft Navision (Dynamics NAV), Office 365, and Power BI corporate digital solutions to support management and analytical processes was also considered. Educational project "Re: Knowledge Industry" was emphasised as an element of the system for developing and transferring professional competencies of personnel (Kernel agroholding uses..., 2023). In addition, the remuneration system at Kernel was considered as a component of stimulating staff performance to determine its role in increasing productivity and consistency of management decisions (Kernel HR strategy, 2025). A descriptive analysis of corporate and institutional materials addressed the cooperation between Astarta-Kyiv (2025a) and the European Bank for Reconstruction and Development (EBRD) based on the AgriAcademy platform as an institutional mechanism for human capital development. Astarta's motivational model and management innovations were also analysed based on materials presented by Astarta in the report for 2024 (Astarta-Kyiv, 2025b),

which characterised approaches to improving management efficiency in agribusiness. Based on a summary of materials on the activities of these companies, recommendations were formulated for optimising management processes through human capital development, aimed at their practical implementation in small and medium-sized agricultural enterprises.

RESULTS

Human capital as a factor in the effectiveness of management processes in agribusiness

Human capital in economic science is interpreted as the accumulated stock of knowledge, professional skills, abilities, health status and motivational characteristics of employees, which is formed as a result of investments in education, training and professional development and determines the level of labour productivity and the effectiveness of economic activity. Unlike the traditional approach, in which labour was viewed primarily as a quantitative factor of production, the concept of human capital focuses on its qualitative dimension, which explains differences in the efficiency of resource use under the same technological and natural conditions. For agribusiness, this approach is fundamental, as productivity growth depends less on the expansion of land areas or the growth of the material and technical base and increasingly on the level of staff competence (Lisnichenko, 2018).

The theory of human capital was developed in the 1960s by G.S. Becker (1962) and T.W. Schultz (1960), conceptually proving the investment nature of education and professional training costs. Both researchers viewed human capital as a productive resource, similar to physical capital, which is part of the production function and provides economic returns in the form of income and productivity growth. At the same time, their approaches differed in terms of the level of analysis and scope of application, which determines the different analytical value of these concepts for the study of agribusiness in the context of structural changes. A summary comparison of the key characteristics of the approaches of G.S. Becker and T.W. Schultz is presented in Table 1.

Table 1. Comparative characteristics of approaches to human capital theory

Aspect	G.S. Becker	T.W. Schultz
Definition of investment	Rational individual investment in education and training to maximise income, similar to business investment in capital	Socially significant investments in human capital for economic growth, with an emphasis on education as the foundation for development
Profitability	12-14% annual return on education explains the dispersion of earnings	Similar profitability, but emphasis on the role in the transformation of sectors such as agriculture
Scope of application	The general labour market, education as "capital" for any job	Economic development, especially in the agricultural sector, where education overcomes inefficiency
Key difference	Microeconomics: firms and individuals take human capital into account in production	Macroeconomics: Education is more relevant than physical capital for the growth of poor countries

Source: compiled by the authors based on T.W. Schultz (1960), G.S. Becker (1962)

The approach of G.S. Becker determines the mechanisms of productivity formation at the enterprise level through individual investment decisions of employees and employers, which is relevant for the analysis of personnel management, motivation and efficiency of production resources use. In the context of agribusiness, this is evident in the ability of employees to apply new technologies, optimise production operations and increase the return on the material and technical base. The approach of T.W. Schultz demonstrates the role of human capital as a factor in overcoming the structural inefficiency of traditional agriculture, where limited knowledge and skills hinder the introduction of innovations and reduce the effectiveness of resource use. In the context of innovation and structural change, human capital in agribusiness is becoming increasingly relevant, as it determines the ability of enterprises to adapt to digitalisation, climate change, market transformation and demographic shifts. Staff qualifications and

motivation ensure labour productivity growth, increase resource management efficiency and create the conditions for sustainable development of production processes. Thus, human capital development is the economic basis for improving the performance of agribusiness and shaping its long-term competitiveness.

In the agricultural enterprise management system, human capital is central in transforming resource potential into real production and financial results. This influence is manifested not only in the professional training of employees, but also in motivational, managerial and digital competencies, which ensure the effective organisation of production processes and the rational use of material and financial resources. In the context of increasingly complex technologies and growing demands for precision in production operations, it is human capital that acts as the integrating element of the management system. A significant factor in efficiency is the system of remuneration and incentives for staff. An increase in remuneration attracts qualified personnel and reduces staff turnover, increasing labour productivity by 5-15% (Dvornyk, 2021). This has a positive impact on the financial results of enterprises through a 10-20% increase in profits due to more efficient use of resources and reduced costs associated with staff turnover. Piecework wages create a direct link between performance and employee income, which improves performed work volume by 20-25% and reduces costs per unit of output. Bonus systems focused on achieving specific production and financial indicators stimulate innovation and adaptation to change, ensuring an average increase in profitability of 8-12%. In contrast, low wages lead to a loss of motivation and a decrease in productivity of approximately 10%, accompanied by financial losses due to staff turnover and deterioration in product quality (Lanchenko, 2023).

The digital skills of personnel are becoming increasingly relevant, as they determine the efficiency of the use of technology and the material and technical base of agricultural enterprises. Employees trained on digital platforms for production management, precision farming systems, drones, Internet of Things (IoT) sensors, and analytical tools can reduce equipment downtime by 20-30%, reduce fuel, fertiliser and seed costs, and increase yields (Ministry of Digital Transformation of Ukraine & WinWin, n.d.). Digital literacy of personnel ensures precise control of equipment (tractors with Global Positioning System (GPS), combines with Artificial Intelligence (AI)), reducing fuel and fertiliser overconsumption by 10-20%. Training agronomists and mechanics to use monitoring platforms (FMS) improves yield forecasting and maintenance, extending the service life of the material and technical base (MTB). In Ukraine, the shortage of AgroTech specialists is holding back digitalisation, but retraining programmes increase efficiency by 25% in pilot projects (Khadzhinova & Hryshyn, 2025).

The interconnection between human capital and material and financial resources manifests itself in the growth of returns on investments in technology and infrastructure. Qualified and motivated personnel ensure the efficient operation of the material and technical base, optimisation of costs and increased capital turnover. As a result, human capital is not only a separate factor of production, but also a system-forming element of management that determines the level of productivity, financial performance and sustainability of production processes in agricultural enterprises. The impact of human capital is reflected in the level of professional, motivational, managerial and digital competencies of personnel, which determine the efficiency of the use of material and technical resources and financial resources and ensure the adaptation of production processes to innovative and structural changes, creating the conditions for growth in the performance and sustainability of agricultural enterprises.

Analysis of the impact of human capital on the efficiency of resource and production process management

In 2020-2025, agricultural enterprises in Ukraine were developing in the context of structural transformations, changes in the labour market, decline in employment and a growing role of human capital in the efficiency of production processes. One of the effects of the changes is the wage dynamics in the agricultural sector, reflecting both financial capabilities and labour potential retention and restoration. In 2020,

the average nominal annual wage of the agriculture industry in Ukraine was approximately UAH 9,737, increasing throughout the year. In 2021, the wage increased even further, as the average monthly wage reached UAH 12,226, corresponding to an increase of 18-20%. This indicated a recovery of agricultural enterprise solvency and an increase in demand for skilled labour, given the favourable conditions in agricultural markets (Minfin, n.d.a). At the beginning of 2022, wages in the agricultural industry reached UAH 13,070, reflecting the positive trend on the eve of the Russian full-scale invasion. At the same time, wages fluctuated significantly throughout 2022 due to war, logistical disruptions, a reduction in productive areas, and the relocation of enterprises. In these conditions, the agricultural sector demonstrated greater resilience than many other types of economic activity, but employee income levels varied significantly across regions and seasons (Minfin, n.d.a).

In 2023, the average wage of the agriculture industry in the first quarter was UAH 12,326, and in the third quarter, UAH 15,690. The average annual figure was approximately UAH 14,954, demonstrating a gradual recovery of the labour market and adaptation to wartime conditions. In 2024, wages were growing, as in the first quarter, the average monthly wage was UAH 15,004, and by the third quarter, it was UAH 18,970. At the same time, the average wages in Ukraine during the period were higher, demonstrating the gap between the agricultural sector and the national average (Minfin, n.d.a). In 2025, the trend for wage increases was still present. According to labour market data, in the first quarter, the average wage in the agriculture sector was UAH 21,413, and, as of August 2025, reached approximately UAH 25,000 (Minfin, n.d.a). The highest values were recorded among agronomists and veterinary specialists, indicating an increase in demand for highly skilled human capital. The average monthly nominal wage dynamics in agriculture in Ukraine in 2020-2025 are presented in Figure 1.

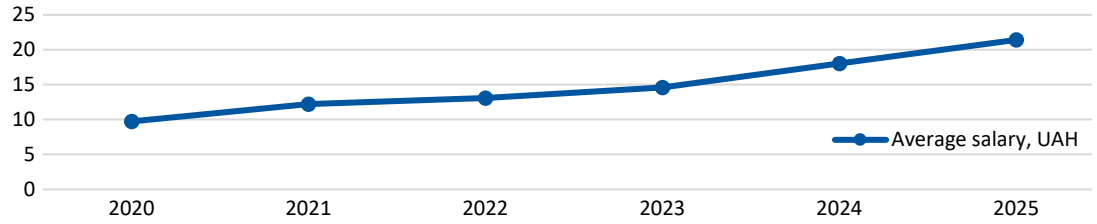

Figure 1. Dynamics of average monthly nominal wages in agriculture in Ukraine in 2020-2025
Source: compiled by the authors based on Minfin (n.d.a)

The data presented indicates a consistent trend towards growth in nominal wages in Ukrainian agriculture in 2020-2025, despite military and macroeconomic challenges. The increase in wages amid a decline in the number of employees indicates the growing role of human capital as a factor in maintaining the efficiency of resource and production process management in agricultural enterprises. Changes in wages occurred during a decline in employment in the agricultural sector. While in 2020, official employment in agriculture was about 659,000 people, in 2023 it grew to about 682,000 people, which corresponds to an increase of about 3.5%. This growth occurred amid structural changes and labour shortages, which increased the value of labour productivity, professional training and accumulated experience of personnel in maintaining production volumes (Pepelya, 2023).

In 2020, the gross added value of the Ukrainian agriculture sector was UAH 388 billion, equivalent to 10.8% of gross domestic product (GDP), while in 2021, the agricultural sector covered more than 10% of GDP and improved production by 19.2%, thus a primary contributor to economic growth (In 2021, more than 10%..., 2022). In 2022-2023, the gross value added of the Ukrainian agriculture sector was formed under military and macroeconomic constraints, which affected the production dynamics. In

2024, agriculture accounted for approximately 17% of Ukrainian GDP, confirming a systemic role in the structure of national production amid military and macroeconomic challenges (The agricultural sector..., 2025). A structural factor affecting the efficiency of resource management is the age of those employed in agriculture. In 2020-2025, the share of workers over 50 years of age increased from 45% to over 60%, while the share of employees under 30 remained within 10-15%. Such statistics demonstrate a high level of accumulated production experience but limit the implementation of digital technologies and management practices, especially among small and medium-sized enterprises (Razumkov Centre, 2024). An additional macroeconomic factor influencing the formation and use of human capital in the agricultural sector is the dynamics of the unemployment rate in Ukraine in 2020-2024, as demonstrated in Figure 2.

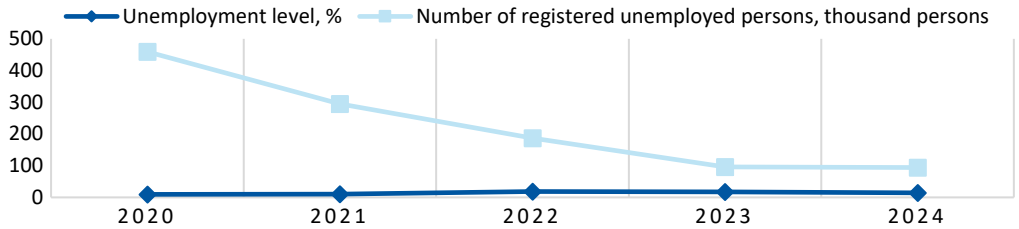

Figure 2. Unemployment trends in Ukraine in 2020-2024
Source: compiled by the authors based on Minfin (n.d.a; n.d.b)

In 2020, the unemployment rate in Ukraine was 9.5%, while the official unemployment rate was 459,200. In 2022, the unemployment rate was 18.5%, while official unemployment declined to 186,500. In 2024, the unemployment rate declined to 14.3%, but it was still 4.8 percentage points higher than in 2020, while official unemployment dropped to 94,200. The combination of relative unemployment growth and absolute decline reflects structural transformations in the labour market and an increasing labour shortage. An analytical review of the obtained results concluded that, in shrinking labour resources and rising labour costs, the efficiency of agricultural enterprises is increasingly determined by the qualitative characteristics of human capital rather than its quantitative parameters. A decrease in the number of employees accompanied by an increase in wages means an increase in specific personnel costs, which raises the bar for the effectiveness of every management and production decision. Under such conditions, even minor miscalculations in the organisation of labour, planning of production processes, or use of material and technical resources can lead to disproportionately large economic losses.

The increasing role of human capital is transforming approaches to resource management in agricultural enterprises, shifting the focus from extensive expansion of production factors to optimisation of internal processes. The high cost of labour encourages enterprises to use land, equipment, fuel and working capital more rationally, as the efficiency of their use correlates with professional training and managerial competencies of the personnel. In this context, human capital is an integration element that ensures consistency between technological capabilities, financial constraints and the organisational structure of production. At the same time, the existing age structure of the workforce creates additional management challenges. The predominance of older workers ensures stability in production experience, but hinders adaptation to changes in the technological environment and the introduction of management methods. In the absence of targeted management decisions, this may limit the return on investment in technology and infrastructure, even under favourable macroeconomic conditions. Thus, human capital in Ukrainian agricultural enterprises is becoming systematically relevant as a key factor in improving

resource management efficiency and ensuring the sustainability of production processes.

Practices and directions for improving the efficiency of agricultural enterprise management based on human capital development

Human capital management practices at leading agricultural enterprises in Ukraine in 2020-2025 were characterised by a transition to systemic models in which staff training, motivational mechanisms and management innovations are integrated with resource management and production processes. At MHP (n.d.a; n.d.b), human capital management is based on a developed educational ecosystem that includes an in-house training centre, a network of specialised schools (agricultural school, business analytics school, human resources (HR) school) and more than 80 educational events annually. The system includes 10 programmes for management personnel and over 50 online courses, which are implemented according to a model where 70% is practical experience, 20% is mentoring, and 10% is formal training. This training structure prioritises the development of professional, managerial, and digital competencies, including working with SAP, Power Platform, and AI tools, as well as funding for obtaining a second higher education degree. According to the estimates of the company, the integration of training programmes with digital transformation has made it possible to increase the efficiency of production processes by 20-30% by reducing errors, equipment downtime and optimising the use of resources. In addition, MHP develops citizen development programmes and competence centres, uniting more than 350 internal experts, and implements initiatives on stress resistance and reintegration of veterans, which strengthens staff adaptability and reduces personnel risks in wartime (Major agricultural producer..., 2021).

The MHP (n.d.b) motivational model combines tangible and intangible tools. Tangible incentives include competitive salaries, bonuses for achieving key performance indicators (KPI) (productivity, quality), interest-free loans for housing and medical treatment, company housing, and financial assistance in crisis situations. In 2024, the volume of social initiatives exceeded UAH 37 million, in particular in the form of additional payments to military personnel and their families. Intangible incentives include educational programmes, mentoring, flexible working hours, dual education, and a corporate culture of engagement. As a result, the set of motivational tools has reduced staff turnover by 15-20%, achieving an optimal balance between material (about 60%) and non-material (40%) incentives.

Kernel (n.d.) implements a systematic approach to human capital development based on a digital HR infrastructure that includes LMS Collaborator (n.d.) and Kernel HUB (n.d.). It also includes Microsoft Navision and Office 365, covering the entire HR cycle – from recruitment and staff onboarding to performance evaluation and training. The use of these tools ensures transparency in management decisions through automated KPI monitoring, the use of analytics in Power BI, and real-time access to management data, which minimises subjectivity in the assessment process. In addition, the job profile system supports professional training of production personnel and regular competency assessment based on the Kirkpatrick model. As part of the Re: Knowledge Industry project, knowledge is being scaled up for more than 1,000 factory workers through microlearning, which can be used for expertise in agrotechnology, processing, and logistics to be preserved and transferred in the context of military challenges and seasonal fluctuations (Kernel agroholding uses..., 2023). Kernel HUB has over 500 daily users and provides access to training materials, videos and internal courses. The training and mentoring system has contributed to a 15-25% reduction in operational losses and an increase in the utilisation of material and technical resources to 85-95% (Forbes, n.d.). Kernel's remuneration system is based on a transparent model, where the base salary is supplemented by monthly bonuses of 30-50% of the salary for production assets for the fulfilment of operational KPIs, annual bonuses for the achievement of strategic goals, and additional payments in the event of exceeding financial plans. Linking remuneration to indicators of MTB utilisation, yield and logistics reduces losses by 15-20% and increases productivity in grain and oil processing

by 10-30%, which ensures staffing levels at 99% (Kernel HR Strategy, 2025).

Astarta-Kyiv (2025a) develops human capital through partnership programmes with educational institutions and international organisations, including cooperation with the European Bank for Reconstruction and Development (EBRD) within the AgriAcademy platform, which offers 25 online courses on sunflower and rapeseed cultivation and processing. The educational initiatives have reached over 1,000 farmers and are complemented by cooperation with Ukrainian universities, dual education programmes, and the involvement of young people in practical work. Partnership programmes have ensured that key positions are filled at a rate of about 80% and reduced staff turnover by 15.20%. Astarta-Kyiv's incentive model combines a base salary with annual reviews, KPI bonuses (yield, MTB efficiency) and career development programmes, which have contributed to increased staff engagement and stability in production processes. Astarta's management innovations in the context of military risks included decentralisation of management, diversification of supply chains, consolidation of assets in safe regions, and the introduction of AI forecasting tools. In 2024, the company recorded a 34% increase in profit, an Earnings Before Interest, Taxes, Depreciation and Amortisation (EBITDA) margin of over 30% and revenue of EUR 612 million, confirming the effectiveness of integrating human capital with resource management and production processes (Astarta-Kyiv, 2025a). A summary of the results of a case study of human capital management practices implemented at MHP, Kernel and Astarta identifies a range of institutional approaches that are relevant for small and medium-sized agricultural enterprises in Ukraine. These approaches were developed during labour shortages, military risks and complications in production processes, which makes their application indicative in terms of optimising management decisions with limited financial resources.

One of the general areas is the organisation of professional training for personnel with an emphasis on specific production functions and management tasks. Within small and medium-sized enterprises, this can be achieved by combining internal mentoring, short-term modular programmes and the involvement of external educational resources without the formation of separate training structures. From an economic point of view, this is associated with a reduction in operational losses, a reduction in equipment downtime and the stabilisation of technological processes without additional capital investment. Another area for optimising management processes is the formalisation of incentive mechanisms that link remuneration to the performance of employees and departments. The practices identified in the case study demonstrate the possibility of using performance indicator systems to align individual labour performance with the economic performance of the enterprise. For small and medium-sized businesses, this can be implemented in the form of simplified systems for assessing productivity, quality of work and compliance with technological regulations, which reduces unproductive costs and stabilises the personnel structure.

Another area is the development of managerial and digital competencies of personnel as an element of human capital integration with production and accounting systems. Within small and medium-sized enterprises, such integration can be achieved through the gradual introduction of basic digital tools for planning, monitoring and accounting, combined with training personnel in their use. This reduces information gaps, improves the consistency of management decisions and reduces time lags between planning and execution of production operations. Adapting organisational management structures to the age and professional characteristics of staff is also a separate area for optimisation. With older employees dominating the workforce, it is advisable to formalise production procedures, standardise operations and transfer accumulated knowledge within the enterprise. This reduces the dependence of performance results on the individual experience of individual employees and contributes to the reproducibility of production processes in the medium term (Lesik *et al*., 2020). Overall, the results of the case study by MHP, Kernel and Astarta show that human capital management at leading agricultural enterprises in Ukraine in 2020-2025 has become systematic and is based on the integration

of staff training, motivational mechanisms and management innovations with the processes of using material and financial resources. The practices identified demonstrate the interconnection between the level of human capital development and the effectiveness of production processes, which creates the basis for their adaptation to the conditions of small and medium-sized agricultural enterprises, incorporating resource and organisational constraints.

DISCUSSION

Scientific literature on the development of the agricultural sector highlights the role of human capital, particularly different approaches to interpreting its role in resource management and the organisation of production processes in agricultural enterprises. For instance, S. Saha *et al.* (2025) considered human capital primarily as an investment resource that increases the productivity of agricultural labour through education, health and remittances to households. The study addressed the regional dimension, using panel data from households and econometric models to explain differences in productivity. In contrast, in this study, human capital was interpreted not as an external socio-economic factor, but as an internal system-forming resource of agricultural enterprises that determines the effectiveness of resource and production process management through the qualification, motivational and digital competencies of personnel. A similar difference in the level of analysis was noted during comparison with the study by Y. Hu *et al.* (2023). While sharing the theoretical foundations based on the concept of human capital, the Chinese authors shifted the focus to the macro level, analysing the impact of human capital on the environmental efficiency of agricultural production, considering regional differentiation and digital infrastructure. At the same time, in the study by Y. Hu *et al.*, performance was interpreted much more narrowly and practically – as the ability of enterprises to optimise management decisions, increase resource efficiency and ensure the sustainability of production processes, without a direct link to environmental indicators.

The expansion of this approach was traced in comparison with the study by X. Lei *et al.* (2025), where the effectiveness of agricultural development was correlated with the formation of new qualitative productive forces and the growth of "green" production efficiency in regions. In this case, the human factor was considered indirectly – as part of a broader innovation and technological transformation. In contrast, in this study, human capital was the central analytical category that directly determined the effectiveness of managing production and resource flows at the enterprise level. A similar gap between the macro and micro levels was also characteristic of the comparison with the study by R. Xie (2025), in which human capital was interpreted as a factor in the growth of green total factor productivity through technological innovation and workforce modernisation. In this study, on the contrary, human capital was considered as an internal management resource that determines the efficiency of production organisation regardless of general economic or environmental transformations. The transition from macroeconomic approaches to the management aspects of human capital was most clearly seen in comparison with the study by M. Ogrezeanu *et al.* (2025). Both studies recognised the decisive role of personnel in ensuring the sustainability of agribusiness, but M. Ogrezeanu *et al.* regarded HRM practices – recruitment, staff retention and succession planning – as tools for the development of farms. In this study, the emphasis was shifted from individual HR tools to the systemic role of human capital in resource management, production processes and the digital transformation of enterprises.

A more socially oriented approach was presented by H. Jin & H. Liu (2025), in an analysis of human capital at the household level and correlated with food security through the mechanism of agricultural specialisation. In this study, on the contrary, human capital was interpreted not as a factor of consumer or social stability, but as a production and management resource that shapes the economic performance of agricultural enterprises. Compared to the study by E.H.Y. Deme & S.A. Doli (2025), there was a common definition of the role of investment in human capital, but a fundamental difference in the channels of influence. While D.E.H.Y. Deme & S.A. Doli viewed human capital through the

prism of the macroeconomic effects of foreign direct investment and the growth of agricultural value added, the presented study interpreted human capital as an internal factor of management efficiency, not directly related to external financial flows.

A comparison of the presented study with the analysis by X. Li & Y. Jin (2025) revealed a common definition of the growing role of intangible factors in improving agricultural production efficiency. In both approaches, development efficiency was linked to the quality of production factors, primarily human capital and innovative capacity. At the same time, X. Li & Y. Jin interpreted human capital as an element of broader regional transformation associated with the integration of the digital and real economies, while in this study, it was considered as a direct factor of managerial and production efficiency at the enterprise level. A similar logic was observed in comparison with the study by M.A.M. Dávila *et al.* (2025). The common aspect was the recognition of the decisive role of knowledge, skills and organisational practices in shaping economic outcomes. The difference lay in the analytical focus: M.A.M. Dávila *et al.* linked human capital to organisational learning and innovation processes in the context of sustainable development, while this study focused on its role in ensuring the efficiency of resource and production process management.

A comparison with the study by H. Jin & H. Liu (2025) revealed a common interpretation of the impact of labour quality on the productivity of agricultural enterprises. However, H. Jin & H. Liu viewed human capital primarily through the prism of institutional factors – agricultural labour policy, employment regulation and migration processes. In this study, however, the internal management mechanisms for performance formation were addressed without a direct emphasis on the regulatory environment. A comparison of the presented study with the analysis by Y. Buchana *et al.* (2025) revealed a common approach to the multifactorial nature of agricultural productivity and the role of human capital in improving production efficiency. At the same time, Y. Buchana *et al.* emphasised the quantitative analysis of classical production factors at the local level, while this study emphasised the qualitative measurement of human capital as a factor of managerial coordination and resource efficiency.

The similarity of theoretical foundations was also evident in comparison with the study by Y.S.A. Frijat & A.A. Elamer (2024), where human capital was interpreted as a key intangible asset of enterprises. The difference lay in the interpretation of performance: Y.S.A. Frijat & A.A. Elamer associated it with corporate governance, financial transparency and investment attractiveness, while the presented study addressed the production and management aspects of agricultural activity. E. Sánchez-García *et al.* (2025) considered human capital and management practices as tools for ecological performance through green HR approaches and behavioural factors. There was a common recognition of the role of staff competencies, but the difference lay in the targets: environmental responsibility in E. Sánchez-García *et al.* was contrasted with the management and resource efficiency that this study focused on.

A comparison with the study by M. Bin & H. Qiong (2024) demonstrated a common interpretation of human capital as a factor in the socio-economic development of the agricultural sector. At the same time, M. Bin & H. Qiong analysed it at the macro level, linking it to the processes of rural revitalisation and professionalisation of farmers, while this study addressed the micro level of enterprises and resource management mechanisms. A comparison of the presented study with the analysis by D. Antonioli *et al.* (2025) revealed a common recognition of human capital and HRM practices as key factors in improving the performance of enterprises. Both studies emphasised that training, employee engagement and organisational change improved corporate adaptability to technological and structural transformations and increased resource efficiency. Another common aspect was the perception of human capital as a dynamic resource that shapes the innovative potential and long-term sustainability of a business. At the same time, the analytical focus differed. D. Antonioli *et al.* addressed the "dual transformation" of combining digital and green innovations in industrial enterprises, where HRM practices were considered as a tool to support

environmental and digital innovations. Instead, in this study, human capital was analysed in an agricultural context as a system-forming factor in the effectiveness of resource management and the organisation of production processes, without a direct emphasis on ecological and digital transformation.

A summary of scientific approaches showed that human capital was consistently considered a key factor in improving the performance of the agricultural sector, but approaches to its analysis differed significantly in terms of the level of generalisation and interpretation of the mechanisms of influence. Most studies addressed macroeconomic, social, environmental or institutional aspects, interpreting human capital as a prerequisite for structural transformations, innovative development and productivity improvement. At the same time, in practical terms, it was treated as an internal resource that determined the effectiveness of resource management and the organisation of production processes at the level of agricultural enterprises. This confirmed the multidimensional nature of human capital and its decisive role in shaping the performance of agricultural production.

CONCLUSIONS

The study confirmed that between 2020 and mid-2025, human capital became a key factor in the effective management of resources and production processes at Ukrainian agricultural enterprises amid a decline in labour resources, rising labour costs and a more complex technological environment. The statistical data obtained showed that during the study period, the number of people employed in agriculture increased by 3.5%, while the average monthly nominal wage increased from UAH 9,737 in 2020 to UAH 21,413 in the first quarter of 2025, and for certain specialities in 2025 exceeded UAH 25,000. This means an increase in specific personnel costs and, accordingly, higher requirements for the effectiveness of each management decision. An analysis of wage and productivity dynamics showed that investments in staff qualifications, motivation and management skills resulted in a 5-15% increase in labour productivity and a 10-20% increase in enterprise profitability due to reduced staff turnover, time losses and unproductive costs. The use of results-oriented wage systems made it possible to increase the volume of work performed by 20-25%, while insufficient motivation and low wages contributed to a decline in productivity of approximately 10%. In a situation where agriculture accounted for about 17% of Ukrainian gross domestic product in 2024, the efficient use of human capital had a direct impact on the macroeconomic stability of the agricultural sector.

The results of case studies of MHP, Kernel, and Astarta demonstrated the economic return on systematic human capital development. At MHP, the integration of educational programmes, mentoring and digital management tools has increased the efficiency of production processes by 20-30%, reduced equipment downtime and lowered staff turnover by 15-20%. At Kernel, the digitalisation of HR processes and the use of KPI analytics helped reduce operational losses by 15-25% and increase the utilisation of material and technical resources to 85-95%, which ensured a 10-30% increase in processing productivity and maintained staffing levels at 99%. At Astarta, a combination of partner educational programmes, performance-based motivation and management innovations made it possible to maintain staffing levels for key positions at around 80%, reduce staff turnover by 15-20% and achieve a 34% increase in profit in 2024 with an EBITDA margin of over 30%. Based on the results obtained, it was recommended to address the management decisions of agricultural enterprises on systemic investments in human capital development through modular professional training, results-oriented motivation systems, and the phased digitalisation of management processes, which would increase labour productivity, resource efficiency, and the sustainability of production processes within limited financial constraints.

The results obtained showed that the improvement of employees' qualifications, the development of professional competencies and the application of motivational mechanisms were accompanied by an increase in the efficiency of resource management and production processes in agricultural enterprises. The limitation of this study is the temporal,

statistical, and institutional conditions of the Ukrainian agricultural sector in 2020-2025, which determine the specificity of the results obtained. Further research should expand analytical models for assessing human capital, incorporating regional differentiation, the digital maturity of enterprises, and the long-term effects of management innovations.

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Вплив людського капіталу на ефективність управління ресурсами та виробничими процесами сільськогосподарських підприємств

Анотація. Метою дослідження було визначення ролі характеристик людського потенціалу у формуванні управлінських рішень та функціонуванні виробничої діяльності. Методологічну основу дослідження становив емпіричний підхід із застосуванням описового, динамічного, структурного та порівняльного аналізу офіційних статистичних даних, аналізу відносних показників ринку праці, а також методу кейс-стаді та аналізу практик управління людським капіталом провідних аграрних підприємств. Результати засвідчили, що у період 2020 – середини 2025 років чисельність зайнятих у сільському господарстві зросла на 3,5 %, тоді як середньомісячна номінальна заробітна плата зросла з 9,737 грн у 2020 році до понад 21,413 грн у першому кварталі 2025 року, а за окремими спеціальностями перевищила 25,000 грн. За умов дефіциту робочої сили підвищення вартості праці посилило роль якісних характеристик персоналу в управлінні ресурсами. Встановлено, що інвестиції у кваліфікацію та мотивацію персоналу забезпечували приріст продуктивності праці на 5-15 % і зростання прибутковості підприємств на 10-20 %, тоді як результатоорієнтовані системи оплати праці дозволяли збільшувати обсяги виконаних робіт на 20-25 %. Частка сільського господарства у валовому внутрішньому продукті України у 2024 році досягла близько 17 %, що відображало структурні трансформації трудового потенціалу. Практики управління людським капіталом, проаналізовані на прикладі «Миронівського хлібопродукту», Kernel та Astarta-Kyiv, засвідчили скорочення плинності персоналу на 15-20 %, підвищення продуктивності праці на 10-30 % та зростання ефективності використання матеріально-технічної бази до 85-95 %, що дозволяло зменшувати операційні втрати на 15-25 %. Практичне значення дослідження полягає у можливості використання отриманих результатів аграрними підприємствами для підвищення ефективності управління персоналом і ресурсами

Ключові слова: безробіття; продуктивність; компетентності; кваліфікація; заробітна плата; мотивація

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Competitiveness of floriculture as a direction of agrarian entrepreneurship: Economic risks and prospects

Abstract. The aim of the work was to quantitatively assess the competitiveness of floriculture as a direction of agrarian entrepreneurship in Ukraine, to identify key risks, and to propose management and policy solutions taking into account international experience. The methodology combined theoretical frameworks (five forces model, resource-oriented and cluster approaches) with empirical analysis: monthly series for 2019-2024 from international databases of foreign trade

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and official statistics were used; a linear regression model of sales profitability with indexed factors (base: 2021=100) was constructed for energy prices, imported inputs and wages; a scenario analysis was performed. Due to the lack of publicly available system data on domestic production, market estimates were obtained using the HS 0603 proxy; for the HS subsegment 0603.10 (roses) in 2021 imports amounted to USD 20.72 million and 5.81 thousand tonnes, in 2022 – USD 24.45 million and 4.57 thousand tonnes; in 2023 exports in total – about USD 0.743 million (42.9 tonnes). The specific cost of imports (0603.10) increased from ≈3.57 to 5.35 USD/kg. Regression estimates showed that an increase in the energy price index by 10 points (≈+10%) is associated with a decrease in sales profitability by 4.1 pp, an increase in the import input index by 10 points – by 2.7 pp, and the wage index – by 1.5 pp. Seasonal peaks of demand (February-March) significantly concentrate revenue, which increases the requirements for inventory and sales planning. The practical significance lay in the quantitative assessment of the expected effects of vertical integration, procurement cooperation, energy-efficient investments, cold logistics hubs and digital sales channels; the combination of these solutions together with targeted grants and preferential lending can increase the profitability of the industry by ≈3-6 pp in the medium term

Keywords: flower market; losses; export; import; profitability

INTRODUCTION

Floriculture in Ukraine is affected by three systemic constraints: import dependence on critical inputs (planting material, plant protection products), high energy intensity of greenhouse cycles and logistical disruptions due to the full-scale invasion of Ukraine by the Russian Federation, which began on February 24, 2022. As a result of these factors, the market structure, prices, and margins changed, and the sensitivity of enterprises to currency and energy shocks, as well as to disruptions in transport infrastructure, increased. In the European context, the temporary liberalisation of access for Ukrainian agricultural products to the EU market and its gradual winding-down were of additional importance, which affected the expectations of participants regarding tariff and procedural costs (Regulation (EU) 2022/870, 2022; Regulation (EU) 2024/1392, 2024). In combination with fluctuations in the official hryvnia exchange rate and inflationary dynamics, these circumstances formed a demand for a quantitative assessment of the industry's sustainability and tools for increasing competitiveness.

In the national scientific discourse, researchers L. Stepasyuk & R. Usov (2025) focused on behavioural determinants of demand and management decisions in floriculture. It was shown that consumer heuristics, price anchors, and time patterns of purchases influenced the formation of revenue and the choice of sales strategies of enterprises. Separately, trends and institutional mechanisms of development in leading countries were summarised, in particular the role of clustering, auction and logistics hubs, and quality standards in ensuring stable export flows. The work systematised comparative characteristics of production and logistics models, identifying the Dutch auction hub as a standard of network coordination. The effects of scale and reduction of transaction costs in cooperative sales formats are substantiated in the work of A. Kolesnikov (2024), which shows an increase in export predictability and contract quality. Further analysis by A. Kolesnikov (2025) highlighted the patterns of globalisation of the flower market and the tools for Ukraine's integration into global value chains, with special attention to export support institutions and clustering as mechanisms for reducing entry barriers and smoothing price fluctuations.

International cases provided a comparative framework for interpreting Ukrainian challenges. For Mexico, A. Elvires *et al.* (2022) established the production structure, export niches, and productivity factors that determined competitive positions in the cut flower market. For India, D. Sinha & R. Sharma (2024a) assessed the dynamics of comparative advantages and trade intensity after the implementation of the National Horticulture Mission; the authors noted

changes in the commodity structure of exports and strengthening of positions in individual product types. In subsequent works, D. Sinha & R. Sharma (2024b) summarised the dimensions of the growth of the Indian floristic trade, including logistical and marketing aspects that affected the stability of margins.

I. Adebayo *et al*. (2020) and N. Devrani *et al*. (2024) noted the increase in technological requirements for post-harvest processing, cold chain and digital sales channels. The status and prospects of the global industry were summarised, the risks of energy volatility and dependence on imported materials were outlined, and directions for diversification of value-added products were described. Current trends in production and marketing included expanding the range, standardising quality, and implementing digital tools for demand management and just-in-time logistics, which increased the predictability of cash flows. In addition, A. Ingole *et al.* (2025) showed that the use of CRM platforms, pre-orders, and subscriptions shortened the average inventory turnover cycle and reduced the frequency of write-offs during peak periods. In parallel, the human resource dimension was formed: X. Wu *et al*. (2025) proposed a framework of qualifications for training florists that influenced service standards and competitiveness in sales segments. The framework was based on a competency-based approach with a modular structure (bouquet design, quality management, customer service, e-commerce) and provided for standardised assessments of learning outcomes. A summary of the sources cited showed that competitiveness in floriculture was determined by a combination of energy, institutional and logistical factors, as well as the ability to integrate into global value chains through quality standards, logistics infrastructure and digital channels.

The purpose of the study was to quantitatively assess the competitiveness of the Ukrainian floriculture sector, identify critical risk factors and justify management and government tools to increase efficiency, taking into account international practices. Accordingly, the following tasks were set: first, to summarise the conjuncture and foreign trade indicators of the Ukrainian cut flower market, taking into account the limitations of statistical availability; second, to quantify the relationship between cost indices and enterprise profitability and to outline management and policy solutions that can reduce sensitivity to challenges.

MATERIALS AND METHODS

The object of analysis was the competitiveness of Ukrainian floriculture, primarily the cut flower segment, in the period 2019-2024. The empirical base combined monthly series for the econometric part with customs statistics of foreign trade, which were aggregated to a monthly frequency if necessary. During 2019-2024, official summary data on domestic production of cut flowers (in units/UAH) were not systematically published in open access. Due to the lack of systematic official indicators of domestic production during this period, the market situation was reconstructed according to trade flows HS 0603 "fresh cut flowers and buds" and subsegment HS 0603.10 "roses" (WITS, 2021; 2022). Additionally, industry reviews and supplier profiles were taken into account to compare the market structure (Netherlands Embassy in Ukraine, 2019; OEC, n.d.). Macro indicators – the official hryvnia exchange rate, inflation rates, and wages – were taken from official statistics, and reference prices of energy carriers for industry – from specialised sources (National Bank of Ukraine, 2022; Ministry of Energy of Ukraine, 2022; State Statistics Service of Ukraine, 2023a; State Statistics Service of Ukraine, 2023b). Additionally, the paper compared the approaches of Ukraine, Poland, and the Netherlands to the integration of value chains, cooperation and logistics (Netherlands Embassy in Ukraine, 2019; OECD & FAO, 2024). The foreign trade block mentions key countries supplying cut flowers – the Netherlands, Ecuador, Colombia, Ethiopia, Kenya, Nigeria and Turkey, as well as the main export markets of Ukraine – Poland and Lithuania (WITS, 2022; 2023; n.d.).

The key regressors were presented in the form of indices with a base of 2021 = 100, which allowed for a direct interpretation of deviations in percentage points. The base year 2021 was chosen due to the stability of economic indicators during this period, which allowed for a correct comparison of changes in subsequent

years, in particular after the impact of economic or energy shocks. The G index reflected the dynamics of energy prices for industry, and S – the cost of import-dependent inputs (planting material, plant protection products) based on relevant HS 0602/0603 commodity headings (WITS, 2021; WITS, 2022; Ministry of Energy of Ukraine, 2022). To estimate the cost of import-dependent inputs, average prices were used for HS 0603 commodity headings (cut flowers) and the corresponding subcategories of plant protection products (PPP) imported into Ukraine. This approach allowed for a correct interpretation of the change in the cost of inputs within the general commodity groups representing the main costs for the floriculture sector. The W index characterised the average wage in the relevant type of activity (State Statistics Service of Ukraine, 2023a). To control for supplier structure and import market concentration, the Herfindahl-Hirschman index was additionally calculated based on the shares of partner countries in HS 0603 imports (OEC, n.d.).

The econometric estimation was performed using the least squares method with robust standard errors (HC) in the specification, where the profitability of operating activities (ROS (Return on Sales), pp) was the dependent variable, and the indices G, S and W were explanatory. The basic model was built without the use of seasonal dummy variables, while the extended model tested the robustness of the results when including the "peak" months (February, March), which are important for flower demand. Diagnostics included multicollinearity (VIF) tests, residual autocorrelation (Durbin-Watson) and sensitivity to alternative indexing bases (2020 = 100; 2022 = 100) and lag factor specifications. All cross-validations confirmed the qualitative stability of the signs and order of influences (WITS, 2021; WITS, 2022; State Statistics Service of Ukraine, 2023b). To assess the competitiveness of floriculture, M. Porter's (1979) five forces model was used, which allows for a systematic analysis of the competitive environment of the industry, taking into account the following factors: the level of competition among existing enterprises, the threat of new market participants, the influence of suppliers, the influence of buyers and the threat of substitutes.

The scenario analysis was performed for the period 2022-2023, as this period allowed for a more accurate assessment of current trends and to take into account factors affecting the demand for flowers, such as energy shocks, inflation, and changes in consumer preferences, compared to other years of the study (2019-2024). Typical shocks were considered: gas price increase during the heating season, UAH/USD exchange rate fluctuations, increase in the price of imported inputs and increase in logistics costs. Each scenario was translated into a change in the corresponding index (G or S) taking into account incomplete price transmission into cost and contract lags (Ministry of Energy of Ukraine, 2022; National Bank of Ukraine, 2022). The effects on ROS were calculated through the estimated elasticities and adjusted for the seasonal structure of costs and the share of energy in COGS (Cost of Goods Sold) (WITS, 2022). This approach ensured consistency between model parameters and observed ranges of impacts. The interpretation of the results relied on comparing the signs and relative magnitudes of the effects with conjunctural observations – in particular, with the increase in the unit cost of cut flower imports between 2021 and 2022 and with shifts in the geography of supply in favour of large external hubs (WITS, 2021; WITS, 2022; OEC, n.d.). This allowed linking formal estimates of profitability sensitivity to real market disturbances and preparing applied conclusions for business and policy. Regression analysis was conducted to assess the dependencies between variables. The analysis used the least squares method (Gujarati & Porter, 2009), which allows estimating the impact of independent variables on the dependent variables. The analysis included a check for multicollinearity, as well as an assessment of the robustness of the results using tests for heteroscedasticity and autocorrelation of residuals. The regression results are presented in Table 2.

Given the elasticities and scenario calculations obtained, the methodology directly led to the proposal block: energy-efficient investments in greenhouse cycles, cooperative purchasing and development of local nursery base to reduce the S index, deployment of cold chain and JIT logistics, as well as digital sales channels with pre-orders and subscriptions. These

directions are consistent with international efficiency benchmarks in agricultural production and trade (World Bank, 2021; OECD & FAO, 2024). These measures form a practical "action map" for increasing margin resilience (World Bank, 2019; BRDO, 2023).

Data processing was performed using Python 3.11 (Jupyter Notebook – United States) with pandas/numpy (data preparation), statsmodels (OLS estimation), matplotlib (visualisation). The overall significance of the regressions was tested by ANOVA/omnibus F-test (Statology, 2022); partial F-tests (ANOVA between models with/without seasonal dummies and lags) were used to compare nested specifications. Significance levels: 1% / 5% / 10%; robust SE type HC3. Diagnostics: VIF < 5 (multicollinearity), Durbin-Watson/Ljung-Box (autocorrelation), Breusch-Pagan/White (heteroscedasticity). Levene's test was used to test the ANOVA assumptions regarding the equality of variances of groups (e.g., months/seasons), and Shapiro-Wilk was used to test the normality of the residuals. If necessary, post-hoc comparisons of means for seasonal factors were performed using the Tukey HSD method (Abdi & Williams, 2010). For time series, ADF and KPSS tests were additionally used; in case of instability, indexation (base: 2021=100), seasonal adjustment, or first-difference estimation were used.

RESULTS AND DISCUSSION

During the pre-war period (2019-2021), HS 0603 imports were relatively stable, while in 2022, a price increase was recorded with a reduction in physical volumes, which corresponded to the increase in energy and logistics costs in wartime conditions. For the HS 0603.10 subsegment, imports were estimated at USD 20.72 million and 5.81 thousand tonnes in 2021 and USD 24.45 million and 4.57 thousand tonnes in 2022; key supplier countries are the Netherlands, Ethiopia, Ecuador, Colombia, Turkey (WITS, 2021; 2022). In 2023, the supply structure (according to partner data) shifted in favour of Ecuador and the Netherlands: the leaders remained Ecuador (USD ≈6.3 million), the Netherlands (USD ≈5.23 million), Colombia (USD ≈1.31 million), Nigeria (USD ≈0.69 million), Turkey (USD million ≈0.66 million) (OEC, n.d.). Exports remained marginal: in 2023 – about USD 0.743 million and 42.9 tonnes, with a concentration on the markets of Poland and Lithuania (WITS, 2023), which confirmed the import-dependent nature of the domestic market and was consistent with the conclusions of the industry review (Netherlands Embassy in Ukraine, 2019). Ukraine's foreign trade indicators in the cut flower segment are presented in Table 1.

Table 1. Ukraine's foreign trade indicators in the cut flower segment

Year	Indicator	HS	Imports, million USD	Import, thousand tonnes	Top suppliers (partner data)	Exports, million USD	Export, tonnes
2021	Illustrative subsegment	0603.10	20.72	5.81	Netherlands, Ecuador, Colombia, Kenya, Turkey	n/a	n/a
2022	Illustrative subsegment	0603.10	24.45	4.57	Netherlands, Ethiopia, Ecuador, Colombia, Turkey	n/a	n/a
2023	Supply structure	0603	–	–	Ecuador, Netherlands, Colombia, Nigeria, Turkey	0.743	0.043

Note: for 2023, the aggregated value of imports under HS 0603 in the source n.d. (2023) is presented by component (by partner countries) without a summary row
Source: developed by the authors based on WITS (2021; 2022), OEC (n.d.)

Table 1 records the import dependence of the market: in the subsegment HS 0603.10, imports in 2022 increased to USD 24.45 million with a decrease in mass to 4.57 thousand tonnes compared to 2021 (USD 20.72 million; 5.81 thousand tonnes), which indicates a significant increase in unit value (≈ millionfrom USD 3.57/kg to USD 5.35/kg) against the background of energy and logistics shocks. The supply structure in 2023 (by HS 0603 aggregate) is

shifted towards Ecuador and the Netherlands, while exports remain marginal (USD 0.743 million; 0.043 thousand tonnes), which emphasises the weak external position of the industry. At the same time, 2023 is presented by region without a consolidated import line, so aggregated estimates should be restored by summing partner data and carefully compared through the non-comma between 0603.10 and 0603. Taken together, this indicates an increase in price pressure on the cost price and a stable import dependence of the floriculture segment of Ukraine.

It is advisable to begin with the interpretation of the competitiveness of floriculture through the five forces model by M. Porter (1979). Market entry is constrained by the high capital intensity of greenhouse complexes and the requirements for the construction of sales channels. At the same time, the market power of suppliers is increasing due to the significant import component – planting material, plant protection products, fertilisers – while the power of buyers remains generally moderate due to the coexistence of imported and Ukrainian alternatives. As a result, the intensity of competition is high: the number of small producers is combined with the active presence of imports, which pushes prices and quality standards up (Netherlands Embassy in Ukraine, 2019).

Expanding the analysis, the resource-based approach (RBV) and the concept of dynamic capabilities explain the sources of advantages where market forces only set the "playing field". Key resources are natural and climatic conditions, the availability and quality of labour resources, as well as management practices: operational efficiency of greenhouse capacities, precise planning of cutting and sales, digital accounting. At the same time, these advantages are weakened by limited access to cheap capital and technological dependence on imports, which reduces resilience to price and currency shocks (Netherlands Embassy in Ukraine, 2019). Therefore, even with the correct positioning in the five forces, the internal "filling" of the enterprise – processes, competencies, flexibility – determines whether market opportunities are converted into sustainable financial results. Discussion of the research results indicates similar configurations of cost and institutional factors compared to Asian cases presented in the literature. According to A. Titisari (2025), it was shown that for Indonesia and India, energy costs, access to planting material and logistical compatibility with sales markets remained crucial; these findings were consistent with the estimated elasticities for energy and imported inputs in the Ukrainian model. It was additionally outlined that regional differences in transport infrastructure determined the spread of marginal indicators between clusters, which corresponded to the scenario effects of the cold chain and JIT logistics.

Finally, the cluster perspective adds a spatial and institutional dimension. Unlike the Netherlands with its auction-logistics hubs, Ukrainian floriculture does not yet have developed clusters with joint auctions, standardised cold chain logistics and agreed quality standards. Existing regional clusters demonstrate a lower level of infrastructural integration, which limits the effects of scale and collective branding and, accordingly, increases dependence on imports and demand fluctuations (Netherlands Embassy in Ukraine, 2019). Thus, the three frameworks – Porter, RBV and clusters – consistently complement each other: the structure of the industry creates pressure, internal resources determine the ability to respond, and cluster infrastructure multiplies effects and reduces transaction costs.

In terms of price and quantity, Ukraine's position remains vulnerable: in 2023, cut flower exports were low – about USD 0.743 million and 42.9 tonnes, with supplies concentrated mainly on the markets of Poland and Lithuania (WITS, 2023). Against this backdrop, in 2021-2022, for the HS 0603.10 subsegment, imports exceeded USD 20-24 million, and the unit value increased significantly – from approximately USD 3.57/kg in 2021 to USD 5.35/kg in 2022, which is consistent with rising costs during a period of energy and logistics volatility (WITS, 2021; 2022). Structurally, Ecuador and the Netherlands remained key sources of supply in 2023, highlighting the continued dependence on a few major external partners (OEC, n.d.).

The regulatory background was determined by a combination of tariff and non-tariff conditions. In 2022-2025, a temporary liberalisation regime for Ukrainian agricultural

products to the EU market (Autonomous Trade Measures) was in effect, which ended on June 6, 2025 with the gradual return of tariff rate quotas (TRQs) within the DCFTA; the parameters of the subsequent regime were under review. These changes affected participants' expectations regarding customs, tariff and procedural costs (Regulation (EU) 2022/870, 2022; Regulation (EU) 2024/1392, 2024; European Commission, n.d.). At the same time, phytosanitary and other standard EU requirements (TARIC/NTM), which form a non-tariff barrier to the export of flower products and require proper compliance by producers, remained unchanged (Commission Implementing Regulation (EU) 2019/2072, 2019; European Commission, n.d.). In a broader comparative context, global trade in cut flowers in 2023 was estimated at approximately USD 10 billion, which outlines the significant capacity of the global market (OEC, n.d.). But at the same time, there is a high threshold for entry for new exporters without developed cluster logistics and auction infrastructure – elements that are crucial for competitive participation in international value chains.

The efficiency of floriculture enterprises in Ukraine was determined primarily by the dynamics of costs for energy, imported planting materials and logistics. Given the structure of foreign trade, the share of imported components in the costs of planting material was significant, which made the cost price sensitive to exchange rate fluctuations and customs and non-tariff conditions (WITS, 2022; National Bank of Ukraine, 2022; OEC, n.d.). In a typical greenhouse production cost structure, energy resources accounted for approximately 25-35%, planting material together with plant protection products – about 30%, labour costs – up to 20%, logistics and storage – 10-12% (Netherlands Embassy in Ukraine, 2019; World Bank, 2021). The profitability of operating activities (ROS) fluctuated around 5-12% depending on the season and technology (greenhouses/open ground). Seasonality of demand played a significant role: during peak periods (February-March), a disproportionately large share of annual revenue was formed, which increased the volatility of cash flows and the requirements for planning of cuts, inventories, and sales (Netherlands Embassy in Ukraine, 2019).

The indicators in Table 2 showed that the energy factor has the greatest marginal impact on profitability: an increase in G by 10 pp is associated with a decrease in ROS by ≈ 4.1 pp ($p < 0.01$), while a similar increase in the import input index S reduces ROS by ≈2.7 pp ($p = 0.02$), and the wage index W by ≈1.5 pp ($p = 0.03$). The basic level of profitability, reflected by the constant 15.30 pp, together with $R^2 \approx 0.68$ indicates sufficient explanatory power of the model for applied use. This hierarchy of effects is consistent with the 2021-2023 situation: rising energy and logistics costs have increased the unit value of cut flower imports from approximately USD 3.57/kg to USD 5.35/kg, and the supply structure has maintained dependence on external hubs (WITS, 2022; Ministry of Energy of Ukraine, 2022; OEC, n.d.). This led to practical priorities, which are detailed below: energy efficiency in greenhouse cycles, reducing S through cooperative purchasing/local nursery production, and optimising the cold chain to reduce losses and stabilise margins.

Table 2. Results of regression analysis of the influence of factors on the profitability of flower growing enterprises

Variable	Coefficient β	Standard error (robust)	t-statistic	p-value
Constant	15.30	1.12	13.66	<0.01
Cost of energy carriers (G)	–0.41	0.08	–5.13	<0.01
Cost of planting material (S)	–0.27	0.11	–2.45	0.02
Wage level (W)	–0.15	0.07	–2.14	0.03

Source: developed by the authors based on WITS (2021; 2022), Ministry of Energy of Ukraine (2022), State Statistics Service of Ukraine (2023b), OEC (n.d.)

The basic model (without seasonal dummies) outlines a stable hierarchy of influences (G > S > W) (Table 2). The extended model with seasonal dummies (base period – January or

Q1) confirms the constancy of signs and order of magnitudes of the main coefficients, and also reveals the expected seasonal fluctuations in profitability with an increase in peak months (February-March) relative to the base period. The obtained estimates confirmed the dominant negative impact of the energy factor on profitability, a secondary one – of the imported component of planting materials, and a relatively moderate one – of wages. The direction and relative magnitudes of the effects were consistent with conjunctural observations: the increase in the cost of energy and logistics in 2022-2023 correlated with an increase in the unit cost of imports and a decrease in the marginality of greenhouse farms. According to the guidelines presented in the literature, cost management practices and planning for seasonal peaks are aspects for the successful functioning of commercial floriculture. In particular, L. Larkin (2024) emphasised that the marginality of farms is determined by a combination of cost control, inventory discipline and synchronisation of the cut with demand, which is one of the main practical strategies for commercial floriculture, based on cost and demand analysis. These approaches correlate with the elasticities for energy and imported inputs obtained in the study in monthly dynamics.

Floriculture enterprises operated in a field of multidimensional risks: macroeconomic (currency, inflation), production (energy intensity of the greenhouse cycle), market (import competition), and logistics (cost and duration of delivery in wartime conditions). At the macro level, the key factor remained the currency factor: during 2022-2023, the official hryvnia exchange rate to the dollar increased from 27.3 UAH/USD (January 2022) to 36.6 UAH/USD (August 2023), which increased the hryvnia cost of imported inputs (planting material, fertilisers, energy sources) (National Bank of Ukraine, 2022). Inflation in 2022 was 26.6%, which was reflected in the increase in the price of raw materials and services (State Statistics Service of Ukraine, 2023a). Production risk was concentrated on energy dependence: average natural gas prices for industry in 2022 exceeded ≈20 thousand UAH/thousand m³ (compared to 2020) (Ministry of Energy of Ukraine, 2022). This increased the cost of greenhouse production during the heating season and made profitability highly sensitive to energy shocks. Market risk was exacerbated by import competition: imports of cut flowers (HS 0603) in 2021 – USD 20.72 million (5.81 thousand tonnes), in 2022 – USD 24.45 million (4.57 thousand tonnes); at the same time, exports in 2023 – USD 0.74 million (42.9 tonnes) with a concentration on Poland and Lithuania (WITS, 2021; WITS, 2022; OEC, n.d.). Logistical risk was manifested by increased transportation costs and changes in routes: in 2022, the logistics costs of the agro-industrial complex increased by more than 30% y/y, which is critical for products with a short sales period. African cases confirmed the importance of "value addition" and quality infrastructure, which was consistent with the obtained estimates for the cold chain and standardisation. According to T. Wanyonyi (2023), it was found that in Kenya, limitations in value added in the chain were associated with a lack of post-harvest infrastructure, certifications and working capital financing. In the study of G.M. Njogu (2022), it was shown that the economic sustainability of the chain required reducing energy costs, compliance with environmental standards and increasing labour productivity, which corresponded to the estimated coefficients for energy and labour in the Ukrainian model.

To outline the practical limits of the sustainability of floriculture farms, the key risks that businesses face each season were considered: rising energy prices during the heating season, currency fluctuations, rising imported input prices, and shifts in logistics costs. Each of these factors exerts different pressures on costs and margins, and the impact is amplified by the winter energy consumption profile and the high share of imports in the cost basket. Table 3 shows how typical changes in these parameters translate into losses in profitability, thereby setting priorities for management decisions – from energy efficiency to cooperative purchasing and cold chain optimisation. The base period of 2022-2023 was chosen to analyse the impact of key risks on the costs and profitability of floriculture enterprises, as this period allowed assessing the latest stable trends, in particular after significant economic changes caused by the COVID-19 pandemic and energy crises. These years represent the latest available period with

complete cost and profitability data, allowing for the most accurate assessment of the impact on enterprises in the context of current economic and political challenges. Given the 2019-2024 study period, choosing 2022-2023 as a base allows for a correct comparison of changes that occurred after economic shocks and adaptive changes with earlier data.

Table 3. Impact of key risks on the cost and profitability of flower growing enterprises in Ukraine (base: 2022-2023)

Risk	Base value	Scenario	Impact on cost	Expected impact on profitability (ROS, pp)
The cost of natural gas	≈20,000 UAH/ thousand m³	+20% (heating season)	+12-15% in winter (due to the high share of energy in the cost price)	–5...–7 pp (β_G = –0.41 → +20 index points ≈ –8.2 pp; taking into account partial compensation by price/mix – observed –5...–7 pp)
UAH/USD rate	27.3 → 36.6 (Jan. 2022 → Aug. 2023)	±10%	±8-11% for imported items (planting material, crop protection products, fertilisers)	∓ 2... ∓ 3 pp (through 0.8-1.1 transmission on S; β_S = –0.27)
The cost of imported planting material	USD 24.45 million (HS 0603, 2022)	+15%	+5-7% in total cost	–1.5...–2.0 pp (β_S = –0.27; +15 index points → ≈ –4.0 pp; taking into account the share in COGS – –1.5...–2.0 pp)
Logistics costs	+30% y/y in 2022	another +10%	+4-5%	–1.0...–1.5 pp (due to direct transportation costs and indirect quality losses/write-offs)

Source: developed by the authors based on WITS (2021; 2022), Ministry of Energy of Ukraine (2022), National Bank of Ukraine (2022)

The presented scenarios confirm the hierarchy of sensitivities revealed by the regression: the most powerful negative impact is caused by an energy shock – +20% to the gas price adds +12-15% to the winter cost price and reduces ROS by ≈5-7 pp (modelled −8.2 pp, but partially compensated by pricing and mix). Currency fluctuations of ±10% are translated into ±8-11% increase in the price of imported items and reduce ROS by ±2...±3 pp, which is consistent with β_S and the assumption of incomplete pass-through to the cost price. A local increase in the price of imported planting material by +15% gives a relatively more modest, but tangible effect of −1.5... −2.0 pp through its share in COGS. Finally, an additional +10% of logistics costs reduce ROS by ≈1.0-1.5 pp, summing up both direct transportation costs and indirect quality losses/write-offs. Taken together, the table forms a "risk map" that suggests priorities for action: energy efficiency and diversification of energy sources during the heating season, hedging/cooperation tools against currency and import shocks, and investments in cold chain and JIT logistics to minimise write-offs. The discussion of the study results showed that institutional factors, such as limited access to financing and regulatory fragmentation, as well as logistical barriers identified in international examples from Latin America, were important for the competitive positions of enterprises. This was consistent with the study by C. Arcos & A. Carrera (2022), which identified barriers to innovation in the Ecuadorian sector, such as limited access to finance, technological gaps, and regulatory difficulties, which increased cost risks and delays in technology diffusion. The study by I. Guaita-Pradas *et al.* (2023) showed that the competitiveness of the Ecuadorian industry in 2016-2020 was determined by logistical integration, quality certifications, and stable export channels, which was consistent with the findings on the effects of cold storage hubs and JIT logistics on improving profitability.

In 2021-2023, the profitability of flower-growing enterprises was determined primarily by energy and currency risks, exacerbated by logistical shocks and a high share of imported inputs. The energy factor had the greatest weight: a 10% increase in the cost of energy carriers was accompanied by an average drop in profitability of approximately 4 pp. The impact of imported inputs was more moderate,

but significant: the 10% increase in price was associated with a 2.7 pp decrease in profitability. A 10% increase in labour costs reduced profitability by approximately 1.5 pp. Scenario calculations confirm this hierarchy: a gas price shock of +20% in winter reduces profitability by 5-7 pp; fluctuations in the UAH/USD exchange rate by ±10% give ∓2…∓3 pp; additional increase in logistics costs by 10% – another −1.0…−1.5 pp. Taken together, this indicates that the competitiveness of the industry is most vulnerable to energy and currency shocks, while logistics amplifies the amplitude of fluctuations.

Given the identified sensitivity, the following are of primary importance: energy-efficient investments in greenhouse complexes (LED, heat screens, recuperation, automation), which are able to return 2-4 pp of profitability in winter (Boyacı *et al*., 2025). Reducing import dependence on inputs through a local nursery base, certified planting material and cooperative purchases (potentially +1.3…+2.7 pp due to cheaper input basket) (FreshPlaza, 2024). Supply chain optimisation – cold chain, local JIT hubs, packaging standards and pre-ordering – which together can add about +0.8…+1.5 pp (NewCold, 2024). Thanks to these steps, companies increase the resilience of ROS/PCM (Return on Sales/Profit Contribution Margin) and reduce sensitivity to external shocks.

Increasing the competitiveness of floriculture enterprises is achieved not so much by individual steps, but by holistic business models that simultaneously reduce transaction costs, strengthen quality control and reduce sensitivity to energy and currency shocks. The logical first step is vertical integration: when cultivation is combined with post-harvest processing (sorting, packaging, cold chain) and its own sales channels, the company is less dependent on intermediaries, reduces quality losses and stabilises margins. In practice, this usually translates into an increase in gross margin by 1.5-3.0 pp and ROS profitability by 1.0-2.0 pp, as part of trade discounts and shortages disappear (Netherlands Embassy in Ukraine, 2019; OECD & FAO, 2024).

The next block is cooperation among small producers. When small farms combine purchases of inputs (planting material, pesticides, substrates), coordinate logistics and quality standards, small producers gain economies of scale and a better negotiating position. In monetary terms, this means a decrease in the import input index S by 5-10 points and, according to the estimated elasticities, an additional +1.3…+2.7 pp to ROS. Polish practice shows that cooperative structures can provide up to 30-40% of sales of decorative products, creating stable supply channels for small and medium-sized enterprises (SMEs) due to a "long" shelf life and predictability of demand (Netherlands Embassy in Ukraine, 2019; OECD & FAO, 2024). One of the striking examples is the Polskie Kwiaty cooperative, which unites more than 100 flower farms throughout Poland. Thanks to joint purchasing and joint marketing efforts, this cooperative was able to ensure stable sales for its members even during off-peak periods, which allowed increasing average sales by 25%. In addition, thanks to the "long shelf life", the cooperative members were able to predict the demand for seasonal flowers, which helped to reduce storage costs and reduce the risks of cash shortages (Kwiaty Polskie, n.d.). In parallel with the cooperation, it is worth developing own brands and premium segments: differentiation by variety, consistent quality and certifications (GlobalG.A.P., MPS) allows maintaining a 5-12% price markup at retail, which, with proper operational control, adds +2…+4 pp to PCM, although it requires more sophisticated demand management (OECD & FAO, 2024). Micro-level indicators of entrepreneurial capacity were consistent with the identified role of digital channels and standardised post-harvest processing. The study by K.A. Kiriveldeniya *et al.* (2020) indexed the entrepreneurial success of small-scale flower farms in Sri Lanka and highlighted the importance of market factors, skills, and access to finance. The results obtained in the work on the impact of vertical integration, branded lines and CRM solutions were consistent with the identified positive effects of increasing the share of direct sales and reducing transaction costs.

To smooth out seasonal revenue "dips", it is appropriate to integrate agro-tourism and event marketing – from tulip or lavender festivals to excursions and photo shoots in the fields. For example, the Keukenhof company in the Netherlands, known for its flower festivals, was able to significantly increase its sustainability

by organising an annual tulip festival. According to the results of 2023, the festival brought an additional EUR 5 million in revenue, and the number of visitors increased by 20%. This allowed the company to smooth out seasonal fluctuations in demand and increase the average revenue per visitor by 12%. In addition, the introduction of field tours and photo shoots with tulips has increased souvenir and flower sales by 15% in off-peak months (Keukenhof, 2023). This creates additional, less energy-intensive sources of income that can increase revenue by 3-7% y/y outside peak times and add 0.5-1.0 pp to ROS, provided that the variable cost of such services is low (OECD & FAO, 2024). As a result, the "integration – cooperation – branding – agro-tourism" link works as a mutually reinforcing system: integration reduces costs and losses, cooperation makes the input basket cheaper and stabilises supply, branding monetises quality through a premium, and event formats reduce seasonal volatility. The ranges of effects given are expressed in percentage points and are based on the cost structure and elasticity obtained in the previous sections; specific values should be verified on a sample of a specific enterprise or cooperative. A comparison of the study results showed that cross-industry collaborations in sales demonstrated the potential to increase marginality through joint packages with event, gastronomic and tourism products. According to S. Khade & D. Awsarikar (2025), partnerships with related industries were shown to reduce customer acquisition costs and increase the share of repeat purchases. This was consistent with the findings on the role of agro-tourism and event marketing in smoothing seasonal revenue.

The development of direct sales channels begins with e-commerce: own online storefronts and presence on marketplaces, a pre-order system for peak dates (14.02; 8.03), bouquet subscriptions and CRM management of customer lifetime value and repeat purchases. For example, Interflora UK recorded revenue growth of 5-10% in 2024 compared to the previous year, reaching USD 107 million. This indicates the effectiveness of direct sales channel strategies, including e-commerce, pre-orders and subscriptions, in stabilising demand and increasing financial sustainability (Interflora UK, 2024). When the share of direct sales increases to 30-50% of the portfolio, dependence on intermediaries and trade discounts decreases by 8-12 pp, which usually translates into an increase in gross margin ΔPCM = +3...+5 pp and profitability ΔROS = +1.5...+3.0 pp due to higher margins and better demand predictability (BRDO, 2023). For small and medium-sized producers, social media is the logical "front end" of this strategy. Instagram, Facebook and TikTok, combined with local same-day delivery, provide cheaper and faster access to the target audience, reducing the cost of customer acquisition by 20-35% compared to classic marketing and accelerating inventory turnover by 10-20%. Lower CAC (Customer Acquisition Cost) and faster turnover directly support liquidity and add to ROS, especially during off-peak periods (Fresh Produce Association, 2025). A discussion of the research results showed the consistency of the conclusions regarding the role of digital channels and differentiation with entrepreneurial strategies in the retail segment. N. Rahmawatini & M. Isti Raafaldini Mirzanti (2023) proposed a combination of positioning, online sales and customer base management as a means of increasing revenue sustainability, which correlated with the identified effects of e-commerce, pre-orders, and subscriptions. In addition, the authors pointed out service standardisation and branded offerings, which was also consistent with the results obtained for premium segmentation and private labels.

To monetise demand without losing quality, digital sales should rely on just-in-time logistics and the cold chain. Local "fast-turnover" hubs, slot contracts with carriers and packaging/temperature standards reduce transportation costs by 10-15% and quality losses/write-offs by 20-30%. In total, this adds about ΔROS = +0.8...+1.5 pp, and also reduces the risk of cash gaps during peak demand (World Bank, 2019; 2021). Operational assortment planning completes the connection. Shifting area and heat load to varieties with higher margins and lower elasticity in "off-peak" months allows maximising under existing area and energy constraints. In practice, such a mix adjustment can add +1...+2 pp to seasonal ROS, especially if it is aligned with

the pre-order calendar and cold chain capabilities (OECD & FAO, 2024). Discussion of the study results showed that the Northeast India region demonstrated limitations in entrepreneurial opportunities due to infrastructure, access to finance and lack of skills, which affected the speed of scaling export-oriented niches. According to K. Chittibomma *et al*. (2023), the importance of cluster approaches, incubation, and training in management practices for increasing competitiveness was highlighted. This was consistent with domestic results, where a positive impact of cooperative purchasing, cold storage hubs and quality certifications on ROS indicators was observed. South American sources noted that innovation and sustainability were a condition for maintaining an export position in the presence of logistical risks. In M. Pizano (2022), it was shown that innovation tools – from breeding to post-harvest technologies – reduced losses and increased quality uniformity in batches, which was consistent with the estimated effects of the cold chain. In parallel, the importance of "green" logistics and supply chain traceability was consistent with the sensitivity of profitability to transport costs found in the scenario analysis.

The chain "risk → decision → expected effect" for flower farms is best viewed as a sequence of controllable levers that reduce the sensitivity of the business to external shocks and restore profitability. It is worth starting with energy risk: when gas costs increase by 20%, the greenhouse cycle becomes sharply more expensive precisely during the heating season. The answer lies investments in energy efficiency – LED lighting, heat screens, recuperation, climate automation. Such solutions usually reduce energy consumption by 15-25% and return to profitability by about +2...+4 pp in the winter months, when margins are most vulnerable (World Bank, 2019; OECD & FAO, 2024). It is equally important to neutralise currency and import risk: a 10-15% increase in the price of imported inputs directly affects the cost price. Here, a combination of cooperative procurement and the development of a local nursery base with contracts for certified planting material works. The scale effect reduces the import input index S by 5-10 points, which – taking into account the estimated elasticities – adds approximately +1.3...+2.7 pp to ROS (WITS, 2022; OECD & FAO, 2024). To realise this effect, cooperatives should coordinate delivery schedules, quality requirements and currency formulas in contracts. A comparison of the results of the study showed that the regional example of the Indian state of Orissa demonstrated a connection between statistical indicators of production, access to markets and volumes of value added. According to S.S. Jena *et al*. (2025), it was found that logistics and standardisation bottlenecks caused deviations between potential and realised income during seasonal peaks by 12-15%. This conclusion was consistent with the estimated seasonal dummy variables, which showed a decrease in revenue variance by 8-10% when implementing a subscription/pre-order system as a tool for smoothing cash flows.

The third block is logistics. With unstable routes and an increase in costs by another 10%, enterprises lose not only money on transportation, but also product quality due to cold chain failures. The answer is local JIT hubs, slot contracts with carriers and packaging/temperature standards, i.e. a full-fledged cold chain infrastructure. As a result, transportation costs are reduced by 10-15%, write-offs by 20-30%, and the total increase in ROS is approximately +0.8...+1.5 pp (World Bank, 2021). Such projects are especially beneficial for cooperatives that can evenly load the hub. Finally, seasonal demand volatility, which traditionally "breaks" cash flow in the off-peak months. The move to pre-orders, subscriptions, and holiday packages allowed businesses like Bloom & Wild to significantly increase the resilience. According to the 2023 report, thanks to the implementation of a subscription system, demand in off-peak periods increased by 8%, and margins stabilised at 15%. As a result, cash gaps decreased by 18%, which allowed the company to maintain financial stability even during seasonal fluctuations in demand (BRDO, 2023). Taken together, these steps form a mutually reinforcing strategy: energy efficiency reduces base costs, cooperation reduces the cost of the input basket, JIT + cold chain minimises losses in logistics, and subscriptions and pre-orders smooth out seasonality – all of which directly translates into higher and more sustainable profitability. The demand structure for niche cut flowers confirmed the

need for a flexible assortment and rapid variety renewal. According to A. Darras (2021), it was found that the "speciality cut flowers" segment required shorter innovation cycles and closer interaction with designers and retailers, which increased the requirements for JIT logistics and quality standards. The results obtained on assortment planning and shifting the heat load to higher-margin varieties were consistent with these findings and demonstrated the potential for increasing ROS in off-peak months.

Empirical estimates have shown that the greatest pressure on profitability is exerted by energy costs and imported inputs, so the priority is models that simultaneously reduce energy intensity, import dependence and "cost of sales". A logical start is vertical integration: when cultivation is combined with processing (pre-cooling, sorting, packaging standards, cold chain) and control of sales channels, the enterprise loses less on intermediaries and defects and usually adds ΔPCM = +1.5...+3.0 pp and ΔROS = +1.0...+2.0 pp. To reduce the "price noise" of imported inputs, small producers should unite in purchasing cooperatives: joint tenders for planting material, crop protection products and substrates, longer contracts with a fixed price/currency formula provide economies of scale, reducing the S index by 5-10 points and adding approximately +1.3...+2.7 pp to ROS. In parallel, the "technical insulation" of the business should take place: investments in energy efficiency of greenhouses (LED, heat screens, recuperation, climate automation) and, where appropriate, the transition to hybrid sources (biomass, heat pumps) reduce winter energy consumption by 15-25% and return +2...+4 pp profitability in the peak season of consumption. Additional margin reserve is opened by branding and premium segmentation: certifications (GlobalG.A.P., MPS), transparency of origin and premium lines can provide +5...+12% markup in retail, which is converted into ΔPCM = +2...+4 pp with stable quality. Digital channels enhance the effect: own e-commerce, subscriptions, pre-orders for peaks (14.02; 8.03) and CRM campaigns paired with courier logistics "day-to-day" increase the share of direct sales to 30-50%, reduce the trade discount by 8-12 pp and add ΔPCM = +3...+5 pp and ΔROS = +1.5...+3.0 pp, while smoothing out cash gaps in "off-peak" months. The picture is completed by the development of a local nursery base (including in vitro) for cooperative demand and licensed varieties: this reduces currency and logistics lags, stabilises S and delivery times. To monitor progress, it was advisable to track: the share of energy costs in the cost of goods sold (E/COGS), the input index S (2021=100), the level of write-offs/returns, ROS/PCM, the share of direct sales and inventory turnover (in days). A comparison of the results of the study showed that conceptual reviews from the landscape and decorative industries confirmed the importance of innovative practices and cross-sectoral connections. A. Ferrante & F. Ferrini (2023) summarised that the integration of bioeconomic principles, urban greening and sustainability standards strengthened effective demand and opened additional sales channels for decorative products. This was consistent with the positive effects found in the study from the diversification of sales channels and premium segmentation.

At the macro level, policy should address three bottlenecks – energy, logistics, and import dependence of inputs – with simple tools with transparent effect metrics. First, capital grants/compensations for energy efficiency of greenhouses (20-40% of capex for LED, heat screens, recuperation) with priority for cooperative applications can systematically reduce energy consumption in the sector by 15-25% and reduce the sensitivity of ROS to price shocks by 20-30%. Second, preferential financing and credit guarantees (rate not higher than inflation +2-3 pp, guarantees up to 70-80% of the loan amount) reduce WACC (Weighted Average Cost of Capital) by 2-4 pp and compress the payback of energy projects to 3-5 years, opening a window for SMEs. Third, the logistics infrastructure of "fast turnover" – regional cold storage hubs with slot rental, standardised packaging and pilot e-auctions – reduces transportation costs by 10-15% and write-offs by 20-30%, while increasing the transparency of pricing and capital turnover. Next – clustering and cooperation programmes (co-financing of purchasing/marketing cooperatives, vouchers for quality standards, joint marketing campaigns), which reduce input purchase prices by 5-10% and expand SMEs' access to markets. A separate track – scientific and

innovative support (nursery, variety renewal, phytosanitary): grants/vouchers for applied R&D (research and development work), accelerated variety approval, laboratory base and "field-test" platform push import substitution and quality. Finally, the digitalisation of access to support – a single application portal, standard estimates, fixed deadlines, public ratings and prioritisation of energy savings and cooperation – reduces the transaction costs of participation for SMEs and increases competition for quality projects. The effectiveness of the policy should be measured by a set of KPIs: area of modernised greenhouses (ha) and share with LED/screens; energy savings (kWh/m²) and reduction of t CO_2-eq.; share of production passing through cold storage hubs; share of cooperative purchases and level of import substitution of inputs; ROS/PCM dynamics in the sample of beneficiaries versus the control group. Discussion of the study results showed that the Turkish case confirmed the need to combine energy efficiency and quality standardisation in a sustainable development strategy. According to A.Ü. Çürük & E. Alptekin (2022), the priority of measures to reduce greenhouse energy consumption and introduce certifications for access to external markets was justified. These findings were correlated with the estimated dominant negative impact of energy on profitability and with the proposed policy instruments of grants and preferential lending.

Thus, the results of the study showed that key strategies, such as energy-efficient investments, reducing import dependence and optimising supply chains, have an impact on increasing the competitiveness and sustainability of flower enterprises. The introduction of innovative technologies, cooperative purchasing and the use of modern logistics solutions allow not only to reduce costs, but also to stabilise income in conditions of seasonal fluctuations in demand. These results correlate with existing practices at the international level, where such strategies have proven the effective in improving the financial performance of enterprises.

CONCLUSIONS

The study found that the competitiveness of floriculture in Ukraine is determined by the structural import dependence of inputs and sales, the energy intensity of the greenhouse cycle, and logistical vulnerability. At the conjuncture level, it was confirmed: in 2021, imports of cut flowers amounted to USD 20.72 million (5.81 thousand tonnes), in 2022 – USD 24.45 million (4.57 thousand tonnes), while exports in 2023 remained at about USD 0.743 million (42.9 tonnes). The specific cost of imports increased approximately from USD 3.57 to USD 5.35 per kilogram, which reflects the increase in energy and logistics prices. Econometric results showed the dominant influence of the energy factor: a 10% increase in energy prices reduces the profitability of operating activities by an average of 4.1 percentage points; a 10% increase in the cost of imported inputs – by 2.7 points; a 10% increase in wages – by 1.5 points. Scenario modelling showed that a 20% gas price shock can reduce profitability by 5-7 points in winter; exchange rate fluctuations by ±10% – by ±2…±3 points; an additional increase in logistics costs by 10% – by 1.0-1.5 points. In practice, this means prioritising measures that reduce energy intensity and dependence on imports and reduce losses in supply chains. At the enterprise level, the feasibility of vertical integration (expected +1.0…+2.0 pp to profitability), cooperative input procurement (reducing the cost index by 5-10 points gives +1.3…+2.7 pp), investments in the cold chain and JIT logistics (+0.8…+1.5 pp), as well as the development of digital sales channels (+1.5…+3.0 pp) has been proven. At the political level, an effective combination is capital grants for energy efficiency (20-40% of the cost, total +2…+4 pp per season), preferential lending with guarantees (reducing the cost of capital by 2-4 pp), launching regional cold storage hubs, and supporting clustering and applied research in nurseries and phytosanitary. The limitations of the study relate to the use of proxy metrics of production based on foreign trade, potential endogeneity of individual factors, and the linear form of the model. Further directions encompass collection of panel microdata of enterprises, identification approaches to energy and exchange rate shocks, assessment of the effects of the return of tariff quotas in 2025, payback models of energy-efficient technologies, analysis of cluster viability and export readiness. Taken together, the quantitative results substantiate a roadmap for

increasing the profitability of the industry by 3-6 percentage points in the medium term.

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Конкурентоспроможність квітникарства як напряму аграрного підприємництва: економічні ризики та перспективи

Анотація. Метою роботи було кількісно оцінити конкурентоспроможність квітникарства як напряму аграрного підприємництва в Україні, виокремити ключові ризики та запропонувати управлінські й політичні рішення з урахуванням міжнародного досвіду. Методологія поєднувала теоретичні рамки (модель п'яти сил, ресурсно-орієнтований і кластерний підходи) з емпіричним аналізом: використано місячні ряди 2019-2024 років із міжнародних баз зовнішньої торгівлі та офіційної статистики; побудовано лінійну регресійну модель рентабельності продажів з індексованими факторами (база 2021=100) для цін на енергоносії, імпортних інпутів і заробітної плати; виконано сценарний аналіз. Через відсутність у відкритому доступі системних даних про внутрішнє виробництво ринкові оцінки отримано за проксі HS 0603; для підсегмента HS 0603.10 (троянди) у 2021 році імпорт становив 20,72 млн дол. і 5,81 тис. т, у 2022 році – 24,45 млн дол. і 4,57 тис. т; у 2023 році експорт загалом – близько 0,743 млн дол. (42,9 т). Питома вартість імпорту (0603.10) зросла з ≈3,57 до 5,35 дол./кг. Регресійні оцінки засвідчили, що підвищення індексу цін на енергоносії на 10 пунктів (≈+10%) асоціюється зі зниженням рентабельності продажів на 4,1 п.п., зростання індексу імпортних інпутів на 10 пунктів – на 2,7 п.п., індексу заробітної плати – на 1,5 п.п. Сезонні піки попиту (лютий-березень) суттєво концентрують виручку, що підвищує вимоги до планування запасів і збуту. Практична значущість полягає у кількісній оцінці очікуваних ефектів від вертикальної інтеграції, кооперації закупівель, енергоефективних інвестицій,

холодових логістичних хабів і цифрових каналів збуту; поєднання цих рішень разом із таргетованими грантами та пільговим кредитуванням здатне підвищити рентабельність галузі на ≈3-6 п.п. у середньостроковій перспективі

Ключові слова: ринок квітів; втрати; експорт; імпорт; рентабельність

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Fiscal instruments for supporting the financial security of agricultural enterprises in the face of global challenges

Abstract. The aim of this study was to assess the role of fiscal instruments in maintaining the financial security of Ukraine's agricultural enterprises in the context of military and global challenges. The research methodology was based on the application of systemic,

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institutional-normative, functional-analytical and statistical methods, which made it possible to analyse tax incentives, budgetary support, preferential lending, as well as the impact of inflation and monetary policy on the liquidity and solvency of agricultural enterprises. A summary of the results of the comprehensive analysis showed that the introduction of a minimum tax liability averaging around 1,400 UAH/ha was associated with increased transparency in land use, whilst simultaneously increasing the tax burden on farms with low margins. The differentiation of value-added tax rates (20%, 14% and 0%), combined with wartime tax relief, according to secondary sources, helped to reduce the cash flow gaps of individual enterprises by approximately 20-30%. Direct budgetary support in 2022-2025, estimated at between UAH 4 and 5 billion annually, as well as preferential lending, which exceeded UAH 104 billion in 2024, are seen as factors reducing debt servicing costs by approximately 15-20%. At the same time, the share of agricultural enterprises with insufficient absolute liquidity reached 74% in 2024. Peak inflation of 26.6% in 2022 and the National Bank of Ukraine's increase of the discount rate to 25% significantly constrained the agricultural sector's investment capacity. The directions for adapting fiscal mechanisms included the digitalisation of tax and budget administration, regional differentiation of tax and budgetary incentives, integration with European financial programmes, and the combination of fiscal, credit and insurance instruments to enhance the financial security of the agricultural sector. The practical significance of the study lies in the possibility of its results being used by public authorities to improve fiscal policy and by agricultural enterprises to enhance liquidity and financial stability in the face of wartime challenges

Keywords: liquidity; solvency; lending; subsidies; volatility; budgetary support

INTRODUCTION

The financial security of the agricultural sector is under pressure from global challenges, including geopolitical instability, market volatility, climate risks, inflation and limited access to financial resources, which leads to an increased tax burden, the cost of capital and threatens the solvency, investment capacity and long-term financial stability of agricultural enterprises. Under conditions of wartime and macroeconomic instability, agricultural entrepreneurship faces rising financial risks, restricted access to credit, logistical disruptions, and increasing costs, which has necessitated the strengthening of state financial support. These issues were addressed in the research of L. Vdovenko (2022), which assessed state measures to support agricultural enterprises during martial law, analysed the dynamics of bank lending, the role of interest rate compensation programmes, budgetary subsidies, and state guarantees, and demonstrated the positive impact of adapting the "Affordable Loans 5-7-9%" programme on increasing the share of credit resources in financing agricultural producers.

The functioning of small and medium-sized agricultural enterprises under wartime and post-war transformations has been accompanied by increased financial vulnerability due to asset losses, limited access to financing, logistical disruptions, and heightened investment risks, which has constrained recovery and stable development. I.O. Feduniak & W.S. Habor (2025) examined the economic security of small and medium-sized agricultural enterprises as a component of national security, analysed the dynamics of business structures between 2010 and 2023, identified the key factors of their financial instability in wartime conditions, and assessed the role of state support programmes, in particular the "5-7-9%" preferential lending scheme, relocation programmes, and budgetary stabilisation mechanisms. The results of the study showed that small and medium-sized agribusinesses have the potential to adapt with state support, but are characterised by a low level of economic security and limited access to finance. The study by N. Zelisko *et al.* (2024) analysed the impact of digitalisation, the use of Big Data, blockchain technologies, the Internet of Things and artificial intelligence on the improvement of business processes and the enhancement of economic security for agricultural

enterprises; it was also demonstrated that the implementation of smart farming, automation and risk management systems contributes to cost reduction, increased productivity and the stabilisation of financial results. The findings demonstrated the effectiveness of an integrated combination of technological innovations and financial planning in strengthening the resilience of the agricultural sector.

The functioning of agricultural enterprises in Ukraine was accompanied by heightened financial risks associated with the seasonality of production, price volatility, climatic threats and restricted access to financial resources, which necessitated the development of a comprehensive financial security system. B. Khakhula *et al.* (2024) focused on innovative risk management tools for production activities, examining them in relation to the institutional environment, digital financial technologies, contract farming, and futures and spot pricing mechanisms. The authors demonstrated that the integration of these tools creates the conditions for enhancing the financial stability, liquidity and capacity of agricultural enterprises for sustainable reproduction. In conditions of uncertainty and rising financial risks, the issue of a well-founded choice of enterprises' financial strategies becomes increasingly relevant, taking into account the impact of external and internal factors that threaten the stability of operations, as evidenced by the study by L. Kostyrko *et al.* (2024). In their work, the authors developed methodological foundations for a comprehensive risk analysis, combining a scenario-based approach, an indicator-based assessment system and a financial stability audit, and demonstrated the practical application of the proposed tools using the example of large Ukrainian enterprises, which made it possible to identify the impact of risks on profitability, liquidity and market value. V. Sapych (2024) focused on the current state of financial support for the agricultural sector, analysed the dynamics of government expenditure, the effectiveness of budgetary subsidies and grants, and justified the advisability of reorienting support from direct budgetary payments towards grant mechanisms, taking into account regional disparities and losses incurred by enterprises in frontline and de-occupied territories.

The growing financial vulnerability of agricultural entrepreneurship under conditions of wartime and global transformations highlights the need to improve approaches to state intervention aimed at enhancing the resilience and predictability of economic outcomes of business entities. V. Dankevych *et al.* (2025) focused on the interaction between economic policy, institutional prerequisites, and digitalisation, analysing the role of state programmes, regulatory decisions, and financial mechanisms in increasing transparency, investment efficiency, and the adaptive capacity of agricultural enterprises, substantiating that the combination of politico-economic incentives with digital tools contributes to reducing transaction costs and strengthening financial discipline.

At the same time, existing studies have largely focused on the institutional, technological or financial aspects of support for agricultural enterprises, whilst the role of fiscal instruments, their impact on financial security, liquidity, debt sustainability and the ability to counter global challenges have remained insufficiently systematised and require further academic examination. The aim of this study was to determine the impact and effectiveness of fiscal mechanisms in shaping the financial security of Ukraine's agricultural enterprises in the context of military and global challenges. To achieve this aim, the following objectives were set out in the article: to analyse existing tax incentives, budgetary funding and other forms of state fiscal support for agrarian enterprises from the perspective of their impact on the financial stability and solvency of economic entities; to assess the effectiveness of fiscal policy in the context of global challenges by summarising statistical data and determining the impact of the war and inflationary processes on the financial security of agricultural enterprises.

MATERIALS AND METHODS

The study covered the period from 2022 to early 2025, as this period is characterised by the introduction and implementation of key fiscal changes and state support mechanisms for agricultural enterprises under martial law. Within the scope of the study, the impact of key fiscal instruments, in particular value added tax (VAT),

was examined based on an analysis of aggregated data from KPMG (n.d.) and R. Yemets & O. Borodkin (2022), using a systematisation approach and a comparative-analytical method. Key VAT concessions and wartime adaptations for agricultural enterprises were examined, including the reduced rate of 14%, the 0% rate, VAT deferral mechanisms, a moratorium on tax audits, and simplified registration of tax invoices. These instruments were analysed according to criteria of accessibility, duration and impact on enterprises' cash flows, with the aim of interpreting their role in reducing cash flow gaps and maintaining current liquidity under martial law.

The impact of fiscal and credit instruments was assessed through statistical and dynamic analysis of lending volumes to agricultural enterprises under the "Affordable Loans 5-7-9%" programme (PrivatBank, n.d.). Changes in the volume of credit resources raised, the number of recipients and the terms of financing were examined to determine the role of preferential lending in reducing the cost of capital and maintaining the solvency of agricultural enterprises during a period of limited access to market financial resources. Particular attention was paid to the analysis of direct budgetary support for the agricultural sector. Using statistical and structural analysis, the dynamics of budgetary funding volumes, its allocation, and its impact on the current liquidity indicators of small and medium-sized agricultural enterprises were assessed. Additionally, the sectoral structure of budget support allocation was analysed to identify priority funding areas and their stabilising effect under a wartime economy (Dragan *et al*., 2023; Gontagro, 2025).

The resilience of agricultural enterprises under the influence of global challenges was analysed using an institutional-regulatory approach. The specific features of VAT liability formation during the wartime period were examined, as well as the provisions of current legislation, in particular Law of Ukraine No. 2120-IX (2022) and Resolution of the Cabinet of Ministers of Ukraine No. 560 (2024), with the aim of determining the regulatory conditions for the operation of agricultural enterprises during the period of martial law and their impact on the financial behaviour of economic entities. Macroeconomic factors affecting the financial security of the agricultural sector were assessed through a dynamic analysis of inflation rates in Ukraine during 2022-2025 and changes in the discount rate of the National Bank of Ukraine, based on official reports from MinfinMedia (n.d.a; n.d.b). An analysis of inflationary processes and the cost of capital was carried out to assess their impact on the debt burden and investment capacity of agricultural enterprises. Based on a synthesis of the results obtained using systemic, comparative and institutional analysis, directions for adapting fiscal mechanisms to enhance the financial security of the agricultural sector were substantiated. To this end, the method of functional-institutional analysis was used, which enabled an assessment of the role of digital tools for tax and budget administration in ensuring liquidity and reducing transaction costs for agricultural enterprises, in particular the State Agrarian Register (n.d.), the Electronic Taxpayer's Cabinet (n.d.) and the electronic value-added tax refund system (Ministry of Finance of Ukraine, n.d.b).

The analysis of European financial support programmes for the agricultural sector was carried out using institutional-normative and analytical-review methods, which made it possible to determine the potential for integrating the instruments of the Ukraine Facility programme (European Commission, n.d.a), the EU4Business initiative (n.d.) and the financial mechanisms of the European Investment Bank (n.d.) into Ukraine's fiscal support system for the agricultural sector. The mechanisms of the European Union's Common Agricultural Policy (CAP) (European Commission, n.d.b) were analysed separately. In particular, the study examined CLLD (Community-Led Local Development) approaches (European Commission, 2014), support instruments under the Common Agricultural Policy – Pillar I (European Union, 2016a) and the Common Agricultural Policy's investment support programme for agricultural holdings – Pillar II (European Union, 2016b). The application of an institutional-analytical approach to these programmes was aimed at identifying opportunities for their adaptation to national fiscal policy with a view to enhancing the financial sustainability and investment capacity of agricultural enterprises.

RESULTS

An assessment of the impact of existing fiscal instruments on the financial security of agricultural enterprises

Between 2022 and 2025, tax regulation of agricultural enterprises in Ukraine became more dynamic, and the system came to be based on risk assessment following the simultaneous introduction of a minimum tax liability (MTL) on land, the differentiation of VAT rates for specific types of agricultural produce, and the introduction of wartime exemptions. The most significant structural shift for most farms was the introduction of the MTL in 2022: tax payments began to depend more heavily on the normative monetary valuation (NMV) of land and the actual use of that land, rather than solely on financial results. The MTL amounted to approximately 700-1,400 UAH/ha (on average ~1,400 UAH/ha), whereas the single tax for Group 4 for a typical farm was estimated at around ~270 UAH/ha, which reinforced the "threshold" effect and encouraged the legalisation of land use and more accurate recording of areas (AgroTimes, 2022).

The evolution of changes over the years demonstrates the logic of the transition from incentives to the strengthening of control mechanisms and "targeted" relaxations during the war period. In 2021, for a number of key crops, the VAT rate was reduced from 20% to 14% (from 1 March) for supplies to the domestic market, whilst preferential terms were provided for certain transactions (in particular, breeding animals and genetic material) (PwC, 2021). In 2023, exemptions from land tax were introduced for contaminated, occupied territories and land in combat zones (in particular under Law of Ukraine No. 3050-IX (2023)), which effectively reduced costs for affected plots by approximately 10-15%, but required documentary proof of the land's status. In 2024, alongside the tightening of anti-shadow economy measures (MTL of 700-1,400 UAH/ha), an additional factor was the increase in the military levy to 5% from December, which affected the overall tax burden (Kurkul, 2024). In 2025, the MTL coefficient changed (from 0.05 to 0.057), whilst payments for 2024 were calculated based on a 5% of the NMV, creating upward expectations for 2026 and the need for accurate forecasting of payments (Latifundist Media, 2025). The impact of VAT on liquidity was evident not only through the rates (20% standard, 14% for certain crops, 0% for exports and specific transactions), but also through wartime concessions, which directly "eased the burden" on cash flows (Agroreview, 2025). The systematisation of key VAT reliefs and wartime adaptations is presented in Table 1.

Table 1. Key VAT reliefs and wartime adaptations for agricultural enterprises

Relief	Details	Conditions of application
Reduced rate of 14%	Supply of cereals (maize, barley, oats), soybeans, sunflower, and sugar beet	In force since 2021; applies to the domestic market for specified categories
0% rate	Export of agricultural products; breeding animals and genetic material	VAT payer registration and proper documentary confirmation required
Deferral of VAT payment	Up to 12 months for operations in combat or occupied areas	Wartime relief measures; application linked to territorial status and specific circumstances
Moratorium on inspections	Restrictions on documentary VAT audits	Wartime period; dependent on the control regime and reporting period
Simplified registration of invoices	Registration of electronic invoices without blocking in crisis-affected regions	Compliance with electronic registration procedures and primary documentation requirements

Source: compiled by the authors based on R. Yemets & O. Borodkin (2022), KPMG (n.d)

In view of Table 1, VAT instruments provided a "rapid" effect on liquidity through the deferral of payments and the reduction of cash outflows; for frontline farms, this could reduce cash gaps by approximately 20-30%, although it increased requirements for the substantiation of transactions and the quality of accounting (classification of goods, primary documentation, territorial status). An additional practical factor was the difference in tax regimes: agricultural producers under the single tax of the 4th group are not VAT payers, but upon exceeding the

revenue threshold (UAH 1.99 billion) they transition to the general taxation regime, which may significantly alter the structure of tax payments. At the same time, the increase in social contributions (unified social contribution (USC) – 22%) in 2025 intensified the burden on payroll: the minimum contribution rose from approximately UAH 1,562 per month to UAH 1,760 per month, while the maximum base expanded to 20 times the minimum wage, increasing the need for budgeting and automation of calculations (7eminar, 2025).

In 2022-2025, budgetary funding, subsidies and compensation mechanisms became a key instrument for supporting the solvency and investment activity of Ukraine's agricultural enterprises amid martial law, macroeconomic instability and limited access to market-based financial resources. The total volume of direct budgetary support for agricultural enterprises during this period fluctuated between UAH 4-5 billion annually, with a noticeable shift in the structure of expenditure towards liquidity support programmes and targeted investment incentives, focused primarily on small and medium-sized farms. From 2022 onwards, the role of indirect budgetary liquidity support instruments, primarily preferential lending, grew. Under the "Affordable Loans 5-7-9%" programme (PrivatBank, n.d.), farmers raised UAH 90.85 billion in 2022, and in 2024 – already UAH 46.9 billion for 8,750 farms, which exceeded the previous year's figures by over 20% (Kurkul, 2022). The total volume of lending to the agricultural sector in 2024 exceeded UAH 104 billion, with peak disbursements in December, which allowed for a 15-20% reduction in debt servicing costs compared to market conditions and helped maintain solvency during periods of seasonal peak expenditure (Ministry of Agrarian Policy and Food of Ukraine, 2025).

In 2023-2024, the volume of direct budgetary support rose to UAH 4.5 billion, whilst eligibility for the programmes was strictly tied to registration in the State Agricultural Register, asset insurance and the principle of limited rotation of beneficiaries. In 2024, 20-30% of budget funds (approximately UAH 800-1,500 million) were directed directly towards liquidity support through subsidies per hectare and livestock maintenance, enabling farmers to finance social contributions, insurance and basic production needs (Gontagro, 2025). These payments contributed to an increase in the current liquidity ratio of small and medium-sized farms by an average of 0.2-0.5 points, and for farms up to 120 ha – to a level of 1.8, reducing cash flow gaps during sowing and harvesting. In parallel with liquidity instruments, the investment component of budgetary support was expanded. In 2024-2025, 70-80% of funds were allocated to grants for horticulture (UAH 383 million), greenhouse complexes (UAH 96 million), processing, and compensation for 25% of the cost of Ukrainian-made agricultural machinery, which facilitated the sale of over 7,000 units of machinery worth approximately UAH 5 billion. These programmes generated a multiplier effect in attracting private investment at a ratio of 1:2-1:3, but remained more accessible to financially sounder enterprises. At the same time, the effect of budgetary support was mixed. Delays in payments and the growth of current liabilities during the war period limited the impact on absolute liquidity: the proportion of enterprises with insufficient liquidity rose to 74% in 2024, indicating that a cash deficit persisted even as state support increased (Dragan *et al.*, 2023).

Thus, in 2022-2025, the combination of tax changes, wartime relief measures, and budgetary support formed a hybrid model of financial regulation of agricultural entrepreneurship, in which fiscal instruments simultaneously performed de-shadowing and stabilisation functions. The introduction of the minimum tax liability increased the transparency of land use and the predictability of revenues, while VAT reliefs and wartime exemptions ensured short-term improvements in liquidity. Budgetary subsidies and concessional lending partially reduced insolvency risks and supported investment activity, particularly for small and medium-sized farms; however, their effect remained uneven and was constrained by payment delays and the growth of current liabilities. This indicates the need for further improvement in the targeting and synchronisation of fiscal and budgetary mechanisms with the actual liquidity needs of agricultural enterprises.

An analysis of the resilience of agricultural enterprises in the face of global challenges

Wartime risks in 2022-2025 reshaped the fiscal and budgetary environment of agricultural entrepreneurship, simultaneously narrowing the tax base and forcing the state to introduce "crisis" regimes to preserve the solvency of producers and food security. The tax regime became more territorially differentiated: for land located in zones of active hostilities, temporary occupation, contamination, or mining, special rules were applied to land tax, the single tax (in particular the 4th group), and the MTL, including the possibility of proportional accrual by months or temporary non-accrual/non-payment during the preferential period. For agricultural enterprises, this meant a short-term reduction in tax pressure precisely during critical periods of sowing and harvesting; however, for local communities, it resulted in direct losses of local budget revenues, where land payments often constituted a significant share of own revenues (approximately up to 20-30% in rural communities). Such a preferential regime created funding shortages for infrastructure and social services and increased dependence on interbudgetary transfers, while the recovery of revenues depended directly on the pace of de-occupation, demining, and the restoration of economic use of land. Additionally, a "deferred fiscal effect" emerged: part of the provisions functioned as a deferral rather than a final exemption, complicating medium-term budget planning for communities and increasing the risk of simultaneous fiscal pressure after the easing of wartime exemptions (Prostir, 2023).

At the same time, martial law significantly altered the administration of indirect taxes, primarily VAT, which for the agricultural sector became an instrument of anti-crisis relief for cash flows. Some producers were able to temporarily switch to a special regime with a 2% single tax on income, which effectively eliminated VAT liabilities on sales during the period of application of this regime, while the tax credit formed prior to the transition was preserved for use upon returning to the general system (Fomenko, 2022). In combat zones, the relaxation of requirements for confirming the VAT credit was also critical: during disruptions in electronic document circulation, it was permitted to form tax credit based on primary documents with subsequent clarification after invoice registration, reducing the risk of costs being excluded from accounting and supporting working capital. Specific provisions were also introduced for cases of destruction of products, inventories, or fixed assets due to force majeure: such losses were not treated as use outside economic activity, thereby eliminating the risk of accruing "deemed" VAT liabilities, provided that proper documentation (inspection reports, certificates, etc.) was available. Targeted exemptions and simplifications were also applied to the import of certain goods for simplified tax groups and to operations related to defence needs, which reduced cash gaps in the supply of fuel, materials, and equipment (Nesterov, 2022). At the same time, the retention of differentiated VAT rates (in particular 14% for certain agricultural products and 0% for exports and specific operations) remained an important factor in pricing, net revenue, and liquidity, although it increased sensitivity to errors in product classification and the quality of primary documentation (State Tax Service of Ukraine in Sumy region, 2025).

The legal framework for the introduction of wartime tax relief is provided by Law of Ukraine No. 2120-IX (2022), which sets out the specific provisions for taxation during the period of martial law, in particular the mechanisms for tax relief and deferrals, with tax liabilities being carried forward to the post-war period without the imposition of penalties or interest. The implementation of these provisions was detailed in subordinate legislation, notably Resolution of the Cabinet of Ministers of Ukraine No. 560 (2024) (as amended by Resolution No. 1364 of 24 October 2025), which clarified the procedural aspects of applying preferential regimes in the context of mobilisation and security restrictions. The practical application of tax regulations in wartime conditions was also based on official clarifications from the Ministry of Finance of Ukraine (Ministry of Finance of Ukraine, n.d.a) and the State Tax Service of Ukraine (State Tax Service of Ukraine, n.d.), which ensured the adaptation of tax administration to unstable economic conditions.

The budget framework in 2022 underwent a sharp contraction due to the reallocation of

resources to defence and a decline in economic activity: real GDP fell by almost 30%, the budget deficit rose to approximately 17.6% of GDP, and expenditure in a number of "non-defence" sectors was significantly reduced (economic activity – by 58% in real terms, environmental protection – by 61.3%, housing and communal services – by 42.9%) (Government portal, 2023). This meant that the scope for rapidly increasing direct support for agribusiness was limited, and priorities shifted towards programmes offering the quickest impact on the survival of production (operational subsidies, per-hectare compensation in risk zones, relief from local payments) and towards targeting based on territorial status. At the same time, even with tax relief in place, the financial performance of agricultural enterprises deteriorated under wartime conditions due to a combination of production and market shocks: the occupation of around 20% of agricultural land and damage to infrastructure reduced production volumes, whilst logistical constraints and port blockades forced exports onto more expensive routes, whilst rising costs of fuel, energy and fertilisers (by 50-100%) increased production costs by 25-35% and compressed margins. Additionally, price discounts on Ukrainian produce due to the risk associated with its origin (20-30%) reduced revenue even amid relatively high global prices. Ultimately, the risks of war affected tax revenues and budgetary capacity not only through formal concessions but also through an objective narrowing of the tax base, uneven recovery of economic activity across regions, and a chronic cash shortage in the sector, which made supporting liquidity through short-term instruments necessary, but an insufficient condition for restoring profitability (Fesenko *et al*., 2022). In 2022-2025, inflation in Ukraine was volatile and became one of the key sources of financial risk for agricultural enterprises, simultaneously affecting production costs, liquidity, debt burden and investment activity (Fig. 1).

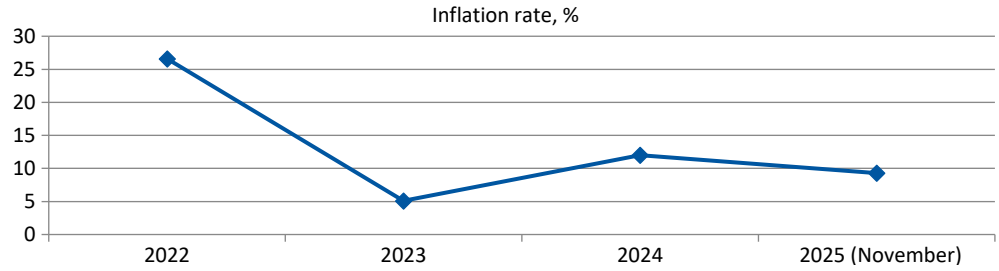

Figure 1. Annual inflation rate in Ukraine, 2022-2025
Source: compiled by the authors based on MinfinMedia (n.d.a)

The most significant price shock occurred in 2022, when annual inflation reached 26.6%, sharply increasing nominal operating costs for fuel, fertilisers, electricity, machinery maintenance, and logistics. In 2023, inflation slowed considerably to 5.1%, which formally reduced the rate of increase in input costs; however, this did not offset the losses of the previous year and maintained high inflationary expectations. In 2024, inflationary pressure intensified again to 12.0%, while as of November 2025, annual inflation had slowed to 9.3%, indicating partial stabilisation. Inflationary pressure was driven by five groups of factors, each of which had measurable consequences for the economic performance of agricultural enterprises. First, energy costs and electricity shortages increased production costs, and the effect was felt particularly acutely in energy-intensive segments of agribusiness. Second, disruptions to logistics and supply chains caused by hostilities increased transport and storage costs, which were passed on to the prices of food and industrial goods. Third, devaluation and currency risks drove up the cost of imported inputs (seeds, fertilisers, machinery), fuelling inflationary expectations and increasing production costs. Fourth, the import dependency of agricultural costs, combined with rising global prices for raw materials and fertilisers, increased the cost base and reduced the ability

to "pass on" costs to the end consumer without losing competitiveness. Fifth, military and macroeconomic factors – rising defence spending, the disruption of production chains and general instability – sustained the inflationary backdrop and made it less predictable (Danylyshyn, 2022; National Bank of Ukraine, 2023). In parallel with inflation, the cost of capital rose, which directly affected the debt sustainability of agricultural enterprises (Fig. 2).

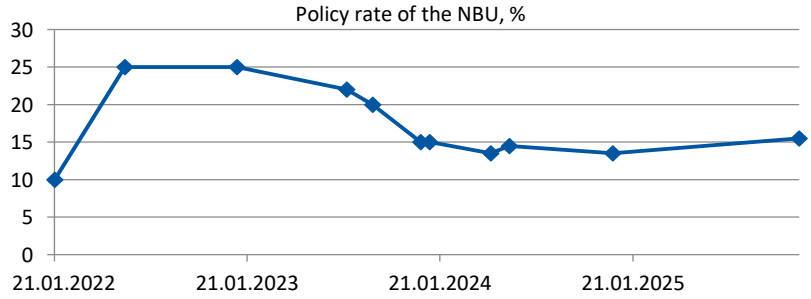

Figure 2. Dynamics of the policy rate of the National Bank of Ukraine in 2022-2025
Source: compiled by the authors based on MinfinMedia (n.d.b)

In 2022, the policy rate of the National Bank of Ukraine increased from 9-10% to a peak level of 25% in response to the full-scale invasion. In 2023, following a period of tight monetary policy, a gradual reduction of the rate took place to 15% by the end of the year. In 2024, the rate fluctuated within the range of 13.5-14.5% and ended the year at 13.5%. As of December 2025, the policy rate had risen to 15.5%, indicating the persistence of tight financial conditions. Overall, the dynamics of the rate suggest that even with slowing inflation, the cost of credit resources remained high, and for agricultural enterprises, particularly under wartime risks, the effective cost of financing was further elevated (MinfinMedia, n.d.b). In 2022-2025, war risks radically transformed the fiscal and budgetary environment for Ukraine's agricultural sector, combining a narrowing of the tax base with the introduction of crisis tax and budgetary regimes. Geographically differentiated concessions regarding land tax, the single tax and the minimum tax liability allowed agricultural enterprises to reduce the tax burden during critical periods, but resulted in significant losses of revenue for local budgets and created a deferred fiscal impact for communities. War-related changes in VAT administration and the introduction of special regimes became a significant tool for short-term liquidity support, but raised the bar for accounting quality and tax compliance. At the same time, the state's budgetary capacity remained limited due to the fall in GDP and the reallocation of expenditure towards defence, which led to a focus on operational rather than investment support for the agricultural sector. Inflationary shocks and rising capital costs further worsened the financial performance of agricultural enterprises, intensifying pressure on production costs, liquidity and debt sustainability. Ultimately, state support during the war played a key stabilising role, but remained insufficient to restore the pre-war levels of profitability and investment activity in the agricultural sector.

Areas for adapting fiscal mechanisms to enhance the financial security of the agricultural sector

The intensification of global challenges, war risks and structural transformations in agricultural production necessitate a shift from a uniform fiscal policy to an adaptive model capable of accounting for the scale of operations, regional specificities and varying levels of financial risk among agricultural enterprises. In the 21st century, fiscal mechanisms must fulfil not only a fiscal function but also a stabilising and restorative one, helping to preserve the liquidity, debt sustainability and investment potential of agribusiness. The adaptation of fiscal mechanisms to support the agribusiness sector in the face of global challenges must be

based on a combination of the digitalisation of administration, regional differentiation of tax and budgetary incentives, and the alignment of fiscal policy with risk management tools. A key priority is the digitalisation of tax and budget administration, which reduces transaction costs for agribusinesses and speeds up access to state support. In particular, the State Agrarian Register (n.d.) is used to identify recipients of subsidies and grants, the Electronic Taxpayer's Cabinet (n.d.) – to administer tax relief and deferrals, and the electronic VAT refund system (Ministry of Finance of Ukraine, n.d.) to expedite tax credit refunds for export-oriented producers. The combined use of these tools is aimed at improving liquidity and reducing tax compliance costs.

The analysis of the integration of Ukraine's fiscal instruments with European financial programmes has shown that such interaction is formed through the combination of national tax and budgetary mechanisms with external investment and grant resources. The European Union programme Ukraine Facility (European Commission, n.d.a) functions as a framework instrument for budgetary and investment support, within which national-level fiscal incentives (tax reliefs, interest rate compensation, state guarantees) are used to co-finance agricultural programmes and reduce financial barriers to attracting funds. This approach enables the integration of tax policy into the implementation mechanisms of EU-supported investment projects. The EU4Business initiative (n.d.) is integrated into the system of fiscal support through the combination of grant and credit instruments with national tax regimes, including simplified taxation, tax deferrals, and partial compensation of financial costs. This creates conditions for reducing the tax burden on small and medium-sized agricultural enterprises at the stage of attracting financing and enhances their solvency during periods of wartime instability. Programmes of the European Investment Bank (n.d.) are used to finance infrastructure and "green" agricultural projects, where integration with fiscal instruments is implemented through the combination of long-term concessional lending with tax incentives for capital investment. Such interaction contributes to reducing the cost of capital, distributing financial risks, and strengthening the investment activity of agribusiness. Overall, these mechanisms form a combined support model in which fiscal instruments perform a compensatory function, while European financial programmes fulfil an investment function, thereby enhancing the financial resilience of Ukraine's agricultural sector and aligning its support system with European approaches.

The third direction is the regional differentiation of fiscal incentives, which is of particular importance for frontline and de-occupied territories in Eastern and Southern Ukraine, including the Kharkiv, Kherson, Zaporizhzhia, Donetsk, and Luhansk regions, where agricultural production operates under heightened security risks, land contamination, and destroyed infrastructure. The application of targeted tax reliefs, per-hectare subsidies, and compensation for crop losses makes it possible to support the liquidity of agricultural enterprises in high-risk regions, where production is associated with additional costs for security, logistics, and insurance. In this context, not only tax relief measures are important, but also budgetary expenditures on humanitarian demining, the restoration of irrigation systems, and infrastructure, without which the full recovery of agricultural production is impossible (Interfax-Ukraine, 2025). The fourth direction of fiscal policy adaptation is the diversification of financial risks through the combination of tax, insurance, and credit instruments. The integration of tax holidays, state guarantees for loans, crop insurance, and the development of cooperation reduces income volatility of agricultural enterprises and increases their ability to withstand price, climate, and wartime shocks. Practice shows that the comprehensive application of such instruments can reduce fluctuations in agribusiness profitability by 15-20% and stabilise cash flows even under crisis conditions (Stepanenko & Kanelska, 2024).

The systemic nature of the approach to adapting fiscal mechanisms is complemented by medium-term budgetary priorities. The 2026 State Budget provides for a significant increase in support for the agricultural sector, with total funding amounting to UAH 14.1 billion, which is UAH 4.5 billion more than in 2025. The main focus is on instruments that enhance the financial security of producers: per-hectare subsidies

for farms in frontline regions, support for agricultural insurance, the restoration of irrigation, and humanitarian demining of land. In addition, UAH 2.6 billion is allocated to support farming through concessional lending and subsidies, and UAH 2 billion is directed towards clearing agricultural land of explosive hazards, which is a key condition for returning land to economic use (Government portal, 2025). The summary of the main directions for adapting fiscal mechanisms and their impact on the financial security of agricultural business is presented in Table 2.

Table 2. Directions for adapting fiscal mechanisms to enhance the financial security of agricultural business

Direction of adaptation	Instruments and programmes	Expected impact on financial security
Digitalisation of administration	E-services of the State Tax Service, State Agrarian Register, automated access to reliefs and subsidies	Reduction of administrative costs, acceleration of cash inflows
Integration with the EU	CAP programmes – CLLD, Common Agricultural Policy – Pillar I, Investment Support for Agricultural Holdings (Pillar II); "green" loans and insurance mechanisms	Diversification of financing, reduction in the cost of capital
Regional differentiation	Reliefs and subsidies for frontline and de-occupied territories	Support for liquidity under conditions of elevated risk
Risk diversification	Crop insurance, state guarantees, cooperation	Reduction of income volatility, stabilisation of cash flows
Budgetary support for 2026	Per-hectare subsidies, demining, land reclamation, 5-7-9% loans	Enhancement of resilience and investment capacity of agribusiness

Source: compiled by the authors based on European Commission (2014), European Union (2016a; 2016b), European Commission (n.d.b), PrivatBank (n.d.)

Summarising the data in Table 2, it can be stated that the combination of digitalisation of fiscal administration, European integration financial instruments, regionally oriented incentives, and risk diversification mechanisms forms a comprehensive model for enhancing the financial security of agricultural business. The Common Agricultural Policy was considered as an instrument for diversifying sources of financing and reducing the cost of capital for agribusiness, as its mechanisms combine budgetary support with tax and financial instruments, thereby reducing the dependence of enterprises on domestic fiscal resources. Within the table, CLLD correlated with the direction of regional differentiation of fiscal incentives and may be adapted through the application of targeted tax reliefs and budgetary subsidies for frontline and de-occupied territories, which contributes to supporting the liquidity of agricultural enterprises in high-risk regions and enhances the targeting of budgetary support. The instruments of the Common Agricultural Policy – Pillar I (European Union, 2016a), aimed at stabilising the income of agricultural producers, correspond to the objective of reducing cash flow volatility and may be adapted through a combination of direct budgetary subsidies with tax compensatory mechanisms, thereby creating conditions for increasing the predictability of financial results of agricultural enterprises without increasing the tax burden. The programmes of the Common Agricultural Policy – Pillar II (European Union, 2016b), related to investment support for agricultural holdings, correspond in the table to instruments of "green" financing, insurance, and long-term lending, and their adaptation within national fiscal policy is aimed at reducing the cost of capital and strengthening the investment activity of agribusiness through the combination of investment programmes with tax incentives. Such an approach makes it possible to simultaneously reduce administrative and financial costs, support liquidity in regions with elevated wartime risks, and strengthen the investment potential of enterprises. The instruments incorporated into the 2026 budget complete this model, ensuring short-term stabilisation and forming the prerequisites for the long-term resilience of the agricultural sector under global challenges.

Thus, the adaptation of fiscal mechanisms in the agricultural sector of Ukraine under global challenges and wartime risks is becoming

systemic in nature and extends beyond purely budgetary regulation. The study has shown that the transition from a uniform to an adaptive fiscal model is an objective necessity, as only a differentiated approach allows for the simultaneous support of liquidity in agricultural enterprises, the reduction of financial risks, and the preservation of national food security. The combination of digitalisation of fiscal administration, integration with European financial programmes, regionally oriented tax and budgetary incentives, and risk diversification mechanisms forms a coherent model for enhancing the financial security of agricultural business. The introduction of electronic services of the State Tax Service and the State Agrarian Register reduces administrative costs and accelerates access to state support, while European integration instruments expand opportunities for attracting long-term and relatively low-cost capital. At the same time, the regional differentiation of fiscal incentives and budgetary expenditures for frontline and de-occupied territories makes it possible to mitigate the asymmetry of financial risks and sustain economic activity in the most vulnerable regions. The complementing of tax measures with insurance, credit, and guarantee instruments reduces income volatility and enhances the stability of cash flows of agricultural enterprises.

DISCUSSION

In research, fiscal support is increasingly viewed not as a passive mechanism for the redistribution of resources, but as an active instrument for the structural transformation of the agricultural sector. This was precisely the approach adopted by J. Li *et al.* (2024), who interpreted fiscal instruments as a catalyst for the integration of the primary, secondary and tertiary sectors in rural regions of China. Their analysis focused on the development of infrastructure, agro-processing and agritourism, as well as on the reallocation of factors of production between sectors. Within the scope of this study, fiscal policy was also interpreted as a tool for enhancing resilience; however, the focus shifted from cross-sectoral integration to the financial security of agricultural enterprises, particularly in the context of military, inflationary and macroeconomic shocks, which led to a prioritisation of liquidity, solvency and debt sustainability.

A similar logic was evident in the study by Q. Ma & X. Li (2025), where state support was recognised as a key factor in enhancing the resilience of the agricultural sector. At the same time, the authors focused on the quantitative measurement of the effect of fiscal-financial synergy on the growth of total factor productivity in China's agriculture. In contrast to this productivity-based approach, in this study fiscal instruments were analysed not through Total Factor Productivity (TFP) indicators, but as mechanisms for anti-crisis management of financial risks, enabling the continued operation of agricultural enterprises during periods of systemic instability. Turning to studies on innovative financial instruments, A. Kurdyś-Kujawska *et al.* (2025) focused on blended finance and financial innovations, analysing farmers' readiness to use grant-and-loan mechanisms at the micro level. In this study, however, priority was given to the analysis of fiscal policy at the macro- and micro-levels, which allowed for the assessment of fiscal instruments as systemic elements ensuring the financial security of the agricultural sector, rather than as individual financial decisions of individual farms.

A separate group comprises studies that focus on the market and financial risks of agricultural activity. R.L. Manogna & N. Kulkarni (2024) demonstrated that the financialisation of agricultural commodity markets exacerbates price volatility and negatively impacts food security. Within the scope of this study, these risks were also recognised as significant; however, the focus was shifted from market speculation to fiscal mechanisms for stabilising the financial condition of agricultural enterprises, which are capable of partially neutralising external price and macroeconomic shocks. A closely related study is that of F.U. Khan *et al.* (2024), which systematises the structural and institutional constraints on access to agricultural finance in developing countries. At the same time, unlike their focus on credit and institutional barriers, this study examines the financial problems of the agricultural sector through the prism of state fiscal policy, which performs a stabilising function in the context of war and global crises.

Another analytical perspective is presented in the works of W. Ma *et al.* (2024), where the key focus is on farmers' access to markets, distribution channels and the role of e-commerce in increasing incomes and well-being. In contrast to this micro-market approach, this study focused on fiscal instruments as the fundamental mechanisms of financial security, which create the conditions for the stable functioning of the agricultural sector regardless of the level of market integration of individual farms.

The climate dimension of the agricultural sector's resilience is explored in detail in the works of M. Yuan *et al.* (2024) and W. Ma & D.B. Rahut (2024). The former analyse strategies for enhancing the resilience of agricultural supply chains under climate change, emphasising diversification and digital transformation, while the latter investigate the determinants of adopting climate-smart agriculture at the household level. In the present study, climate risks are also taken into account; however, they are considered as an additional factor of financial instability that reinforces the need for adaptive fiscal mechanisms to support liquidity and solvency in agricultural enterprises. In the work by W. Huang & X. Wang (2024), the main focus was on the impact of technological innovations on the productivity and environmental sustainability of Chinese agriculture. In contrast to this technological-environmental approach, this study focused on the fiscal component of sustainability, considering tax and budgetary instruments as a key element of financial security for agricultural enterprises in the context of military and macroeconomic transformations.

In the present study and in the work of F.J. Castillo-Díaz *et al.* (2025), a common position is the recognition that financial constraints constitute a key barrier to enhancing the resilience of the agricultural sector under conditions of climatic, economic, and regulatory challenges, and that public policy should play an active role in overcoming them. At the same time, the approaches differ significantly in their analytical focus. F.J. Castillo-Díaz *et al.* concentrate on the financial challenges associated with the implementation of sustainable technological innovations in Spanish agriculture within the framework of the European Green Deal, identifying investment priorities and the need for "green" financial instruments and public-private partnerships. In contrast, the present study places primary emphasis on state fiscal instruments as mechanisms for stabilising the financial security of agricultural enterprises in Ukraine, with particular attention to liquidity, solvency, and debt sustainability under wartime and macroeconomic shocks.

The issue of financial constraints was also the focus of F. Cisilino & F. Licciardo (2022), who analysed the implementation of financial instruments within the framework of the EU's rural development policy. Using the example of Italian working capital funds, the authors demonstrated that even with state support, the effectiveness of financial mechanisms depended significantly on institutional coordination between regional authorities, financial institutions and farmers. In contrast to this institutional-organisational approach, in this study fiscal instruments were interpreted primarily as anti-crisis elements of financial security, designed to mitigate the risks of liquidity and insolvency for agricultural enterprises in the context of war and global transformations.

The macroeconomic dimension of the role of fiscal policy was explored in the work of T.F. Al-Mujaddid & S. Suwito (2024), where the combination of fiscal and monetary instruments was analysed as a key mechanism for stabilising the Indonesian economy during the global recession. In that study, fiscal policy was viewed as an element of general economic crisis management. In contrast, within the scope of this study, the analytical focus was deliberately narrowed to the sectoral level, which allowed fiscal instruments to be assessed specifically as means of ensuring the financial security of agricultural enterprises, taking into account specific liquidity risks and debt burdens.

A micro-level approach to the issue of business sustainability is presented in the study by L.L. Evinita *et al.* (2025), where the financial performance of micro, small and medium-sized enterprises in Indonesia's agricultural, fisheries and tourism sectors was explained primarily by the level of digitalisation, innovation and internal organisational capabilities. The authors concluded that state support played a support-

ing rather than a decisive role. In this study, this logic was reinterpreted: the state's fiscal instruments were viewed not as a secondary factor, but as a fundamental condition for the financial security of agricultural enterprises, particularly in the context of war risks, when a business's internal reserves are objectively limited. In the work by S.M. Indrawati *et al*. (2024), fiscal policy was analysed from the perspective of Indonesia's post-pandemic macroeconomic stabilisation, with a focus on the budget deficit, tax reforms and social expenditure. Although the results of that study confirmed the key role of the budget in restoring economic activity, in this study such a macro-level approach was supplemented by a sectoral perspective. This allowed fiscal instruments to be considered not merely as tools for general stabilisation, but as targeted mechanisms for supporting the financial security of agricultural enterprises in the face of military and global challenges.

Summarising the analysis, it can be argued that fiscal policy is gradually transforming from a supplementary tool for resource redistribution into a key mechanism for ensuring the resilience of the agricultural sector. Its importance is heightened in the presence of military, macroeconomic, inflationary and climatic shocks, when it is precisely fiscal instruments that determine the ability of agricultural enterprises to maintain liquidity, solvency and debt sustainability. Unlike approaches focused primarily on productivity growth, technological innovation or adaptation at the micro-level, sectoral fiscal support creates the basic conditions for financial security and the continuity of economic activity.

CONCLUSIONS

The conducted study confirmed that under conditions of wartime, macroeconomic, and inflationary shocks, fiscal instruments have become of key importance for ensuring the financial security of agricultural entrepreneurship in Ukraine. In 2022-2025, agricultural enterprises operated in an environment of heightened uncertainty, combining the loss of part of production assets, the occupation of up to 20% of agricultural land, an increase in production costs by 25-35%, and price discounts on export products in the range of 20-30%. Under such conditions, fiscal and budgetary mechanisms became the primary instruments for supporting liquidity, solvency, and debt sustainability of agricultural enterprises. The results of the analysis showed that tax innovations, in particular the introduction of a minimum tax liability averaging around 1,400 UAH/ha, significantly increased the transparency of land use and the predictability of tax revenues, whilst simultaneously increasing the tax burden on farms with low margins. The differentiation of VAT rates (20%, 14% and 0%) and wartime relaxations in the administration of this tax provided a short-term positive effect on cash flows, reducing the cash gaps of individual enterprises by 20-30%, but raised the requirements for the quality of accounting and tax compliance. Thus, tax instruments, by performing a regulatory function within the financial mechanism, provided de-shadowing and stabilisation effects.

Budgetary support in 2022-2025, amounting to between UAH 4 and 5 billion annually, was focused primarily on maintaining liquidity and reducing the debt burden. Preferential lending under the "Affordable Loans 5-7-9%" programme enabled agricultural enterprises to raise over UAH 104 billion in 2024, reducing debt servicing costs by 15-20% compared to market conditions. Direct subsidies and payments per hectare in 2023-2024 contributed to an increase in the current liquidity ratio of small and medium-sized farms by an average of 0.2-0.5 points, but failed to fully offset the cash shortages: the proportion of enterprises with insufficient absolute liquidity reached 74% in 2024. Inflationary pressures and tight monetary policy further undermined the financial stability of the agricultural sector. Peak inflation of 26.6% in 2022 and the rise in the NBU's discount rate to 25% significantly increased the cost of capital, and even its reduction in 2023-2024 did not ensure a full restoration of access to finance. Adapting fiscal mechanisms to enhance the financial security of the agricultural sector involves the digitalisation of tax and budget administration, regional differentiation of tax and budgetary incentives, integration with European financial programmes, and the combination of fiscal, credit and insurance instruments. Implementing

these measures reduces financial risks, supports liquidity and enhances the long-term resilience of agricultural enterprises in the face of military and global challenges, whilst also highlighting the impossibility of fully accounting for regional variations in the financial condition of agricultural enterprises over time. Prospects for further research relate to an in-depth quantitative assessment of the effectiveness of individual fiscal instruments at the micro-level of enterprises and an analysis of their impact on the financial stability of the agricultural sector in the post-war period.

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Фіскальні інструменти підтримки фінансової безпеки аграрного підприємництва в умовах глобальних викликів

Анотація. Метою даного дослідження було оцінити роль фіскальних інструментів у дотриманні фінансової безпеки аграрного підприємництва України в умовах воєнних і глобальних викликів. Методологія дослідження ґрунтувалася на застосуванні системного, інституційно-нормативного, функціонально-аналітичного та статистичного методів, що дало змогу проаналізувати податкові пільги, бюджетну підтримку, пільгове кредитування, а також вплив інфляції та монетарної політики на ліквідність і платоспроможність аграрних підприємств. Узагальнення результатів комплексного аналізу засвідчило, що запровадження мінімального податкового зобов'язання на рівні в середньому близько 1400 грн/га асоціювалося з підвищенням прозорості землекористування, водночас посилюючи податкове навантаження на господарства з низькою маржинальністю. Диференціація ставок податку на додану вартість (20 %, 14 % та 0 %) у поєднанні з воєнними податковими послабленнями, за даними вторинних джерел, сприяла скороченню касових розривів окремих підприємств орієнтовно на 20-30 %. Обсяги прямої бюджетної підтримки у 2022-2025 роках, які оцінювалися в межах 4-5 млрд грн щорічно, а також пільгове кредитування, що у 2024 році перевищило 104 млрд грн, розглядаються як чинники зниження вартості обслуговування боргу приблизно на 15-20 %. Водночас частка аграрних підприємств з недостатньою абсолютною ліквідністю у 2024 році досягала 74 %. Пікова інфляція 26,6 % у 2022 році та підвищення облікової ставки Національного банку України

до 25 % суттєво обмежили інвестиційну спроможність аграрного сектору. Напрями адаптації фіскальних механізмів передбачали цифровізацію податково-бюджетного адміністрування, регіональну диференціацію податкових і бюджетних стимулів, інтеграцію з європейськими фінансовими програмами та поєднання фіскальних, кредитних і страхових інструментів з метою підвищення фінансової безпеки аграрного бізнесу. Практичне значення дослідження полягає у можливості використання його результатів органами влади для удосконалення фіскальної політики та аграрними підприємствами – для підвищення ліквідності й фінансової стійкості в умовах воєнних викликів

Ключові слова: ліквідність; платоспроможність; кредитування; дотації; волатильність; бюджетна підтримка

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Assortment policy in the commodity science of food products in Ukraine and its impact on the economy of retail enterprises

Abstract. The assortment policy of food products represents a key factor determining the efficiency of retail enterprises and the competitiveness of the retail market. It influences the formation of retail turnover, distribution costs and the profitability of operating activities, while also reflecting

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consumer behaviour and priority preferences. This study aimed to formalise cause-and-effect relationships between the structural assortment characteristics and the economic indicators of the trade enterprises and identify the differentiated effect of assortment factors depending on the retail format. The research used methods of bibliographic analysis, grouping, time series analysis, economic and mathematical modelling (cascade model of influence of the assortment structure on retail turnover, distribution costs and operational profitability) and logical generalisation. It was found that the breadth, depth and concentration of the assortment have a significant influence on the economic indicators of the trade enterprise. For the specialised stores, the main focus should be concentrated on the management of retail turnover and the concentration of sales, and for non-specialised ones, the focus is on the distribution costs and optimisation of assortment structure. The application of the cascade model makes it possible to quantify the contribution of each product category and aggregated indicators of assortment policy to financial performance. Macroeconomic environment, primarily the income of the households and food security, forms the context of the assortment policy implementation and affects its efficiency in general. The practical significance of the study involves recommendations for trade enterprises concerning the optimisation of the assortment of products, increasing profitability and competitiveness. The results may be useful for businesses, the public authorities and scientists in the development of a strategy for trade development and improvement of assortment policy management

Keywords: product assortment structure; food retail; economic efficiency; financial performance; selling expenses; operating profitability

INTRODUCTION

Assortment policy is a crucial aspect of modern retail trade management, since it not only affects the assortment of goods on offer to the consumer, but also influences their purchase decisions, the level of demand satisfaction and the performance of retail companies. Thus, according to the research by J. Heger & R. Klein (2024), assortment management, optimisation of the product range, and its adaptation to consumer behaviour ensure an increase in sales and efficiency of retail networks**,** especially in the food segment, where a high variability of the assortment is closely related to consumer preferences and the multiplicity of purchase situations. S. Massaglia *et al.* (2023) pointed out that the formation of the assortment and the planning of the shelf assortment are among the factors determining the competitiveness of retail companies in the physical store and e-commerce channels. This concerns both the breadth and depth of the product assortment and the communication of these assortments to the consumer, which forms consumer expectations and stimulates purchases. At the same time, as noted by D. Aparicio *et al.* (2023), the competitive environment and market conditions prompt retail companies to make adaptive assortment decisions. In mature markets, the availability of an optimal set of product categories and Stock Keeping Units (SKUs) can influence an enterprise's ability to attract and retain customers, particularly in the context of the transition to multichannel retailing. In addition, assortment optimisation in conjunction with pricing policy and inventory management has a significant impact on the financial and economic performance of retail companies, such as profitability, turnover of capital and selling costs. Thus, the study by Y. Mou *et al.* (2024) found that the integration of assortment, inventory and pricing optimisation improves the overall efficiency of retail networks, especially against the backdrop of the growing importance of omnichannel strategies.

The analysis of assortment solutions under modern conditions by Y. Gu & Y. Wu (2023) also found that a structured product assortment can influence consumer behaviour and expectations, which is necessary for building long-term loyalty, especially in the food segment, where the multiplicity of assortment items is combined with high demands on product quality and properties. A. Hübner & H. Kuhn (2024) have also found that, when the assortment is limited or, on the contrary, too wide, it has an uncertain effect

on sales and consumer attitude. This suggests the need for balance between the width and depth of assortment, depending on market conditions and consumer behaviour. Therefore, assortment policy is considered a key instrument of influence on the economic efficiency of trade enterprises, as it combines commodity properties of goods, market decisions and the strategic goals of the enterprise, which predetermines the efficiency of inventory management, sales and competitiveness in the food retail market.

This study aimed to develop a cascade economic and mathematical model for formalising the cause-and-effect relationships between the characteristics of food assortment policy and the economic performance of trade enterprises (retail turnover, selling expenses and profitability). The objectives of the study were to formalise the categorical structure of the food products assortment and identify key segments for the empirical analysis, to determine the impact of different assortment policy strategies on retail turnover, selling expenses and profitability of trade enterprises and to evaluate the relationship between the width, depth and balance of the assortment and financial performance of trade enterprises.

MATERIALS AND METHODS

The following methods were used to investigate the assortment policy of food products in Ukraine and its impact on the economic performance of trade enterprises: bibliographic analysis, grouping, time series analysis, methods of absolute and relative values, economic and mathematical modelling and logical generalisation. The bibliographic method was used to systematise and analyse scientific, statistical and analytical sources, which enabled for evaluation factors that form assortment policy and its impact on the economic performance of trade enterprises. The analysis of market reports, state statistics, studies of consumer behaviour and other scientific sources has become the methodological basis for determining the main trends of development of retail enterprises in the food trade sector. Materials of the State Statistics Service of Ukraine (n.d.a; n.d.b; n.d.c) were used as a source base. Grouping was used to systematise the assortment of food products into categories and sub-segments in accordance with the analytical classification Food – Ukraine (n.d.a; n.d.b). It includes: fruits and nuts; vegetables; meat; fish and seafood; dairy products and eggs; bread and cereal products; oils and fats; sauces and spices; semi-prepared foods; confectionery and snacks; spreads and sweeteners; baby food; and pet food. This categorical structure has provided an opportunity to organise the empirical data, ensure the comparability of indicators of different store formats and distribution channels and evaluate the impact of each product group on retail turnover, sales expenses and profitability of retail trade enterprises. The grouping procedure has allowed making a transition from conceptual generalisations to quantitative analysis of assortment policy, to identify structural changes and evaluate the efficiency of inventory management, pricing and product promotion. The methods of dynamics and structure were also used in the study. Dynamics was used to analyse the changes in sales volumes of food products by distribution channels for the period 2018-2024 and to reveal the main trends of the market. Structural analysis has allowed determining the share of each product group in the total sales, evaluating the concentration of the assortment and identifying the differences in the assortment policies of traditional trade and e-commerce.

The time series analysis was used to identify the trends in retail turnover, sales expenses and profitability of trade enterprises for the period 2018-2024. The chosen time series includes a period of a relatively stable economic situation and a period of large-scale structural transformations conditioned by the COVID-19 pandemic, digitalisation of business processes and military actions in Ukraine. Such an approach allowed taking into account the long-term tendencies of the market development as well as the influence of crisis factors on the activities of economic entities and, therefore, to increase the validity of forecasting estimates. The method enabled the observed data to be decomposed into trend, seasonal and cyclic components, which allowed for the revelation of fluctuations conditioned by the structure of the assortment, dynamics of demand and other macroeconomic factors. The application of this approach made

it possible to assess the differentiated influence of the shares of individual groups of goods as well as the breadth, depth and concentration of the assortment on the financial result, and to introduce these assessments into the cascade economic-mathematical model. In addition, time-series analysis facilitates the adaptation of forecasting models to the transformation of consumers' behaviour and market conditions, which provides a more accurate assessment of the efficiency of assortment policy and resource planning within the retail enterprises. Methods of absolute and relative values were used to assess the scale of economic activity of enterprises and compare it during different time periods. Absolute values allowed to determine the volume of retail turnover and costs of sales, and relative values were used to analyse the structure of the assortment and profitability of activity in different retail formats.

Economic and mathematical modelling involved the construction of a cascade model, which formalises the cause-and-effect relationships between the structure of the assortment, volume of retail turnover, costs of sales and profitability of retail enterprises. The model includes three equations: formation of the volume of retail turnover of foodstuffs; formation of costs of sales; formation of profitability, which are calculated separately for specialised and non-specialised stores. The variables of the model include the sales structure of product groups; breadth, depth and concentration of assortment; the share of food expenditures in household consumption; and the average wage in the trade sector. The proposed method is directed toward the formalisation of cause-and-effect relationships of the descriptive model and harmonisation of structural characteristics of the assortment with the financial and economic activities of retail enterprises. Before formalisation of the economic and mathematical model, a generalised description of the cascade approach is presented, which reflects the logic of the sequential effect of micro-, meso- and macroeconomic factors on the resulting efficiency indicators of trade enterprises. The main variables of the model are presented in Table 1.

Table 1. Variables of the cascade economic and mathematical model of the influence of food assortment policy on the economy of retail enterprises

Symbol	Indicator	Description
Dependent variables		
T_t	Retail turnover of food products	Total sales volume of food products of a retail enterprise expressed in monetary terms in period t. Includes the constant β_0, coefficients β_i, α_1, α_2, α_3, α_4 and the random error
S_t	Selling expenses for food products	Total costs associated with the sale of food products (logistics, storage, personnel and operational support). Includes the constant γ_0, coefficients γ_1, γ_i, λ_1, λ_2 and the random error w_t
R_t^{spec}	Operating profitability of specialised stores, %	Indicator of the performance efficiency of specialised food stores. Includes δ_0^{spec}, δ_1^{spec}, δ_2^{spec}, δ_i^{spec}, ϑ^{spec} and the random error ξ_t^{spec}
$R_t^{nonspec}$	Operating profitability of non-specialised stores, %	Figure effectiveness of non-specialised retail enterprises. Includes $\delta_0^{nonspec}$, $\delta_1^{nonspec}$, $\delta_2^{nonspec}$, $\delta_i^{nonspec}$, $\vartheta^{nonspec}$ and the random error $\xi_t^{nonspec}$
Independent variables (micro level)		
$a_{i,t}$	Share of category i	Share of sales of the i-th product category in the total retail turnover of food products in period t
X_1	Assortment breadth	Number of product categories of food products
X_2	Assortment depth	Number of SKUs within product categories
X_3	Assortment concentration	Share of the top five categories in total retail turnover
Control variables (meso level)		
F_{share}	Share of household expenditure on food, %	Relative share of consumer expenditure on food products, which determines potential demand and the upper limit of retail turnover
W_{trade}	Average wage in the trade sector, UAH	Forms the cost component of the activity of retail enterprises

Source: developed by the authors

The cascade structure of the model provides for a step-by-step transformation of assortment policy characteristics into indicators of trade turnover, cost of sales and operating profitability. This approach reflects the internal logic of the functioning of the trade enterprise as an integrated economic system. The method of logical generalisation was used for systematisation of modelling and data analysis results, which made it possible to formulate well-substantiated conclusions concerning the influence of assortment policy on the economic activities of trade enterprises and develop recommendations for practical activities.

RESULTS AND DISCUSSION

In modern scientific literature, the commodity science of food products is considered not only as a system of knowledge of physico-chemical and consumer properties of goods but also as a methodological and managing system interacting with decision making in the field of assortment policy, inventory management and market behaviour. This approach indicates that product quality and property assessment serve as the basis for commercial and strategic decisions in trade enterprises, which ultimately increase their competitiveness and economic efficiency. This perspective is supported by a number of recent studies that emphasise the integration of product knowledge and managerial approaches in retail trade, particularly in the context of optimising product assortments and adapting to consumer behaviour in a multichannel environment. A. Vasilyev *et al.* (2025) point out that assortment selection methods, which are based on the analysis of demand and consumer behavioural patterns, are gaining more and more practical and theoretical substantiation in the scientific and methodological literature on the management of retail networks. Also, it should be added that commodity science is of great importance in the formation of assortment policy and strategic inventory management and product quality decisions in the post-war period of development of Ukrainian trade**,** since it provides scientifically substantiated criteria for these decisions and strengthens the competitive positions of trade enterprises (Ilchuk *et al*., 2025a). Commodity science affects the efficiency and adaptability of the management of a trade enterprise through the following main functions:

1) analytical function – regular analysis of the consumer properties of goods and quality and safety assessment, which allows the formation of well-grounded criteria for the selection of goods for inclusion in the assortment portfolio;

2) assortment planning function – provision of a scientific basis for forming the product assortment, including the assessment of the optimal breadth and depth of the assortment in order to ensure that products correspond to consumer expectations and market demand;

3) forecasting function – use of data on trends in consumer behaviour and market changes to predict demand, the product life cycle and the adjustment of assortment decisions;

4) information and communication function – ensuring the management of the enterprise with relevant information about the properties of goods, new quality tendencies and legislative requirements, which enables making timely and qualitatively justified product policy decisions.

These functions ensure the effective synthesis of commodity science knowledge and management practice, which is necessary for trade enterprises with a large assortment of portfolios of foodstuffs in a dynamically changing market environment. In this sense, assortment policy is considered the key management mechanism, which translates commodity science knowledge into competitive advantages and economic performance of the enterprise. As R. Sethuraman *et al.* (2022) summarise, an assortment is a collection of items being offered to customers to choose from, while assortment policy is a set of management decisions directed towards the optimal forming, maintaining and adapting the assortment of goods in accordance with the structure of demand, consumer behaviour and long-term strategic goals. According to the studies of S. Fedoseeva & R. Herrmann (2023), the widening of the assortment depth and breadth leads to: an increase in consumer satisfaction with the assortment choice; the growth of frequency of purchases and sales volumes; the change in pricing policy and the margins of product categories. This dependence

is especially strong for food products, for which the assortment quality balance determines not only sales volumes but also the image of the trade mark and the consumer loyalty in the long term. As noted by O. El Housni *et al.* (2025), the methods of assortment modelling, which consider the consumers' behavioural reactions and inter-category relations, are acquiring the status of an important analytical instrument for making the best management decisions in this sphere. The research of S. Fedoseeva & R. Herrmann (2023) also shows that the assortment policy efficiency has a strong impact on the main performance indicators of trading enterprises: sales volumes and market share (welldesigned assortment allows for better satisfying the demand); financial results (product margins, stock turnover); the risk of losses from products remaining unsold or little demanded. For instance, the research in the sphere of electronic commerce of foodstuffs testifies that the growth of the assortment depth has a positive effect on the possibility of keeping the prices high and preserving the market positions more steadily.

Besides, the assortment modelling approaches suggested by N. Tiahunova (2025) consider the complex aspects of consumer behaviour, such as the propensity of the consumer to buy items of different categories within the same shopping trip, which directly influences the expected profit from each product category. All this proves that commodity science, assortment policy and economic activity of trading enterprises represent a single system, in which each of the components influences the ability of the enterprise to adapt to the market changes and to satisfy the consumer demand. To form and analyse an assortment of food products, a well-structured system of commodity categories is necessary, ensuring the comparability of statistical data, the possibility of structural changes, and the evaluation of assortment policy efficiency of a trade enterprise. However, for the practical implementation of assortment policy, in addition to a theoretical understanding of the commodity science role, it is also necessary to have a well-structured system of assortment classification, ensuring the comparability of data and its quantitative analysis. The study presented is based on a categorical classification of food products, which simplifies the transition from theoretical generalisations to empirical analysis of the structure of the assortment. According to the analytical classification of Statista, the food product assortment is structured into main groups and subgroups, which reflect the leading consumption trends in the global food market. The main segments include: fruits and nuts (fresh, processed and frozen); vegetables (fresh, processed and frozen); meat (fresh, processed and meat substitutes); fish and seafood (fresh and processed); dairy products and eggs; bread and cereal products; oils and fats; sauces and spices; semi-prepared and readyto-eat meals; confectionery and snacks; spreads and sweeteners; baby food; and pet food (Table 2).

Table 2. Analytical classification of the food product assortment

Segments	Sub-segments
Fruits and nuts	Fresh fruits; processed and frozen fruits and nuts
Vegetables	Fresh vegetables; processed and frozen vegetables
Meat	Fresh meat; processed meat; meat substitutes
Fish and seafood	Fresh fish; fresh seafood; processed fish and seafood
Dairy products and eggs	Milk; milk substitutes; yoghurt; cheese; eggs; other dairy products
Bread and cereal products	Bread; pasta; rice; breakfast cereals; other cereal products
Oils and fats	Butter; margarine; edible oils; other oils and fats
Sauces and spices	Tomato ketchup; other sauces; spices; culinary herbs
Semi-prepared foods	Soups; ready-to-eat meals
Confectionery and snacks	Confectionery; snacks
Spreads and sweeteners	Spreads; sweeteners
Baby food	Food intended exclusively for infants and young children
Pet food	Food intended exclusively for domestic animals

Source: developed by the authors based on Food – Ukraine (n.d.a; n.d.b)

As can be seen, the presented structure includes not only the traditional food groups but also the modern trends of the food market development, such as the growth of products with added value, semiprepared products, functional products, and alternative products (meat substitutes, plant-based drinks). For trade enterprises, this classification is the basis for the strategic management of the assortment matrix, allowing a differentiated approach to inventory management, pricing, and promotion within each product category. In food commodity science, the categorical structure of the assortment has a system-forming role, uniting consumer properties of goods, technologies of their storage and distribution, and economic efficiency of trade enterprises. Simultaneously, at the level of product categories, assortment policy is developed, which forms the breadth, depth and balance of the assortment depending on the retail format, sales channel (offline or online) and consumer behaviour. Thus, the use of a unified categorical classification of food products provides a methodological basis for further analysis of assortment dynamics, evaluation of its efficiency and the study of the relationship between assortment policy and financial performance of retail enterprises both in the offline and online trade. The proposed categorical structure of the assortment provides an analytical framework for studying the dynamics and structural shifts in the market of retail and e-commerce trade in food products. Analysing sales indicators across individual product categories allows differences in assortment policy formation to be identified according to the sales channel and its economic consequences to be assessed. Evaluation of the food products assortment is most effective when carried out by main product categories, as it allows for determining the structural shifts, dynamics of demand and the peculiarities of assortment policy formation depending on the distribution channel. According to the data of retail and online food trade in Ukraine for 2018-2024, there are significant differences both in the volume of sales and in the structure of the assortment (Food – Ukraine, n.d.a; n.d.b).

At the same time, a study of the wholesale trade in food products by M.M. Ilchuk *et al.* (2025b) showed that the characteristics of the assortment structure and the concentration of sales in key categories remain of a strategic nature for the wholesale trade channel as well, providing stability of turnover and optimising supply chains. This approach makes it possible to consider assortment policy as a systemic mechanism that adapts to the specifics of the sales channel and consumer demand, integrating commodity properties of goods with economic interests of retail enterprises. In the traditional retail segment, the total volume of food sales increased from USD 43.32 billion in 2018 to USD 59.24 billion in 2024, which demonstrates a moderate but steady positive trend, though a decrease is observed in 2022. The basis of the assortment structure is still the food products of daily demand, namely meat, dairy products and eggs, vegetables, bread and cereal products. Thus, in 2024, the turnover of the meat market was USD 14.34 billion, dairy and egg products were USD 9.21 billion, and vegetables were USD 7.62 billion, confirming the dominance of traditional food groups in the consumer basket. In the structure of retail trade, there is an increasing role of products with higher added value, such as confectionery and snacks, semi-prepared foods, sauces and spices. Thus, the turnover of semi-prepared foods in 2018 was USD 2.13 billion, and in 2024 it was USD 3.09 billion, reflecting a shift in consumer preferences towards convenience and time savings (Table 3).

Table 3. Dynamics and structure of the food assortment in retail trade

Indicator	Year							Absolute change 2018-2024, billion USD	Relative change 2018-2024, %
	2018	2019	2020	2021	2022	2023	2024		
Sauces and spices: billion USD share, %	1.12 2.58	1.32 2.59	1.41 2.58	1.50 2.56	1.25 2.69	1.41 2.64	1.55 2.61	0.43	38.39

Table 3, Continued

Indicator	Year							Absolute change 2018-2024, billion USD	Relative change 20182024, %
	2018	2019	2020	2021	2022	2023	2024		
Fruits and nuts: billion USD share, %	4.32 9.97	5.08 9.96	5.44 9.95	5.80 9.9	4.46 9.6	5.53 10.36	6.10 10.29	1.78	41.2
Confectionery and snacks: billion USD share, %	2.94 6.79	3.47 6.8	3.91 7.16	4.31 7.35	3.63 7.81	4.13 7.74	4.51 7.62	1.57	53.06
Pet food: billion USD share, %	0.22 0.51	0.32 0.63	0.43 0.79	0.55 0.94	0.47 1.01	0.51 0.96	0.54 0.91	0.32	145.45
Fish and seafood: billion USD share, %	2.34 5.40	2.81 5.51	2.84 5.20	3.11 5.31	3.05 6.56	3.35 6.28	3.61 6.09	1.27	54.7
Bread and cereal products: billion USD share, %	5.59 12.9	6.55 12.84	6.99 12.79	7.42 12.66	4.63 9.97	5.21 9.77	5.80 9.79	0.21	3.76
Vegetables: billion USD share, %	5.24 12.09	6.16 12.08	6.59 12.06	7.03 11.99	6.08 13.09	6.98 13.08	7.62 12.87	2.38	45.8
Oils and fats: billion USD share, %	1.15 2.65	1.44 2.82	1.54 2.82	1.74 2.97	1.40 3.01	1.66 3.11	1.81 3.06	0.66	57.39
Dairy products and eggs: billion USD share, %	6.98 16.11	8.17 16.02	8.72 15.95	9.26 15.81	7.16 15.41	8.23 15.42	9.21 15.55	2.23	31.8
Baby food: billion USD share, %	0.34 0.79	0.36 0.71	0.39 0.71	0.44 0.75	0.33 0.71	0.34 0.64	0.36 0.61	0.02	5.88
Spreads and sweeteners: billion USD share, %	0.65 1.50	0.75 1.47	0.79 1.45	0.83 1.42	0.57 1.23	0.64 1.20	0.70 1.18	0.05	7.69
Meat: billion USD share, %	10.30 23.78	12.08 23.69	12.90 23.60	13.72 23.42	10.89 23.45	12.59 23.58	14.34 24.20	4.04	39.23
Semi-prepared foods: billion USD share, %	2.13 4.92	2.51 4.92	2.69 4.92	2.88 4.91	2.53 5.45	2.79 5.22	3.09 5.21	0.96	45.07
Total: billion USD share, %	43.32 100.00	51.02 100.00	54.64 100.00	58.59 100.00	46.45 100.00	53.37 100.00	59.24 100.00	15.92	36.74

Source: developed by the authors based on Food – Ukraine (n.d.a; n.d.b)

In comparison with the traditional retail trade, the online food trade demonstrates higher growth rates of turnover and a different structure of the assortment. The total volume of online food trade from 2018 to 2024 increased from USD 266.54 million to USD 703.55 million, except in 2022, when

there was a sharp decline in turnover. The online assortment is represented mainly by commodity groups that have a large turnover, a typical consumer and convenient logistics (Table 4).

Table 4. Dynamics and structure of the food assortment in e-commerce

Indicator	Year							Absolute change 2018-2024, billion USD	Relative change 2018-2024, %
	2018	2019	2020	2021	2022	2023	2024		
Sauces and spices: billion USD share, %	5.78 2.17	7.07 2.07	9.19 1.77	12.65 1.68	3.96 3.01	7.38 2.14	13.78 1.96	8.00	138.41
Fruits and nuts: billion USD share, %	20.90 7.84	26.88 7.87	40.46 7.79	57.99 7.69	11.87 9.01	28.17 8.15	56.00 7.96	35.10	167.94
Confectionery and snacks: billion USD share, %	39.62 14.87	52.83 15.46	89.06 17.14	134.70 17.87	19.96 15.14	59.31 17.17	124.40 17.68	84.78	213.97
Pet food: billion USD share, %	44.49 16.69	52.80 15.45	66.30 12.76	87.35 11.59	8.58 6.51	31.93 9.24	67.35 9.57	22.86	51.38
Fish and seafood: billion USD share, %	11.51 4.32	14.74 4.31	22.09 4.25	31.67 4.2	6.65 5.05	15.58 4.51	30.91 4.39	19.40	168.55
Bread and cereal products: billion USD share, %	22.09 8.29	29.36 8.59	54.95 10.57	88.74 11.77	12.86 9.76	38.44 11.12	80.56 11.45	58.47	264.75
Vegetables: billion USD share, %	24.86 9.33	32.13 9.4	48.67 9.37	70.05 9.29	13.93 10.57	33.79 9.78	67.72 9.63	42.86	172.45
Oils and fats: billion USD share, %	7.57 2.84	9.13 2.67	12.27 2.36	16.43 2.18	5.20 3.95	9.23 2.67	16.21 2.30	8.64	114.14
Dairy products and eggs: billion USD share, %	24.31 9.12	32.13 9.40	47.99 9.24	68.81 9.13	12.01 9.11	32.24 9.33	67.02 9.53	42.71	175.68
Baby food: billion USD share, %	4.45 1.67	4.59 1.34	4.89 0.94	5.12 0.68	4.11 3.12	4.45 1.29	4.99 0.71	0.54	12.13
Spreads and sweeteners: billion USD share, %	10.32 3.87	11.87 3.47	14.45 2.78	18.23 2.42	8.07 6.12	11.66 3.37	17.88 2.54	7.56	73.26
Meat: billion USD share, %	41.84 15.70	56.52 16.54	89.87 17.30	133.30 17.69	20.02 15.19	60.21 17.43	129.00 18.34	87.16	208.34

Table 4, Continued

Indicator	Year							Absolute change 2018-2024, billion USD	Relative change 2018-2024, %
	2018	2019	2020	2021	2022	2023	2024		
Semi-prepared foods: billion USD share, %	8.80 3.30	11.70 3.42	19.37 3.73	28.85 3.83	4.57 3.47	13.14 3.80	27.73 3.94	18.93	215.11
Total: billion USD share, %	266.54 100.00	341.75 100.00	519.56 100.00	753.89 100.00	131.79 100.00	345.53 100.00	703.55 100.00	437.01 100.00	163.95 100.00

Source: developed by the authors based on Food – Ukraine (n.d.a; n.d.b)

In 2024, the largest turnover was recorded for meat products (USD 129.0 million), confectionery and snacks (USD 124.4 million), bread and cereal products (USD 80.56 million), vegetables (USD 67.72 million) and dairy products and eggs (USD 67.02 million). It is interesting to note that ecommerce is characterised by a fairly high share of pet food in 2024 (USD 67.35 million), which indicates the formation of a specialised niche assortment in this sales channel. The comparative analysis shows that in e-commerce, the assortment policy is less focused on the width of the product range and more on the depth and concentration of the assortment in commodity groups with high and stable demand. This is evidence that in the online segment, assortment management is based not only on the commodity properties of goods but also on logistics, standardisation, and consumer behaviour. Thus, the results indicate a differentiation of assortment policy depending on the retail format. The provision of a complete assortment of basic food products is a priority for the traditional trade, while in e-commerce, the leading assortment strategy is to focus on commodity groups with high turnover, stable and predictable demand and high sales potential. This indicates an increasing role of assortment management as an instrument to improve the economic efficiency of trade enterprises. The results of the dynamic and structural analysis make it possible to move from the description of the sales volumes to the evaluation of the economic efficiency of the assortment policy. This transition is of fundamental importance since the real economic effect of managerial decisions in the assortment strategy manifests itself in the financial and economic indicators.

The effectiveness of the assortment policy of trade enterprises of the food market should be evaluated not only based on the absolute sales volumes but also on the structural assortment characteristics, such as the level of sales concentration in individual commodity groups, the stability and predictability of demand and turnover potential. This approach allows moving from the purely quantitative analysis of the assortment to the evaluation of its economic efficiency. According to the data for 2018-2024, in both traditional retail and e-commerce of food products, a high concentration of sales is observed in a narrow range of commodity groups. In retail trade, the commodity groups such as meat, dairy products and eggs, vegetables, bread and cereal products accounted for more than half of the total sales of food products in 2024. This commodity structure is characterised by a focus on commodity groups of the mass demand, which ensures the commodity turnover, but, at the same time, limits the possibilities for expanding the margins. In e-commerce, the concentration of commodity groups of the effective assortment is higher. The largest volumes of sales are observed in the commodity groups such as meat, confectionery and snacks, pet food, bread and cereal products, dairy products and eggs. The high share of these commodity groups in the total online sales shows that the commodity policy of the enterprise is focused on products with stable demand, relatively low risk of write-offs, and the ability to scale through digital channels. From the point of view of commodity science, the efficiency of the assortment is also determined by the balance between fast-moving commodity groups and commodity

groups with a higher risk of losses. In retail trade, a significant share of fresh products (meat, vegetables, dairy products) increases the requirements for inventory management, quality control, and logistics. In e-commerce, the relatively higher share of products with a longer shelf life (confectionery, snacks, pet food, oils and fats) reduces operational losses and increases commodity turnover.

An important criterion for an effective commodity policy of a retail enterprise is the ability to adjust the commodity structure of the assortment to external shocks. The decrease in sales in 2022, observed both in retail trade and in e-commerce, was accompanied by an increase in demand for commodity groups of the main assortment, which indicates their "core" for the assortment. At the same time, in 2023-2024, the restoration of sales volumes occurred more dynamically in commodity segments with a more flexible assortment that more quickly responded to changes in consumer demand, primarily in the online channel. Hence, the findings of the analysis confirm that the efficiency of assortment policy depends not so much on the width of the assortment, but on its structural optimisation, concentration of the main commodity groups, and ability to adapt commodity properties to the economic interests of a trade enterprise, which contributes to the growth of turnover, reduction of losses, and improvement of the financial stability of the multichannel trade enterprise. The commodity structure of the assortment influences the financial results of activities of trade enterprises, the level of revenue, the speed of turnover of capital and the size of operating costs. In the food market, the above-mentioned influence is particularly topical, which is caused by a large share of fast-moving goods, a significant share of fresh products, and relatively low possibilities for long-term storage. In such circumstances, assortment policy is a principal means of adapting the commodity properties of goods to the economic interests of the trade enterprise. When evaluating the economic efficiency of assortment policy, it is advisable to use a system of indicators of sales volumes, efficiency of commodity circulation and financial results of activities. The dynamics of these indicators make it possible to trace the process of transformation of changes in the structure of the assortment into the financial results of the activities of trade enterprises. It should be emphasised that the total sales volume of food products presented in Tables 1 and 2, in economic terms, is comparable to the retail turnover of food products as indicated by the official statistics of the State Statistics Service of Ukraine. However, in the framework of this research, these indicators are used for different analytical purposes: the Statista data for the structural and assortment analysis by commodity groups, and the official data of the State Statistics Service for the estimation of financial and economic results of activities of trade enterprises.

The volume of retail turnover of food products is a basic indicator that characterises the economic effect of assortment policy. Changes in the structure of the assortment, in particular an increase in the share of fast-moving goods, for which there is a stable demand, lead to an increase in the volume of sales even under the influence of external shocks. Meanwhile, the high concentration of sales in a relatively narrow range of commodity groups guarantees a relatively stable sales turnover, but can also limit the growth potential of profitability. A high share of food products in total turnover is typical for the food retail market, which indicates the structural dependence of the financial results of enterprises on the effective formation of the commodity assortment in this group. In this context, the assortment policy acts as an instrument not only for the implementation of consumer demand, but also as a factor in the formation of the revenue base of trade enterprises. The data in Table 5 show the high variability of retail sales turnover dynamics in the period 2018-2024 under the influence of macroeconomic, institutional and crisis factors. In 2020, there was a decrease in total retail turnover against the background of the restrictive measures caused by the pandemic, but in 2021, there was a sharp increase in sales volumes. The reason for the decline in 2022 is the influence of military risks and supply chain ruptures, while in 2023-2024, a steady growth trend is noted due to the adaptation of trade enterprises to the new realities.

Table 5. Dynamics of the main indicators of retail turnover for enterprises

Indicator	Year						
	2018	2019	2020	2021	2022	2023	2024
Total retail turnover, million UAH	930.63	1,094.05	868.28	1,443.83	1,396.27	1,855.38	2,171.98
Turnover of food products, million UAH, including:	317.29	367.78	417.28	480.65	423.94	562.60	n/a
in specialised stores	8.04	9.30	11.59	12.46	10.51	17.11	n/a
in non-specialised stores	309.25	358.48	405.69	468.19	413.44	545.49	n/a
Share of food products in total turnover, %	34.09	33.62	48.06	33.29	30.36	30.32	–

Note: the total volume of retail turnover of food products is defined as the sum of turnover from food, beverages, and tobacco products in specialised stores and non-specialised stores with a predominance of food assortments
Source: the authors' calculations based on the State Statistics Service of Ukraine (n.d.c)

The dynamics of food sales generally repeat the dynamics of total retail turnover, but have relatively higher stability. This fact confirms the countercyclical nature of demand for food products and their leading role in the consumer basket. In 2023, the volume of food sales reached its highest value for the entire period under review, which indicates an increase in the role of the food group in the formation of the revenue base of trade enterprises. According to the structural analysis, the share of non-specialised stores with a prevailing share of food products in food turnover is more than 95%. This indicates a change in retail channels towards the universalisation of the store formats and concentration of the commodity supply in large retail chains. Simultaneously, relatively low and increasing sales dynamics in specialised stores may suggest the formation of niche markets for the products with a differentiated assortment and a higher level of service. The share of food products in the total retail turnover demonstrates a downward trend: it decreased from more than 34% in 2018-2019 to about 30% in 2022-2023. This tendency suggests an increasing role of non-food products; however, it does not reduce the food segment's role as a tool for providing stable cash flows in periods of economic instability. The increase in sales dynamics and the structural shifts in assortment necessitate the analysis of inventory as a component of operational efficiency in retail trade. Due to the dominant share of food products in the turnover structure, the efficiency of inventory management in this segment defines the balance between supply continuity, financial stability and the ability of trade enterprises to adapt to external shocks. According to Table 6, the dynamics of food products inventory in the Ukrainian retail trade during 2019-2023 were uneven, reflecting the reaction of trade enterprises to the changes in consumer demand, logistical risks and inflationary expectations. At the same time, the ratio of inventories to sales, represented by the inventoryto-turnover coefficient, shows relative stability, which is a sign that trade enterprises seek to maintain a certain level of inventory per sales unit.

Table 6. Indicators of inventory management efficiency for food products in trade enterprises

Indicator	Year				
	2019	2020	2021	2022	2023
Food product inventories, million UAH	25,736.50	27,970.80	33,804.40	25,799.90	35,123.20
Turnover of food products, million UAH	367.78	417.28	480.65	423.94	562.60
Inventory-to-turnover coefficient, units	70.00	67.00	70.30	60.90	62.40

Note: the inventory-to-turnover coefficient is a dimensionless indicator representing the ratio of inventory volume to retail turnover, reflecting the amount of stock per unit of sales; classical inventory turnover metrics are not applied in this study due to the aggregated nature of official statistics from the State Statistics Service of Ukraine, which prevents a correct comparison of annual turnover with national inventory volumes; the analysis covers 2019-2023 because official data on food product inventories in Ukrainian retail trade have only been published since 2019; data for 2018 are unavailable, and statistics for 2024 were not accessible at the time of the study, making it impossible to include these years in the analysis
Source: the authors' calculations based on the State Statistics Service of Ukraine (n.d.c)

The decrease in the inventory-to-turnover coefficient in 2022-2023 compared to the pre-crisis period can be regarded as an adaptation of inventory management models to the conditions of increased uncertainty, including through assortment optimisation and inventory redundancy reduction. Thus, the analysis of inventory supplements the assessment of assortment policy performance, allowing not only for the evaluation of sales dynamics but also for the assessment of resource efficiency in the formation and maintenance of the product range. Within the framework of the proposed model, the inventorytoturnover coefficient is an indicator of the operational efficiency of assortment policy. The relatively stable dynamics of this indicator in 2019-2023, against the background of fluctuating turnover, suggest a flexible assortment policy, as well as a conscious effort by trading enterprises to reduce the risk of overstocking without narrowing the core assortment. The pre-tax financial result and the operating profitability of trading enterprises are a generalised indicator of the economic impact of assortment policy on the activities of trading enterprises. A rationally formed assortment contributes to increasing profitability due to the concentration of the trading enterprise on commodity groups with stable demand, optimal proportions of basic and high-margin goods, and a decrease in losses from overstocking. As can be seen from Table 7, the pre-tax financial result of trading enterprises in the food segment has undergone significant fluctuations during 2018-2024, which is caused by the influence of external factors, logistic risks, and changes in demand. The growth in profit in 2021 and 2024 against the background of the growth in the turnover of food products and the optimisation of the assortment structure indicates the economic feasibility of concentrating on commodity items with high turnovers and predictable demand.

Table 7. Financial performance of trading enterprises in the food segment

Indicator	Year						
	2018	2019	2020	2021	2022	2023	2024
Pre-tax financial result, million UAH, including:	3,870.44	8,589.06	1,942.20	12,384.26	-6,303.08	882.54	9,302.80
in specialised stores	143.81	99.01	428.37	958.45	511.17	704.67	774.88
in non-specialised stores	3,726.63	8,490.05	1,513.83	11,425.81	-6,814.25	177.87	8,527.92
Operating profitability, %, by							
specialised stores	9.54	5.04	17.09	26.69	14.85	17.02	12.51
non-specialised stores	9.86	16.22	14.73	17.44	8.13	6.45	10.79
Selling expenses, million UAH, including:	50,850.53	73,092.96	95,634.01	92,411.88	82,168.58	125,593.97	147,469.77
in specialised stores	1,811.86	420.24	415.42	1,042.47	1,026.76	635.65	1,330.37
in non-specialised stores	49,038.67	72,672.72	95,218.59	91,369.41	81,141.82	124,958.33	146,139.40

Note: selling expenses are aggregated from data on large, medium, and small retail enterprises according to store type; a general indicator of operating profitability was not calculated due to differences in enterprise scale and cost structure

Source: compiled by the authors based on the State Statistics Service of Ukraine (n.d.a; n.d.b)

Operating profitability in specialised stores has higher values than in non-specialised stores, which can be explained by the smaller volumes of operations and the possibility of more accurate assortment orientation toward a particular consumer. Non-specialised stores, whose share in the turnover is the largest, demonstrate a relatively stable but lower level of profitability, which is due to high costs of sales and the complexity of logistics of a wide assortment. Costs of sales show the influence of scale and concentration of sales. In non-specialised stores, they are several times higher than in specialised stores; however, when calculated per unit of turnover, they demonstrate the efficient use of resources within trade networks. The reduction of costs of sales during

some periods indicates the optimisation of inventory management and logistics processes, which makes it possible to maintain financial stability in a crisis. At the same time, an expansion of the assortment alone cannot become a factor in increasing profitability. An economic effect is achieved only if the assortment policy corresponds to the financial potential of the trading enterprise, logistical potential, and the characteristics of the sales channel. Thus, assortment policy is an integrating mechanism that combines commodity characteristics of the product and financial indicators of the activities of trading enterprises. To sum it up, the efficiency of assortment policy in the food market is determined by an increase in turnover, inventory turnover and improvement of financial and economic performance and profitability. These results substantiate the grounds to treat assortment management as an economic stability factor of trading and electronic trading enterprises. The research into turnover dynamics, structure of assortment, inventory and operating profitability of food trading enterprises has revealed the presence of sustained differences in the indicators depending on the trading activity format and the efficiency of assortment management. The trends described herein confirm the multiple-factor nature of the financial performance of trading and electronic trading, which makes it impossible to adequately explain the results by a separate indicator. Therefore, it is necessary to formalise the relationships between the main parameters of assortment policy, logistical and resource and format characteristics of trading enterprises in the form of an integrated economic and mathematical model that would allow a quantitative evaluation of their total impact on the operating activities. Table 8 shows the dynamics of the main macroeconomic and socio-economic indicators that affect food security and assortment policy formation of trading enterprises in Ukraine for 2018-2024. It demonstrates the dynamics of Ukraine's position in the Global Food Security Index (GFSI) (n.d.), the average salary of the population in general and of the employees of trade, and the proportion of consumer spending on food. The table reflects the interdependence of the population's income and expenditures and the efficiency of assortment policy, and the influence of economic and external factors on the provision and diversity of the food products.

Table 8. Dynamics of food security, household income and food expenses

Indicator	Year						
	2018	2019	2020	2021	2022	2023	2024
GFSI rank	63	76	54	58	71	n/a	n/a
Average wage, UAH	7,810.88	9,205.19	10,340.35	12,993.56	13,376.21	14,308.46	17,486.60
Average wage in the trade sector, UAH	n/a	n/a	12,028.00	14,556.00	18,346.00	21,797.00	28,040.00
Share of household expenditure on food, %	49.40	48.50	49.20	47.10	–	–	–

Source: compiled by the authors based on Global Food Security Index (GFSI) (n.d.), Average monthly wages by industry (Ukraine) (n.d.), State Statistics Service of Ukraine (n.d.d.)

The analysis of the information in Table 8 demonstrates that Ukraine's position in the Global Food Security Index has changed several times from 2018 to 2022, which indicates an unstable state of food security in the context of economic and external influences. Simultaneous growth of average wages of the population and workers of trade characterises an increase in purchasing power, while a high share of household expenses on food proves the importance of food costs in the family budget. This leads to the conclusion that the effective assortment policy of trade enterprises should be based not only on internal economic resources but also on the variability of the external environment that forms the availability and diversification of the food market. The combination of the analysis of assortment structure, sales dynamics and financial indicators of trade enterprises proved the existence of sustainable causeandeffect relationships between assortment parameters and economic results. In order to

systematise the above-mentioned cause-and-effect relationships and formalise the logic of the influence of assortment policy on key performance indicators, the application of a descriptive model is reasonable. The proposed descriptive model employs both level and block approaches. The levels characterise the scope of assortment policy formation and implementation (macro-, meso- and microeconomic levels), while the blocks illustrate the transformation logic of the external environment into economic results of trade enterprises. The intersection of the levels and the blocks enable to determine the scope of responsibilities and the influence channels, providing the methodological framework for the further econometric modelling (Fig. 1). The descriptive model determines the general logic and influence directions of assortment policy on the economic performance of trade enterprises; however, it does not allow evaluating the quantitative strength or direction of the above-mentioned influence. In this context, the subsequent research stage is the development of a cascading econometric model that would provide an opportunity to formalise the analysis of the identified dependencies. Based on the descriptive model and the analysis results of assortment policy indicators, the cascading econometric model of food product assortment policy influence on the economic performance of trade enterprises has been developed.

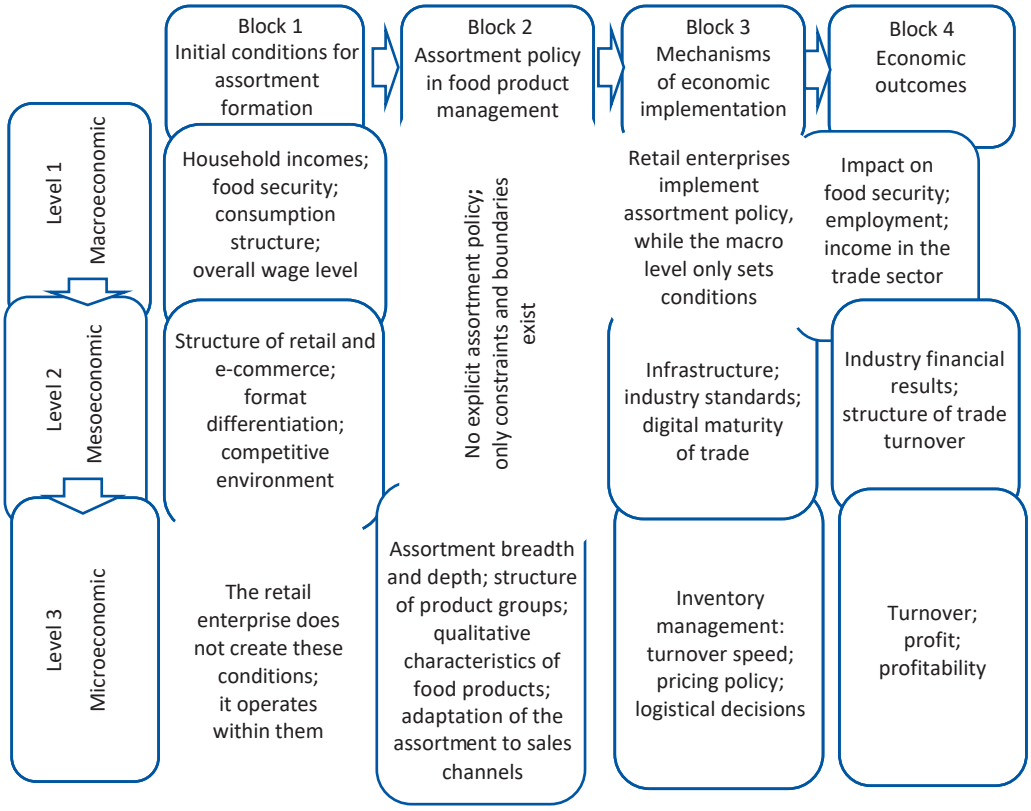

Figure 1. Descriptive model of the impact of food product assortment policy in Ukraine on the economic performance of retail enterprises

Source: developed by the authors

At Level 1, the model involves exogenous constraints and stimuli that are not directly related to the retail business but determine the assortment formation potential. In this sense,

the Level 1 plays the role of a "link" between the macroeconomy and the business enterprise. Level 3 is the core level of the model that implements the assortment policy as an integration of product and economic decisions. The second stage of the cascade includes the model for the formation of selling costs for food products depending on the achieved turnover, assortment structure, and the cost factors of sales. Inclusion of the indicator of assortment concentration makes it possible to account for the scale effects and the complexity of logistics and operational processes, while the average wage in trade reflects the laboriousness of the sales process and is one of the main cost items in the structure of retail business costs. The second model formalises the mechanism of transforming the sales volume and assortment structure into the cost component of activities. At the third stage of the cascade, the operating profitability of retail enterprises is separately modelled for specialised and non-specialised trade formats. Profitability is viewed as the result of the interaction of the achieved turnover, selling costs, and assortment structure that enables tracing the differences in the sensitivity of economic results to assortment factors depending on the trade format. Segmentation of the models by trade formats makes it possible to ensure the greater economic meaningfulness of the results and enhance the analytical value of the study. Macroeconomic indicators (food security, incomes of the population) are not included directly in the models but are used in the interpretation of the results and explanation of the revealed trends. This approach makes it possible to preserve the analytical compactness of the econometric models without sacrificing their economic significance. The proposed cascade econometric model creates the methodological framework for a comprehensive analysis of the influence of food product assortment policy on the main economic outcomes of retail enterprises and forms the basis for a comparative evaluation of the effectiveness of assortment decisions in different trade formats.

Model 1. Turnover of food products:

$$T_t = \beta_0 + \sum_{i=1}^{n} \beta_i a_{i,t} + \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 X_3 + \alpha_4 F_{share} + \varepsilon_t, \quad (1)$$

where β_0 is the model constant; β_i are coefficients reflecting the contribution of the respective product categories to the turnover of food products; α_1, α_2, α_3, α_4 are coefficients for aggregated indicators of assortment policy and consumer demand; ε_t is a random error capturing the influence of non-formalised factors. The condition $\sum_{i=1}^{n} = 1$ is imposed to avoid perfect multicollinearity, with one category used as the base.

Model 2. Selling costs of food products (assortment implementation mechanism):

$$S_t = \gamma_0 + \gamma_1 T_t + \sum_{i=1}^{n} \gamma_i a_{i,t} + \lambda_1 X_3 + \lambda_2 W_{trade} + w_t, \quad (2)$$

where γ_0 is the model constant; γ_1 is the coefficient reflecting the impact of food product turnover on selling costs; γ_i are coefficients reflecting the effect of assortment structure on the cost component of sales; λ_1 is the coefficient for the assortment concentration indicator; λ_2 is the coefficient for the average wage in trade; w_t is the random error. Inclusion of X_3 allows the model to capture the effect of assortment concentration on logistics and operational costs associated with selling food products.

Model 3. Operating profitability (separately by trade format):

Specialised stores:

$$R_t^{spec} = \delta_0^{spec} + \delta_1^{spec} T_t - \delta_2^{spec} S_t + \sum_{i=1}^{n} \delta_i^{spec} a_{i,t} + \theta^{spec} X_3 + \xi_t^{spec}, \quad (3)$$

Non-specialised stores:

$$R_t^{nonspec} = \delta_0^{nonspec} + \delta_1^{nonspec} T_t - \delta_2^{nonspec} S_t + \sum_{i=1}^{n} \delta_i^{nonspec} a_{i,t} + \theta^{nonspec} X_3 + \xi_t^{nonspec}, \quad (4)$$

where δ_0^{spec}, $\delta_0^{nonspec}$ are the constants of the respective models; δ_1^{spec}, $\delta_1^{nonspec}$ are coefficients reflecting the effect of food product turnover on operating profitability; δ_2^{spec}, $\delta_2^{nonspec}$ are the impact of selling costs on operating profitability; δ_i^{spec}, $\delta_i^{nonspec}$ are the differentiated impact of assortment structure on profitability for each trade format; θ^{spec}, $\theta^{nonspec}$ are coefficients for the assortment concentration indicator; ξ_t^{spec}, $\xi_t^{nonspec}$ are the random errors of the respective models.

Thus, the proposed cascading economic and mathematical model enables a comprehensive assessment of the impact of food product

assortment policy on the key economic outcomes of trading enterprises through sequential modelling of turnover, selling costs, and operating profitability. The cascading structure ensures alignment between the structural characteristics of the assortment and financial and economic indicators, while also allowing identification of the differentiated effects of assortment factors depending on the trade format. The modelled results have formed a conceptual framework for further quantitative assessment of the efficiency of assortment decisions and the development of practical proposals for optimising the assortment policy of trading enterprises. The modelled forecast of main economic performance indicators of trading enterprises in the food product segment for 2026-2027 was compiled based on the official statistical information of the State Statistics Service of Ukraine, which was used as input variables for the cascading economic-mathematical model. The forecast does not include the year 2025, since it is already completed, and it is focused on the postcrisis recovery phase of trading activity. The forecast was compiled by inertial extrapolation of the time series of food product turnover and subsequent calculation of selling costs and operating profitability according to the estimated modelled dependencies. This made it possible to bring projected values in line with the actual dynamics of retail trade, in accordance with the logic of the cascading model. The projected economic indicators are interpreted in terms of the assortment concentration parameters, identified at the previous stages of the study. The assortment concentration is understood as the degree of concentration of food product turnover in a limited range of product categories and assortment items that account for the bulk of sales. It was found that in non-specialised stores, a high concentration of turnover is characteristic of everyday consumer goods with fast turnover and low assortment diversity, which provides large sales volumes, but is accompanied by high selling costs. In specialised stores, the concentration is lower, but the greater depth of assortment provides a higher level of operating profitability. During the forecast period, it is assumed that the structure of assortment concentration will be preserved inertially, which makes it possible to consider the changes in economic indicators as the result of the efficient use of the existing assortment, rather than the exogenous expansion of the assortment (Table 9).

Table 9. Modelled forecast of key performance indicators for trading enterprises in the food product segment by trade format, 2026-2027

Indicator	Year		
	2024 (actual/ estimate)	2026 (forecast)	2027 (forecast)
Turnover of food products, million UAH, including:	651.60	788.40	867.20
specialised stores	19.50	23.70	26.00
non-specialised stores	632.10	764.70	841.20
Selling expenses, million UAH, including:	147,469.80	198,400.00	222,300.00
specialised stores	1,330.40	1,780.00	1,990.00
non-specialised stores	146,139.40	196,620.00	220,310.00
Operating profitability, %			
specialised stores	12.51	13.2	13.6
non-specialised stores	10.79	11.4	11.8

Source: developed by the authors

The growth of the food product turnover in non-specialised stores in 2026-2027 is predicted by the forecast calculation to be accompanied by a high concentration of assortment, when the sales volumes are formed by a limited number of commodity groups. This model allows scaling the turnover, but at the same time, there is an unevenly large increase in the costs of sales, which limits the expansion of the possibilities for improving the operating profitability. In specialised stores, despite the low share of total turnover, the moderate concentration of the

assortment and the great depth of differentiation of the products make it possible to maintain a higher level of profitability. This confirms the assumption that the optimisation of the assortment structure has a greater impact on the financial result than the growth of sales volumes. Thus, the concentration of assortment acts as a transmission mechanism between the turnover, sales costs and operating profitability of trading enterprises. The results confirm the practical importance of using the assortment policy as an instrument for managing the business performance. In particular, for non-specialised stores, it is necessary to monitor the concentration of turnover in order to avoid high costs, while for specialised stores, it is important to preserve the depth and diversity of the assortment in order to increase the margin. The modelled forecast for 2026-2027 confirms the validity of the cascade approach to assessing the economic indicators of trading enterprises in the food product segment. The future development of the business is determined not only by the dynamics of turnover, but also by the parameters of the concentration of the assortment, which has a direct impact on sales costs and profitability. Optimising the structure of the assortment can have a positive financial effect even without growth in sales volumes, while the mechanical increase in the turnover, not considering the concentration, does not lead to an improvement in operational efficiency.

The results of this study are consistent with the current state of the literature on the assortment policy and the optimisation of the product offer in retail. In particular, the systematic review of J. Heger & R. Klein (2024) showed that assortment optimisation is a key lever for managing demand and profitability in a wide range of industries, including the food retail sector, and that there are different approaches to the mathematical modelling of assortment decisions, depending on the behaviour of consumers and the constraints of the enterprise's activity. The models of decision support management for assortment, shelf space allocation and replenishment, which have been reviewed, stress the need for integrating assortment optimisation with space and logistics constraints. In particular, A. Hübner & H. Kuhn (2024) proposed an integrated assortment management, shelf space allocation and replenishment model for fast-moving food products. This management model confirms the results of the present research in terms of the need to integrate not only the structural assortment characteristics, but also the operational characteristics of trading enterprises to achieve economic efficiency. The research by O. Arhami *et al.* (2024) also stressed the need for integrating dynamic assortment planning and capacity allocation in a multi-period setting with active demand learning. Therefore, assortment management should be adjusted not only in terms of the static structure of product categories, but also in terms of time-varying demand and capacity constraints, which directly affect the turnover and financial result of the enterprise, especially under uncertainty and limited resources. The results of these recent studies are consistent with the results of the present research, which showed that the structural optimisation of the assortment (not only in terms of breadth or depth, but also in terms of adaptation to the behavioural and operational market characteristics) is an essential condition for the economic efficiency of enterprises operating in the food sector. The comparison of the results of the present research with the research on assortment management in a general marketing context also shows that the assortment policy and consumer behaviour relationship is ambiguous. For example, the research by A.M. Turri & A. Watson (2022) found that, in general, consumers react positively to broader assortments, as they increase the probability of finding the right product, which yields a competitive advantage for retail enterprises. These results are consistent with the present research, in which the concentration of sales volumes in the core product categories provides stable turnover and economic efficiency.

In addition, assortment policy is of particular importance for the strategic management of enterprises, especially in the food sector. The literature review showed that assortment design is not only a function of marketing, but also of management, which ensures the optimisation of turnover and profitability. For instance, in the meta-analytic study, R. Sethuraman *et al.* (2022) pointed out that the size of the assortment is one of the most important factors that affect consumer behaviour in the majority of product

categories. Similarly, the research outcomes of H. Karimi (2024) stressed that joint optimisation of assortment and promotional policies may have a significant impact on the profitability of retail chains, which is in line with the implication of the current study that an integrated assortment policy is a prerequisite for fulfilling the financial performance goals of a company. The algorithmic decision support approaches to assortment management have the same orientation. Thus, the study by O. Iurasova (2025), for example, suggests an algorithm for the optimal management of assortment, inventory, and distribution of goods based on mathematical modelling. The implication of this study is consistent with the current study's conclusion about the need for using quantitative models to analyse the influence of assortment policy on the main economic results. Therefore, a comparison of the current results with recent international studies indicates that assortment optimisation in the context of models of consumer behaviour, logistics, and integrated planning is still a topical problem in retail science. The findings of the current study complement and enhance these implications by adapting them to the specifics of the food products and the Ukrainian market. Based on this, the results of the study enable the formulation of several practical and methodological implications. In particular, the results confirm the need to assess the effectiveness of assortment policy not by separate indicators but by a consecutive chain of influence on turnover, distribution costs, and operating profitability. The suggested approach can be used as an analytical instrument for comparative analysis of assortment solutions in specialised and nonspecialised retail formats, as well as for the identification of reserves for improving the economic efficiency without thoughtless expansion of the assortment. Simultaneously, the model can serve as a methodological basis for subsequent studies directed toward its adaptation to other groups of goods, retail formats, or conditions of market uncertainty.

CONCLUSIONS

The results of the study show that the assortment policy in the food market determines the economic efficiency of trade enterprises in Ukraine. Based on the analysis of the assortment structure, sales dynamics and financial performance of trade enterprises, it was found that the width, depth and concentration of the assortment have a significant impact on the turnover, distribution costs and operating profitability. The application of the cascade economic and mathematical model made it possible to formalise the cause-and-effect relationships between the microeconomic indicators of the assortment, the mesoeconomic demand and financial results of enterprises, and to identify the differences in the sensitivity of profitability to changes depending on the retail format (specialised and non-specialised trade enterprises). The results of the modelling demonstrate that the optimisation of the assortment structure, a balanced combination of mass and niche product categories and efficient management of SKUs contribute to improving the operational efficiency and reducing distribution costs. At the same time, the macroeconomic environment, namely, the level of household incomes and food security, predetermines the conditions for the implementation of assortment policy. The main factors that influence the economic efficiency of specialised trade enterprises are turnover and assortment concentration, while those of non-specialised trade enterprises are cost control and strategic assortment expansion. The forecast for 2026-2027 shows an increase in turnover, distribution costs and operating profitability for both formats of trade enterprises. Non-specialised trade enterprises will increase sales volumes while increasing costs, while specialised trade enterprises will keep the level of margin unchanged due to assortment differentiation. Trade enterprises that will adjust the assortment structure to the specifics of the network and consumer demand will increase the operating profitability and strengthen the market positions. The directions for further research are the study of assortment policy influence on the economic efficiency in the context of trade digitalisation, online distribution channels and changing priorities of consumer behaviour, as well as the study of assortment influence on healthy nutrition and food market resilience.

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Асортиментна політика у товарознавстві продовольчих товарів України та її вплив на економіку торговельних підприємств

Анотація. Асортиментна політика продовольчих товарів є ключовим фактором, що визначає ефективність діяльності торговельних підприємств і конкурентоспроможність роздрібного ринку. Вона впливає на формування товарообороту, витрат на збут та рентабельності операційної діяльності, а також відображає поведінку споживачів та їхні пріоритети. Метою роботи була формалізація причинно-наслідкових зв'язків між структурними

характеристиками асортименту та економічними результатами діяльності торговельних підприємств, а також визначення диференційованого впливу асортиментних факторів залежно від формату торгівлі. У дослідженні використано методи бібліографічного аналізу, групування, аналіз часових рядів, економіко-математичне моделювання, включаючи каскадну модель впливу структури асортименту на товарооборот, витрати на збут та рентабельність операційної діяльності, а також логічне узагальнення. Результати свідчать, що ширина, глибина та концентрація асортименту істотно визначають економічні показники підприємств. Для спеціалізованих магазинів критичними є управління товарооборотом і концентрацією продажів, тоді як для неспеціалізованих – контроль витрат на збут і оптимізація структури асортименту. Використання каскадної моделі дозволяє кількісно оцінити внесок кожної товарної категорії та агрегованих показників асортиментної політики у фінансові результати. Макроекономічні фактори, зокрема доходи населення та рівень продовольчої безпеки, формують контекст реалізації асортиментної політики та впливають на ефективність її впровадження. Практична цінність дослідження полягає у наданні рекомендацій для торговельних підприємств щодо оптимізації асортименту, підвищення рентабельності та конкурентоспроможності. Результати можуть бути корисними для бізнесу, державних органів і науковців при розробці стратегій розвитку роздрібної торгівлі та вдосконаленні управління асортиментною політикою

Ключові слова: структура товарного асортименту; роздрібна торгівля продуктами; економічна ефективність; фінансові результати; витрати на реалізацію; операційна рентабельність

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Strategies for improving the management of enterprise financial resources to enhance the efficiency of investment activities

Abstract. This article aimed to substantiate approaches to optimising the management of enterprise financial resources in order to enhance the effectiveness of investment activities and financial stability under conditions of macroeconomic instability. The methodology involved the application of dynamic, comparative, trend and financial analysis, as well as case analysis, which made it possible to assess the dynamics of capital investment, sectoral structure and structure of investment financing, as well as the financial and investment activities of enterprises. It was established that in 2022, the volume of capital investment in Ukraine decreased to UAH 409.7 billion (-39.2% compared to 2021), in 2023 it was UAH 395.5 billion, and in 2024 it increased to UAH 534.4 billion. In the first half of 2025, the volume of capital investments increased by 30.6% compared to the same period of the previous year. It was established that in 2025, approximately 73.7% of investments were financed from enterprises' own funds. An analysis of the financial results of Myronivsky Hliboproduct indicated an increase in capital investments from USD 106 million in 2022 to USD 219 million in 2025, and an increase in net profit from a negative value in 2022 to USD 215 million in 2025. Metinvest Group showed a decrease in total debt from USD 2,077 million in 2022 to USD 1,572 million in 2025, while maintaining investment activity at a supporting level. The findings indicated that the effectiveness of investment activity is determined by the ability of enterprises to align the management of financial resources with investment decisions, balance sources of financing, and adapt financial strategies to sectoral and macroeconomic constraints. These results may be applied in the practical management of enterprise financial resources

Keywords: capital; stability; budgeting; cash flows; planning

INTRODUCTION

In conditions of increasing macroeconomic instability, limited access to long-term capital and high financial risks, the rational formation and use of cash flows is the main factor ensuring the investment development of enterprises. Growing volatility in financial markets, tightening lending conditions and increasing the cost of borrowed capital require revising approaches to

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planning, distribution and monitoring of financial flows within the investment decision-making framework. The lack of concordance between the formation of cash flows and long-term development goals of an economic entity results in the loss of investment income and aggravates the financial instability in the context of macroeconomic volatility. The research by D. Mavlieva & O. Lysa (2023) discusses the formation of the system of management of financial resources of an economic entity. Special emphasis is placed on the role of the financial strategy, the structure of sources of financing, and the relationship between the equity-to-borrowed-capital ratio and profitability. The study also provided empirical evidence of the influence of financial autonomy and asset turnover on financial performance. These findings substantiated the need to optimise the capital structure and improve mechanisms for the allocation of financial resources.

The lack of a systematic approach to the formation and use of enterprise financial flows, together with the fragmented nature of managerial actions, complicates the achievement of a stable financial position under conditions of increasing uncertainty. The study by M. Adamiv & V. Hanas (2024) proposes a process-structured approach to the management of financial resources, within which financial resources are systematised according to their sources of formation. The sequence of basic management stages is substantiated, and their content structure is clarified in accordance with the classical management logic. The obtained results enable the refinement of the theoretical concept of financial resource management and the demonstration of the advantages of the process-based comprehensive approach to ensuring the stable financial state of an economic entity. At the same time, H. Pavlova *et al*. (2024) examined the relationship between the management of enterprise financial resources and the provision of financial and economic security. The study substantiated the role of a rational capital structure, budgeting, and cash-flow management in reducing risks and maintaining financial stability under conditions of instability. Empirical analysis confirmed that an effective system of management of financial resources contributes to the optimisation of the needs for working capital, the expansion of production capacities, and the maintenance of the appropriate level of economic security of the economic entity.

The lack of coherence in the approaches to the formation, distribution, and internal turnover of an economic entity's funds in the conditions of increased uncertainty complicates the achievement of strategic development goals and the preservation of financial stability. The research by S.A. Nakonechna (2025) systematised the theoretical approaches to the management of financial resources and formed a general mechanism that combines regulatory and supporting methods, information and regulatory support, a system of management levers and factors of influence, and a set of tools for managing the formation, use, and internal movement of an economic entity's financial resources. According to the obtained results, it was possible to prove directions for optimising the cost structure, to determine the potential for development and to form a step-by-step logic for improving the efficiency of financial decisions aimed at ensuring the long-term stability of the enterprise. The article by V. Karaschenko & O. Rybitsky (2024) investigated the conditions and factors for efficient financial resource management. Much attention was paid to the impact of seasonality, market price fluctuations and the level of financial literacy of the management staff on the formation of cash flows. The study also showed the positive role of automation of accounting, information systems and specialised risk management tools in improving the reliability of financial planning and cost control. Based on the results, it was possible to formulate a set of recommendations for optimising the use of financial resources and enhancing the financial stability of the enterprise.

The discrepancy between the existing resource potential of the enterprise and the priorities of its development significantly limits its adaptive capacity, innovation and stability maintenance in conditions of a dynamically changing external environment. N. Bogatska (2025) made a thorough analysis of the concept of enterprise resource potential, considering both the material and nonmaterial components. The structure of the potential was systematised, and a sequence of managerial stages was identified, including

assessment, planning, organisation, control and adjustment of managerial decisions. It also substantiated the role of financial, intellectual, informational, and technological resources in ensuring the stability and effectiveness of enterprise performance. The conclusions obtained provided a coherent understanding of the mechanism for managing resource potential and highlighted the importance of a systemic approach. In the framework of the research on developing a strategy for the financial stability of the enterprise in the digitalisation conditions, A. Goloborodko (2025) substantiated the integration of financial and digital stability as interdependent components of competitiveness. The role of digital platforms, innovative technologies and flexible management technologies in improving the efficiency of financial flows and strategic planning was revealed. The results expanded the understanding of the transformation of traditional models of financial management and highlighted the importance of digital tools in ensuring enterprise stability. K.S. Vynnyk (2024) focused on improving the effectiveness of financial resource management in enterprises. The author substantiated the expediency of using a system of direct and indirect assessment indicators, disclosed a mechanism of formation of the optimal structure of financial resources and proposed a comprehensive financing optimisation model, considering the cost of attracting capital, the time factor of cash flows and financial leverage. The presented approach deepened the understanding of the essence of the financial strategy and outlined the prospects for enhancing the solvency, financial independence and business activity of the enterprise.

At the same time, the questions of integration of financial resources management with the investment planning, quantitative assessment of the influence of financial decisions on investment returns and adaptation of the proposed approaches to the conditions of macroeconomic instability remain not fully explored. This study aimed to create practical recommendations for the improvement of corporate finance through the implementation of innovative tools for stimulating investment activities and enhancing financial stability. To achieve the stated aim, the study set the following objectives: to assess approaches to financial resources management in agricultural and industrial sector enterprises; and to evaluate the investment activity role in the formation of the financial performance and financial stability of enterprises, on the example of the dynamics of capital investments, structure of financing and key financial indicators.

MATERIALS AND METHODS

The study had an empirical character and covered the period from 2022 to 2025, as this interval reflects a phase of a sharp decline in investment activity, followed by a recovery of financial indicators and a transformation of strategies for managing the financial resources of enterprises in Ukraine. The dynamics of capital investment in Ukraine from 2022 to mid-2025 were analysed using the dynamic method on the basis of open sources, namely Experts Club (n.d.) and NBN (2025). This made it possible to identify general trends in the decline and recovery of investment activity and to assess the relationship between macroeconomic conditions and the volume of capital investment. A sectoral comparative analysis was applied to compare the volume and growth rates of capital investment in agriculture and industry in 2024 and in the first half of 2025, as well as to examine the structure of investment financing by source using data from Experts Club (n.d.). The limitation of the study period to 2024 and the first half of 2025 was determined by the need to analyse the stage of postshock stabilisation and the recovery of investment activity. Such an approach enabled the estimation of the non-uniformity of investment activity and the role of the own funds of enterprises in ensuring financial stability.

The financial support of the agro-industrial complex, in particular the scope of losses due to the hostilities and the structural orientation of financial resources, was analysed based on materials of the Committee on Agrarian and Land Policy (2024) by the content analysis method. This approach allowed for systematising the estimated losses, directions of financial support and tools for restoring the sector. The choice of materials for 2024 is explained by the fact that it was during this period that the generalisation of the accumulated losses of previous years of war was carried out and the parameters of financial

restoration of the agro-industrial complex were outlined, which ensured the comparability and comprehensiveness of analytical conclusions.

The analysis of the efficiency of financial resources management strategies was carried out based on the case study of Myronivsky Hliboproduct (MHP) and Metinvest Group, which were chosen as large-scale enterprises, representatives of the agricultural and industrial sectors of Ukraine. These enterprises have different revenue structures, investment priorities and levels of financial risks, which enabled comparison of approaches to financial resources management in conditions of macroeconomic instability. Trend analysis was used to assess the dynamics of such financial and investment indicators of MHP as revenues, net profit, EBITDA (earnings before interest, taxes, depreciation and amortisation), CAPEX (capital expenditures), operating cash flows, net debt, and the Net Debt/EBITDA ratio in 2022-2023. The analysis was carried out on the basis of interim financial statements for the third quarter of each of the corresponding years, which ensured the comparability of the data for the study period due to the absence of publicly available annual reports, and allowed tracing changes in the investment activity and financial performance of the company (MHP, 2022; 2023). A similar trend-based approach was applied to analyse the above financial and investment indicators of MHP (2024; 2025) in 2024-2025 on the basis of comparable interim reporting data as of the third quarter. This allowed evaluation of the stability of financial results and the consistency of investment activity with the dynamics of the company's debt burden under conditions of persistently high risks.

Trend and financial ratio analyses were used to evaluate the dynamics of revenues, EBITDA, EBITDA margin, CAPEX, total debt, and the Net Debt/EBITDA ratio of the Metinvest Group in 2022-2023. This made it possible to characterise changes in the company's financial strategy in the conditions of decreased production and logistics potential, based on the annual reports of Metinvest (2022; 2023). Trend analysis and debt burden indicators presented in the financial statements were used to assess the financial and investment indicators of Metinvest (2024; 2025) for 2024 and the first half of 2025, which made it possible to identify changes in approaches to the management of investment resources and financial stability.

The comparison of strategies for managing financial resources between MHP and the Metinvest Group was carried out based on the actual financial results and dynamics of investment indicators. The officially declared financial strategies of the companies are not presented in the publicly available reports of the companies; therefore, the strategic approaches were interpreted based on the results of cash flow management, investment activity, and debt burden dynamics. Modern concepts for managing financial flows and investment resources of enterprises were generalised and logically modelled based on the scientific studies of I. Pasinovych & O. Sych (2020), S.M. Faisal *et al.* (2025), and L.V. Parii & V.V. Zasansky (2025). Based on the results of the analysis of the financial strategies of MHP and the Metinvest Group, the scenario analysis of the basic financial parameters was conducted, and recommendations for improving the financial stability and investment activity of enterprises with the expected economic effect were developed.

RESULTS

Conceptual and methodological approaches to the management of financial resources and the implementation of enterprise investment activity

The management of enterprise financial resources within the framework of investment activity is formed through a combination of theoretical principles of financial science and methodological approaches to managerial decision-making. Financial resources are the aggregate of own, attracted and borrowed funds, ensuring the continuity of business processes and providing opportunities for the implementation of investment projects. Their structure, sources of formation, and directions of use determine both the financial constraints and the development potential of an enterprise in the long term. Theoretical approaches to financial resource management are based on the concepts of optimal capital structure, cash-flow management, and financial risk management. According to these approaches, the efficiency of financial

resource utilisation depends on the balance between equity and borrowed capital, the cost of attracting financing, and the ability of an enterprise to generate stable cash flows. In this case, investment activity is considered a direction for using financial resources for the reproduction and expansion of production and economic potential (Stus & Chumachenko, 2024). The methodological approaches to managing financial resources in investment activity include a system of financial planning, budgeting and control. Financial planning determines the required amount of resources, the time of their mobilisation and the directions of their use within investment programs. Budgeting provides a detailed elaboration of financial flows by the responsibility centres and the stages of investment decision-making, which increases the transparency of financial management. A special place in the methodological provision of financial resource management is occupied by approaches to investment efficiency evaluation, among which there are discounted cash flow methods, sensitivity analysis, risk assessment and scenario modelling. The application of the above-mentioned tools allows comparing the alternative investment decisions and justifying the appropriateness of allocating financial resources to this or that project. In these approaches, financial resources are not considered only as a limitation but also as a tool for obtaining long-term financial results (Sharma, 2025).

The management of financial resources in investment activities implies the interconnection of operational and strategic management. Operational management includes monitoring liquidity, solvency, and cash flows, and strategic management is related to choosing directions of investment, formation of the investment project portfolio, and definition of priorities of financing. Such interconnection of the levels of management allows making financial decisions in accordance with the long-term development goals of the enterprise. Investment activity is a quantitative and qualitative indicator of the ability of an enterprise to reproduce the economic potential and ensure the financial balance in the medium and long term. The dynamics of capital investments are directly related to the state of financial resources of the enterprise, the availability of financing sources, and the expected results of the investment decisions. In such a way, investment activity becomes a result of the harmonisation of financial opportunities and development needs (Levkiv *et al*., 2025).

In 2022, the volume of capital investments decreased to UAH 409.7 billion, which is 39.2% less compared to 2021 (DerzhZovnishInform, 2023). The reason for this decrease is the insufficiency of financial resources of the enterprise, the growth of uncertainty, and the restructuring of cash flows in favour of ensuring the current activity. Since 2023, there have been signs of investment activity stabilisation and its gradual restoration: in 2023, the volume of capital investments totalled UAH 395.5 billion, which proves that the economy preserved limited investment opportunities under conditions of wartime risk. In 2024, the growth of investment activity was observed: the volume of capital investments reached the level of UAH 534.4 billion, which is 35.1% higher than in 2023 (Open4Business, 2025). In January to June 2025, the volume of capital investments totalled UAH 280.18 billion, which is 30.6% higher than in the same period in 2024, although the growth rates demonstrated a tendency towards deceleration (Experts Club, n.d.).

The restoration of investment activity was followed by changes in the structure of financing sources and the branch structure of investments. The majority of investments were made at the expense of the enterprises' own funds, which in 2025 made up about 73.7% of the total investments (NBN, 2025). Such a financing structure is caused by the lack of external sources, and at the same time, it indicates the importance of internal financial resources for investment activity and the financial stability of enterprises. The sectoral structure of investments testifies to the differentiated recovery of investment activity. In the agricultural sector, the volume of capital investments increased by 35.5% in 2024 and reached UAH 42.9 billion, and in the first half of 2025, by 46.6% and UAH 29.55 billion. In the industrial sector, the growth of investments was 23.1% in 2024 and 32.1% in the first half of 2025, with a total volume of UAH 110.45 billion (Experts Club, n.d.). These tendencies demonstrate the recovery of investment activity in key sectors

of the economy and the formation of financial prerequisites for the renovation of production potential. The connection between investment activity and financial stability is due to the influence of investments on the asset structure, cash flows and the level of debt of enterprises. Capital investments, which are mainly carried out at the expense of internal resources, reduce dependence on borrowed capital but require ensuring the necessary level of liquidity and financial discipline. In such conditions, investment activity becomes an instrument for reconciling current financial needs with long-term development goals of enterprises (Andros, 2025).

Providing financial support to the agricultural sector throughout 2024 was carried out mainly at the expense of internal resources and government support instruments. The total volume of attracted financing exceeded UAH 100 billion, while the "Affordable Loans 5-7-9%" programme has been extended until 31 March 2026 (Agro Finance Summit, 2025). The dominance of internal sources of financing is also evidenced by the structure of investment activity: in 2025, more than 80% of transactions in the Mergers and Acquisitions market accounted for domestic investments, while foreign investments accounted for about one-fifth. This structure indicates the growing role of the internal financial potential of the agricultural sector in conditions of limited activity of foreign investments. At the same time, the war has resulted in substantial financial losses in the agricultural sector. As of June 2023, total direct losses of the agro-industrial complex were estimated at approximately USD 8.7 billion, including over USD 4.7 billion due to the destruction and damage of agricultural machinery and about USD 1.9 billion in losses of produced goods. Indirect losses were estimated at USD 40.3 billion, while additional losses incurred by rural households amounted to approximately USD 2.25 billion (Himmelfarb, 2023). These figures highlight the growing financial vulnerability of small-scale agricultural producers. The financial state of agricultural enterprises during the war is characterised by an increase in the share of unprofitable enterprises and a decrease in the level of profitability. In 2022, 21% of enterprises engaged in agriculture, forestry, and fishery recorded a net loss (while in 2021 this indicator was 11%). The overall return on activity decreased from 37.8% to 14.1%, which limited the ability of enterprises to self-finance and invest in activity. An additional factor of financial pressure was the decrease in the volumes of capital investments and the growth of production costs. There were also significant changes in the structure of the costs of agricultural enterprises. The lack of financial resources resulted in the application of fertilisers and plant protection products at the level of 50% to 60% of agronomic needs, which had a negative impact on both the productivity of crops and the quality of the soil. The most vulnerable to such restrictions were small-scale and frontline farms, the production costs of which were 5% to 10% higher in comparison with medium-sized enterprises. A separate challenge for managing financial resources was the crisis in the livestock industry. The decrease in the number of cattle, in particular on household farms, resulted in a decrease in milk production and cash receipts. At the same time, agricultural enterprises showed higher financial stability, in particular due to the transfer of production to safer regions and the gradual recovery of milk production to the pre-war level in 2023 (Committee on Agrarian and Land Policy, 2024).

Even in such a context, agriculture had the potential to provide food security for the country and continue export activities. This is because the output of main field crops exceeded the domestic consumption needs, which in turn provided an opportunity to receive foreign currency revenues and retain the financial stability of business entities. However, it required adjusting the mechanisms of financial resource management, first of all due to the emphasis on internal sources of their mobilisation, cost optimisation and harmonisation of financial decisions with the increased business risks. The management of financial resources of Ukrainian agricultural enterprises in wartime takes the form of structural losses, financial constraints and adaptation mechanisms, and as a result, a specific model of financial management is formed, which is focused on maintaining solvency, preserving the potential for production activities and partial resumption of investment activities.

Assessment of the effectiveness of strategies for managing enterprise financial resources

In 2022-2025, the investment activities of an enterprise developed against the background of rather big changes in the mechanisms of managing financial resources, conditioned on macroeconomic instability, risks caused by the war and operational transformations. In such a context, investments are considered not only as a means of reproduction and expansion of production potential but also as an element of financial strategy, which is directly related to the mechanisms of cash flow formation, indebtedness level and general financial state of an enterprise. The management of financial resources of MHP in 2022-2025 took place under conditions of instability, which required some changes in approaches to forming the cash flow, investment activities and debt policy. To analyse the dynamics of financial state, investment activities and financial stability, the consolidated indices of MHP performance in 2022-2025 are presented in Table 1. The data have been compiled from the interim financial reports of MHP published as of September of the corresponding years. The annual financial reports for some of the analysed periods were not publicly available at the moment of preparing the research, which is why it was necessary to use the comparable interim reports to provide the time consistency and comparability of the analysed indices.

Table 1. Key financial and investment indicators of MHP, 2022-2025 (according to interim financial statements as of September)

Indicator	2022	2023	2024	2025
Revenue, million USD	1,876	2,294	2,262	2,635
Net profit, million USD	-269	122	141	215
EBITDA (adjusted), million USD	275	111	346	455
Capital expenditure (CAPEX), million USD	106	158	217	219
Operating cash flow, million USD	–	–	265	359
Net debt, million USD	1,186	1,153	1,169	1,529
Net Debt/EBITDA	2.94	2.51	2.12	2.61

Note: the absence of aggregated data on operating cash flow for 2022-2023 reflects MHP's disclosure practices in the respective reporting periods, where the indicator was presented solely within the cash flow statement structure, without being highlighted as a separate key financial metric

Source: compiled by the author based on MHP (2022; 2023; 2024; 2025)

As can be seen from the data in Table 1, the lowest financial results were achieved by MHP in 2022. In this year, the only negative net financial result for the entire period of analysis was recorded (USD -269 million), and the value of EBITDA, although remaining positive (USD 275 million), was insufficient to compensate for currency and operating losses. Along with this, in 2022, the largest debt burden was observed, as evidenced by the maximum value of the Net Debt/EBITDA ratio – 2.94. In 2023, the dynamics of financial results were characterised by the minimum value of EBITDA for the entire period of analysis (USD 111 million), which reflects the remaining influence of the crisis factors of the previous year. At the same time, net profit recovered to the level of USD 122 million, and the value of the Net Debt/EBITDA ratio decreased to 2.51, which indicates the beginning of stabilisation of the financial situation.

The period of 2024 to 2025 is characterised by the transition of MHP to the phase of financial stabilisation, which is accompanied by an intensification of investment activity and improvement of operating efficiency and internal financial capacity. The decrease in the relative debt burden in 2024 contributed to the growth of capital investments without a significant deterioration in the financial stability of the company. In 2025, the growth of operating activity was accompanied by the growth of cash flows, which indicates an improvement in the quality of profit and a balanced investment policy in conditions of preservation of external risks. At the same time, the growth of net debt to the level of USD 1,529 million and an increase in the Net

Debt/EBITDA ratio to 2.61 reflect the activation of investment processes, including the implementation of mergers and acquisition transactions. Consequently, in the period of 2022-2025, the financial model of MHP was characterised by a transition from the phase of low financial results and a high debt burden to the phase of growth of operating activity and expansion of investment activity at a controlled level of financial leverage. This creates an analytical framework for further comparative analysis with other companies.

In 2022-2025, the company's finance management in Metinvest Group was carried out under the conditions of a significant decrease in production capacities, a collapse of logistical chains and an increase in debt risks that predetermined the adaptive orientation of financial and investment policy aimed at ensuring liquidity, servicing debt and operational activities under the conditions of restricted investment opportunities. In order to systematise the dynamics of the company's financial results, investment activity and financial stability indicators, the main financial and investment performance indicators of Metinvest Group for 2022-2025 are presented in Table 2.

Table 2. Key financial and investment performance indicators of the Metinvest Group in 2022-2025

Indicator	2022	2023	2024	2025 (6 months)
Revenue, million USD	8,288	7,397	8,050	3,555
EBITDA, million USD	1,873	861	957	339
EBITDA margin, %	23	12	12	10
Capital expenditure (CAPEX), million USD	354	284	235	91
Total debt, million USD	2,077	1,981	1,705	1,572
Net Debt/EBITDA	0.9	1.6	1.1	1.9

Note: data for 2025 are presented for the first half of the year, as full annual financial statements were not publicly available at the time of the study. The 2025 figures are used not for direct comparison with the full annual values of 20222024 but to capture current trends in the company's operational and investment dynamics
Source: compiled by the author based on Metinvest (2022; 2023; 2024; 2025)

The analysis of the data in Table 2 shows that the best financial results for the considered period were achieved in 2022, when EBITDA amounted to USD 1,873 million, and the EBITDA margin was 23%, which is a maximum for the entire period. At the same time, 2022 was characterised by the largest decline in physical production volumes, which formed a structural imbalance between financial results and the production potential of the company. However, the lowest level of debt burden was also observed in 2022 (Net Debt/EBITDA – 0.9), which indicates a significant financial stability cushion at the beginning of the wartime period. In 2023, the company faced the largest decline in operational activity for the entire analysed period: EBITDA decreased to USD 861 million, and the EBITDA margin to 12%, which is the minimum full-year indicator. At the same time, the ratio of Net Debt/EBITDA increased to 1.6, which indicates an increase in the relative debt burden against the background of a decrease in the level of profitability. Capital investments in 2023 decreased to USD 284 million, which indicates an investment orientation mainly at the level of maintenance and reproduction of existing activities. In 2024, the financial performance indicators of the Metinvest Group demonstrated a partial recovery. Thus, EBITDA increased to USD 957 million, while revenue exceeded USD 8 billion, which is the second-highest indicator for the considered period. Simultaneously, CAPEX decreased to USD 235 million (with the primary focus on capital investments being the maintenance of existing capacity). The lowest value for the post-crisis period of the Net Debt/EBITDA ratio, 1.1, also relates to 2024, which points to an increase in financial stabilisation in the context of deleveraging.

The figures for the first half of 2025 give the lowest values for EBITDA and CAPEX for the entire period under consideration (EBITDA – USD 339 million, CAPEX – USD 91 million), which is indicative of the preservation of logistical constraints and high costs. Simultaneously, total debt decreased further to USD 1,572 million,

while the value of the Net Debt/EBITDA ratio increased to 1.9, which is evidence of the influence of the drop in operational efficiency on the relative indicators of financial stability. In general, during the period under analysis, the financial management of the Metinvest Group was characterised by a transition from a phase of high financial indicators and a minimal debt burden to a regime of financial adaptation, with an emphasis on ensuring liquidity, debt management, and preservation of the core volume of investment activity, which creates the basis for further comparative analysis with agribusiness companies.

Over the course of the period studied, a change in strategic priorities was observed in the financial management of both MHP and the Metinvest Group, which permits the identification of new approaches to financing, liquidity management, debt, and investment activity. For MHP, the inflexion point was 2023-2024, when the financial strategy changed from crisis stabilisation to a strategy of recovery of investment activity under conditions of controlled risk. This manifested itself in an increase in CAPEX, the stabilisation of cash flows, and the preservation of debt at a reasonable level. The change in these results is connected not only with an improvement in external conditions, but also with the restructuring of internal financial policy, in particular, the prioritisation of selffinancing of investments and the harmonisation of investment decisions with the dynamics of operational cash flows. A strategic shift in the Metinvest Group took place in a slightly different way and was noticed back in 2022-2023, when the company switched to an adaptive strategy of financial conservation, aimed at maintaining liquidity, reducing the risks of debt servicing, and minimising capital investments. Further dynamics in 2024-2025 are a consequence of the chosen strategy: despite the partial recovery of revenues, investment activity remained curtailed, and financial decisions were subordinate to maintaining solvency. Therefore, the discrepancy in financial performance and investment behaviour of companies in 2022-2025 should be considered as a consequence of different strategic models of financial resource management, rather than only as a consequence of external market or macroeconomic factors.

Thus, the differences between the companies were revealed in the ratio of investment activity and financial caution. MHP has a financial management model that is focused on development and restoring investment potential under the controlled use of debt instruments, and Metinvest Group has a model of financial conservation, aimed at stability and risk minimisation. The revealed differences testify that the efficiency of financial resource management strategies during the analysed period was determined not only by financial performance but also by the ability of enterprises to adapt investment behaviour to industry and technological constraints. This provides a foundation for generalising approaches to financial resource management across enterprises of different industrial sectors.

Directions for improving financial resource management to enhance the effectiveness of investment activity

Innovative models for managing financial flows and investment resources in enterprises are forming against the backdrop of an increase in economic uncertainty, changes in business models, and complicating logistical and financial ties. In these conditions, financial flows are considered not only as a derivative of the results of economic activity but also as an independent object of management that requires planning, coordination, and integration with investment decisions. The management of financial resources is moving from sectoral solutions to a systemic one, within the framework of which operational, investment, and financial flows are being harmonised. One of the leading innovative directions is the application of a logistical approach to managing financial flows. In this concept, money flows are considered as material and information flows, with emphasis on the time and space synchronisation. This involves synchronising receipts and payments according to the production cycle, investment programs and seasonality, as well as reducing transaction and financial expenses. The use of financial logistics tools enables enterprises to reduce the discrepancy between receipts and payments, reduce the dependence on short-term external financing and enhance the role of internal

working capital in financing investment activities (Pasinovych & Sych, 2020).

An element of innovation is the automation of financial business processes through the use of specialised software, big data analytics and artificial intelligence algorithms. The use of AI analytics and big data improves the accuracy of cash flow forecasting, optimises investment resource allocation and provides an opportunity to promptly correct financial decisions in accordance with the market situation. Digital financial platforms enable monitoring financial indicators in real time, which reduces the likelihood of cash gaps and increases the adaptability of financial resource management. In the agribusiness sector, digital instruments are intertwined with technological and production processes. The integration of sensors of the Internet of Things, unmanned aerial vehicles, and remote monitoring systems with an enterprise resource planning system enables the consolidation of operational, technological and financial data in a single information field. This opens up opportunities for more accurate management of investments in innovative directions, such as agrotechnology, precision farming and digital modernisation of production processes, taking into account real financial flows and limited resources (Faisal *et al*., 2025).

Innovative approaches to the management of investment resources also include enhancing financial risk management. Investment decisions are made taking into account the balance of expected return and risk, which is implemented within portfolio analysis and scenario modelling. The use of alternative development scenarios enables the evaluation of the stability of investment programs to macroeconomic shocks, logistical restrictions and financial perturbations. Moreover, environmental, social, and governance criteria are incorporated in the investment project selection process and access to financing, especially in economic recovery and project implementation in post-conflict territories (Parii & Zasansky, 2025). All innovative forms of financial flows and investment resources management form a systematic model of financial management, where digital technologies, logistical thinking and strategic optimisation ensure the concordance of short-term liquidity and long-term investment goals and allow the enterprise to adapt investment behaviour to the conditions of instability while maintaining the reproduction of investment potential without financial stability loss.

The research on strategies of financial resources management in MHP and Metinvest Group during 2022-2025 makes it possible to formulate the directions of improvement of financial management, aimed at improving the efficiency of investments in the conditions of increased macroeconomic and operational risks. The revealed difference in the financial behaviour models of the companies testifies that financial sustainability and investment development capability are determined not only by industry specifics, but also by the choice of instruments for cash flow management, debt policy and investment priorities. Scenario-based guidelines for improving the management of financial resources at MHP and the Metinvest Group are presented in Table 3.

Table 3. Scenario guidelines for improving financial resource management at MHP and Metinvest Group

Indicator	Baseline scenario (inertial)	Moderately optimistic scenario	Conservative scenario
MHP (agricultural type, vertically integrated)			
Share of internal sources in investment financing, %	55-60	65-75	50-55
Change in reliance on external debt	Without changes	-10%...-20%	-5%
Increase in CAPEX self-financing via operating cash flow (OCF)	5-8%	12-18%	3-5%
Net Debt/EBITDA dynamics	2.4-2.6	stabilisation ≤ 2.5	up to 2.8
Metinvest Group (export-oriented raw materials type)			
Change in Net Debt/EBITDA	±0.1	-0.5...-0.8	-0.2
Change in share of free cash flow	3-5%	10-15%	5-7%

Table 3, Continued

Indicator	Baseline scenario (inertial)	Moderately optimistic scenario	Conservative scenario
Metinvest Group (export-oriented raw materials type)			
Share of maintenance investments in CAPEX	≥ 75%	60-65%	≥ 80%
Reduction of non-productive investments	up to 5%	8-12%	3-5%

Note: scenario intervals are based on the actual dynamics of operational cash flows, debt indicators, and investment structures of the companies during 2022-2025; the table is analytical rather than predictive and is used to substantiate potential directions for improving financial resource management
Source: compiled by the author

According to the scenario recommendations in Table 3, for enterprises with a pronounced export and raw-material orientation, as in the case of Metinvest Group, the priority direction for improving financial resource management is the further strengthening of the debt management strategy and liquidity maintenance as the main condition for maintaining operational sustainability. Analysis of the financial activity of the company in 2022-2024 shows that concentration on deleveraging and debt reduction reduces the dependence of the financial result on the dynamics of operating profit and logistics constraints. In this connection, the expected outcomes of the application of this strategy are understood as the gradual consolidation of the company's financial independence and reduction of the risk of exceeding the limits of its debt commitments in the face of unfavourable external influences. The reinforcement of the role of free cash flow generates the financial conditions for the revitalisation of investment activity after the improvement of operational circumstances, without weakening the financial sustainability of the company. At the same time, for vertically integrated agricultural-type enterprises, as in the case of MHP, the results of the scenario analysis show the usefulness of combining debt policy with the active application of investment tools for development. MHP's financial performance in 2024-2025 has shown that the expansion of investment activity with relatively stable financial leverage is accompanied by an increase in operational cash flows and the company's capacity for self-financing, which provides an opportunity to develop investment programs adjusted to projected cash flows, thus mitigating the risk of exceeding debt limits and increasing the effectiveness of financial resource application. In this approach, investment policy fulfils not only a reproductive function but also a stabilising one, increasing the capacity of the enterprise to adapt to changes in the macroeconomic environment.

A shared direction for the improvement of financial resource management in both companies is the reinforcement of operational cash flow as a core determinant of investment potential. Scenario benchmarks suggest that the dynamics of cash flows constitute the main constraint for investment programming: in the case of MHP, the expansion of operational cash flows came before the activation of investment activity, while in the case of Metinvest Group, a reduction in cash flows required a shift in investment policy towards maintenance-type projects. In this connection, the introduction of investment planning systems on the basis of scenario cash flow analysis enables the adaptation of capital expenditures to changes in operational results without perturbations to financial equilibrium. Another way to improve financial resilience is to adapt investment activities to the risk profile of the enterprise. According to the results of scenario modelling, in the conditions of high production and logistical risks, the investment strategy, aimed at preserving the existing production capacities, allows for minimising financial losses and preventing the formation of excess assets, which is typical for export-oriented industrial enterprises. However, for agribusiness enterprises, investment activities may play the role of risk diversification and vertical integration. Therefore, the adaptation of the investment

strategy to the risk profile of the enterprise is an essential condition for improving the efficiency of financial resource management and ensuring the stability of investment activities in the face of macroeconomic instability.

Thus, the research shows that improving financial resilience and investment activities under risk conditions is provided due to the adaptation of financial resource management strategies to the sectoral and technological features of the enterprise. For MHP, this is expressed in the strategy of investment development in combination with a moderate debt policy, while for Metinvest Group, it is expressed in the financial stabilisation and ensuring liquidity. The expected economic effect from the implementation of such strategies is the preservation of solvency, the formation of internal investment resources and the increased ability of enterprises to withstand a prolonged economic crisis.

DISCUSSION

Financial decisions make a growing contribution not only to the current economic activities of the enterprise but also to its investment activities, financial resilience and ability to withstand external shocks. The research results are consistent with the conclusions of B. Lumanauw & I.R. Lolowang (2024) about the determining influence of strategic financial resource management on business stability. In accordance with their research, this article found a positive impact of integrating financial planning, budgeting, cash flow management and risk management on enterprise performance. However, this article also found that in conditions of macroeconomic instability, this influence is not unconditional and to a large extent depends on the ability of financial tools to ensure investment activities and financial resilience. On the other hand, B. Lumanauw & I.R. Lolowang pointed to the generally positive effect of strategic financial management. A comparison with the results of the study by F.N. Otoo (2024) made it possible to specify the boundaries of the efficiency of individual financial instruments. F.N. Otoo showed empirically that the application of certain financial management tools increased the operational efficiency of small and medium-sized enterprises. However, the data of this study suggest that in conditions of increased instability, the use of these tools in isolation has only a short-term and local effect, while their consistent application, in combination with investment decisions and long-term financial planning, leads to sustained results.

The results are partially congruent with the data of L. Liu (2024), who noted the importance of budgeting and cash flow management for improving management efficiency. However, this study found that in conditions of macroeconomic instability, the perfection of the intra-firm budgetary process does not necessarily lead to an increase in financial sustainability unless it takes into account investment risks and limitations in access to financial resources. Thus, the results complement the conclusion of L. Liu in the aspect of considering external economic uncertainty. A different aspect is observed when comparing the results with the data of the study by X. Zhang & Y. Jing (2024). In their research, financial mechanisms proved to be highly efficient as a means of institutional impact and strengthening the actors' capacity at the supranational level. In contrast, this study found that at the firm level, the efficiency of financial management manifests not in an increase in institutional capacity but in the ability to provide investment efficiency and ensure financial sustainability in the medium and long term.

The comparison with the findings of the study by P. Garrido-Prada *et al*. (2024) made it possible to detail the investment component in crisis conditions. As in their research, it was found that investment activities may contribute to the development of the firm despite economic shocks. Nevertheless, the results of this study indicate that the positive effects of investment were not universal: in the absence of financial balance and proper cash flow management, investment activity could, conversely, increase the risk of losing financial resilience. Further analysis, in comparison with the study by T. Shen & A. Badulescu (2025), allowed the distinction of the role of managerial capabilities from financial outcomes. T. Shen & A. Badulescu found that the indirect influence of managerial competence on the internationalisation of small and medium-sized enterprises was due to more effective management of resources and risks. In contrast, this research revealed that at a given

level of managerial competence, the structure of the financial resources and quality of investment decisions were the determining factors, while the internationalisation orientation was not a determining factor for financial resilience.

This difference can be explained by the results of M. Vega-Pascual *et al.* (2025), which demonstrated that the financial environment of the region could contribute to the development of enterprises. Although M. Vega-Pascual *et al.* demonstrated that a developed regional financial ecosystem stimulated the growth of young small and medium-sized enterprises, the results of this study indicated that, even under favourable external conditions, the key determinant remained the internal capacity of enterprises to convert available financial resources into effective investment outcomes and long-term financial resilience. The results in relation to the research by X. Sheng & Y. An (2024) are of interest for clarifying the role of financial flexibility in ensuring the sustainable development of an enterprise. They found that financial resources were a tool for adaptation to an unstable environment, which is consistent with the results obtained. However, this study showed that the managerial effectiveness of financial flexibility was realised not through a non-linear impact on sustainability metrics, as observed by X. Sheng & Y. An, but through the ability to sustain investment activity, maintain budgetary balance, and preserve financial resilience in practical management terms. In this regard, the comparison with the results of the research by H. Guo & P. Polak (2024) seems justified because they focused on the digitalisation of financial management. The results of this research confirm the need for a systemic approach to the management of financial resources. However, whereas H. Guo & P. Polak pointed to the reduction in costs and improvement in the accuracy of management decisions due to the centralisation of financial services and the application of artificial intelligence, this study showed that in conditions of macroeconomic instability, the key factors were not the level of technological development of financial services but the efficiency of budgeting, cash-flow management, and investment decisions. A deeper analysis for comparison with the study by H. Zhang *et al.* (2025) extended the ideas about the strategic function of financial resources. H. Zhang *et al.* proved the efficiency of optimising retail supply-chain financing through digital data and modelling methods. This study, in turn, showed that at the level of the enterprise, financial efficiency was formed regardless of the supply-chain model and was determined by the general potential of financial management to ensure investment activity and financial sustainability.

The problems of liquidity and the role of management were further detailed in comparison with the study by F. Ali *et al.* (2024). Similar to their research, this study proved the importance of cash reserves and management decisions for the activities of an enterprise. At the same time, it was found that the positive effect of liquidity was not independent and was implemented only if cash-flow management was combined with budgeting and investment strategies, while F. Ali *et al.* pointed to the direct influence of cash reserves moderated by the potential of management. A comparison with the results of the study by S. Xu (2024) separated financial and economic results from institutional transformations. S. Xu pointed to innovations in management methods, personnel, and systemic transformations as the basis for increasing the resilience of Chinese enterprises. In contrast, this study demonstrated that without proper management of financial resources and investment activity, organisational innovations alone did not ensure sustainable financial results in an unstable environment. A more process-oriented dimension of financial management emerged in comparison with F. Zhou *et al.* (2025). As with F. Zhou *et al.*, the results confirmed the importance of budgeting and financial-flow control for risk reduction. However, unlike their conclusions, which focused on improving budgetary efficiency and reducing budgetary "slack", this study showed that the key effect of budgeting lay in its ability to ensure financial resilience and support investment decisions under conditions of macroeconomic instability. An analysis in comparison with X. Huang (2024) allowed applied outcomes to be related to conceptual notions of innovative financial management. X. Huang emphasised the role of digitalisation and new technologies in financial investment management. In turn, the

results of this study showed that technological innovations acquired practical value only if they were incorporated into the system of managing financial resources and investment activities in certain macroeconomic conditions.

The content of organisational management was further clarified in comparison with the study by Z. Fei & J. Depeng (2024). As in their research, the necessity of strategic management and control in the provision of enterprise resilience was proved. At the same time, the authors' results indicate that for high-tech companies, the human-centred and organisational management approaches did not exclude the need for tight financial control, cash flow management and optimisation of capital structure. Comparison with the research of Z. Du & Q. Wang (2024) allowed a clear distinction to be made between external and internal determinants of financial performance. Z. Du & Q. Wang pointed out the critical role of the banking sector and capital market in the acceleration of digital transformation and innovations. At the same time, the present study indicated that even in a favourable financial environment, the decisive factor remained the internal quality of financial resource management, investment decisions, and the financial resilience of enterprises.

The obtained results corroborate the fact that the efficiency of financial resource management is determined by a combination of internal managerial decisions, investment policy and external economic conditions. The financial resilience of the enterprise is not based on the separate application of individual tools, but their integration into the budgeting system, cash flow management, and investment decisions. Even in a favourable financial environment, the decisive role is played by the internal capabilities of the enterprises in transforming the available financial resources into long-term economic effects, which indicates the need for a strategic approach to financial management.

CONCLUSIONS

The article systematises the scientific understanding of the role of financial resource management in the formation of investment activity and financial resilience of the enterprises in conditions of macroeconomic instability and risk growth. The authors' results confirm that the dynamics of investment activity in Ukraine in 2022-2025 depended directly on the availability of own financial resources, the efficiency of cash flow management, and the ability of enterprises to adapt financial strategies to external constraints. According to the statistical data, in 2022, capital investments decreased to UAH 409.7 billion (-39.2% compared to 2021), in 2023-2024, UAH 395.5 billion and UAH 534.4 billion, respectively, and in January to June 2025, by 30.6%, which indicates the gradual stabilisation of corporate cash flows and the resumption of investment activity. As a result of the case study of MHP and the Metinvest Group, it was found that the best practices of the financial management of investment activity, from the point of view of ensuring their growth, include a rational combination of the mechanisms of managing the liquidity of the enterprise, the structure of its capital, and matching investment programs with projected cash flows from operating activities. For an agricultural enterprise, such as MHP, a reasonable combination of these mechanisms is a moderate application of debt financing tools against the background of increasing capital investments (an increase in CAPEX from USD 217 million in 2024 to USD 219 million in 2025, with a simultaneous increase in EBITDA from USD 346 million in 2024 to USD 455 million in 2025, while maintaining a ratio of Net Debt/EBITDA in the range from 2.12 in 2024 to 2.61 in 2025). For an industrial enterprise (Metinvest Group), the priority mechanism was financial stabilisation and deleveraging (a decrease in total debt from USD 2,077 million in 2022 to USD 1,572 million in 2025), while maintaining investment activity at a supporting level.

It has also been proven that the use of innovations (digitalisation of financial management, scenario planning, automated budgeting, and logistical approach to cash flow management) in the activities of enterprises contributes to an increase in their financial stability and competitiveness. The introduction of digital tools and analytics reduces the risk of a shortage of financial resources, increases the reliability of investment decisions, and allows for more effective adaptation to changes in the external environment. It is advisable to use systematic cash-flow management

based on scenario financial planning and the coordination of investment programs with projected operational cash flows and the required level of debt. Increasing the financial stability and competitiveness of the companies can be achieved by giving priority to the use of their own financial resources and applying digital budgeting, automated financial monitoring, and risk-management tools. Summing up, the article proves that sustainable investment growth is possible only as a result of systematic financial management aimed at balancing liquidity, debt, and long-term investments, and, therefore, it creates a financial framework for increasing the competitiveness of the companies in the medium and long term. The limitations of the study are related to the application of aggregated statistical data and several representative company cases, which were used for generalisation of the patterns of financial resources management in the conditions of macroeconomic instability. The prospects for further research are associated with more detailed analysis on the micro-level and with the application of econometric tools for quantitative estimation of the influence of financial strategies and digital instruments on the investment efficiency of the companies.

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Стратегії вдосконалення управління фінансовими ресурсами підприємств з метою підвищення ефективності інвестиційної діяльності

Анотація. Метою дослідження було обґрунтування підходів до оптимізації управління фінансовими ресурсами підприємств для підвищення результативності інвестиційної діяльності та фінансової стійкості в умовах макроекономічної нестабільності. Методологія поєднувала динамічний, порівняльний, трендовий і фінансово-коефіцієнтний аналіз та кейс-аналіз, що дозволило оцінити динаміку капітальних інвестицій, галузевий розподіл і структуру фінансування, а також фінансові й інвестиційні показники підприємств. Основні результати дослідження засвідчили, що у 2022 році обсяги капітальних інвестицій в Україні скоротилися до 409,7 млрд грн (-39,2 % порівняно з 2021 роком), у 2023 році становили 395,5 млрд грн, а у 2024 році зросли до 534,4 млрд грн. У першому півріччі 2025 року обсяг капітальних інвестицій зріс на 30,6 % порівняно з аналогічним періодом попереднього року. Було встановлено, що у 2025 році близько 73,7 % інвестицій фінансувалося за рахунок власних коштів підприємств. Аналіз фінансових результатів «Миронівського хлібопродукту» показав зростання капітальних інвестицій з 106 млн дол. у 2022 році до 219 млн дол. у 2025 році та підвищення чистого прибутку з від'ємного значення у 2022 році до 215 млн дол. у 2025 році. Для групи «Метінвест» характерним було скорочення загального боргу з 2077 млн дол. у 2022 році до 1572 млн дол. у 2025 році за одночасного збереження інвестиційної діяльності на підтримувальному рівні. Висновки полягали в тому, що ефективність інвестиційної діяльності визначалася здатністю підприємств узгоджувати управління фінансовими ресурсами з інвестиційними рішеннями, балансувати джерела фінансування та адаптувати фінансові стратегії до галузевих і макроекономічних обмежень, що може бути використано в практиці управління фінансовими ресурсами підприємств

Ключові слова: капітал; стійкість; бюджетування; грошові потоки; планування

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Artificial intelligence and economic forecasts in climate risks management

Abstract. The physical, financial, and systemic risks associated with climate change continue to increase across global economies. As the frequency and severity of climate-related risks intensify, it becomes increasingly difficult for standard forecasting tools to adequately capture complex ecological-economic interactions. This article examined the role of artificial intelligence (AI) and economic forecasting in managing climate risks. The study demonstrated that the identification and prediction of severe weather events are significantly improved through the use of AI-powered climate models. Explainable AI (XAI) provides additional transparency by enabling analysts and policymakers to better understand the factors influencing predictions generated by drought, flood, and heatwave models. When integrated with economic forecasting frameworks, AI enables comprehensive simulations of how climate challenges propagate through supply chains, labour markets, energy networks, and financial systems. Despite these advantages, AI-based modelling presents several limitations, including data scarcity, limited generalisability, and ethical concerns related to transparency, energy consumption, and inequality. The study concluded that integrating AI with economic forecasting provides a robust interdisciplinary framework for climate risk assessment, policy formulation, and adaptive strategy development. However, the effectiveness of this framework depends on improved governance structures, enhanced data infrastructure, and responsible technological implementation. The research has practical significance in enabling more accurate and early assessment of climate-related impacts on economic systems. The findings are particularly relevant for risk prediction and management in the energy, agricultural, and financial sectors

Keywords: machine learning; explanatory artificial intelligence; agent-based models; climate policy; economic sustainability; innovation

INTRODUCTION

The threat of economic stability, social security, and environmental balance due to climate change is at its peak nowadays. The menace of climate change has turned out to be one of the most important challenges that the world is currently facing, considering its effects on the infrastructure, agriculture, economy, and society as a whole. Changes in temperature, water resources,

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and the environment are not merely environmental issues, as they affect other sectors as well. While economic and statistical models provide some utility, the inherent complexity of climate processes precludes an accurate representation of real-world dynamics; furthermore, the multifaceted, long-range effects of climate change constrain the efficacy of traditional modelling approaches. Advances in artificial intelligence technology offer some advantages in processing large volumes of data and making more accurate predictions in an uncertain environment (Zaidan, 2025). M. Burke *et al.* (2015) noted that every 1°C increase in average temperature reduces global GDP by approximately 1.2%, threatening economic productivity. This indicates an urgent need for effective climate change mitigation to reduce the negative global economic impacts of rising temperatures. According to T. Papadopoulos & M.E. Balta (2022), the integration of artificial intelligence (AI) and deep learning techniques will increase the resilience of businesses to climate change and will be of great importance in risk management. W.Y. Leong (2025) noted that an AI-driven early warning system deployed in California reduced response time by 40%. J. Cowls *et al.* (2023) while analysing the role that AI can and does play in combating global climate change, have shown that AI can contribute to effectively combating the climate crisis. According to H. Yin *et al.* (2025) AI reduces climate risks through increased resource efficiency, green innovation, implementation of environmental policies and green finance growth.

As noted by Z. Zhang *et al.* (2025), artificial intelligence has the ability to process large amounts of data on climate change, reveal new relationships, and improve the precision of forecasts under uncertain conditions. Y. Mohajerani (2025) observed that, apart from improving forecasts, the integration of economic forecasting allows decision-makers to comprehend the effect of risks on production, markets, business, and economic development. Consequently, the management of climate risks becomes more complete, data-driven, and forward-looking as a result of this change. The integration of artificial intelligence and economic forecasting allows the development of a complex and systematic approach in the management of climate risks, while at the same time facilitating the modelling of future scenarios and the pre-assessment of the consequences (Mehryar, 2024). In the current economic environment, increased competition, accelerated technological change, and resource constraints make decision-making processes more complex. Wrong or delayed decisions can lead to serious financial losses and weakening of market positions. Inadequate resource management can negatively impact overall performance and long-term stability in uncertain conditions. Given this, the implementation of agile, analytically based, and predictive management mechanisms for organisations to make effective decisions is of particular importance. As a result, as the essence of the problem, with the emergence of modern economic and technological dynamics, the decision-making process within organisations has become increasingly complex and unpredictable. Formulating successful strategies is becoming increasingly difficult for businesses, as they are exposed to both competitive demands and a rapid pace of innovation (Imanova, 2025).

Although climate change, strategic management and decision-making issues are widely studied in the existing scientific literature, a joint and integrated analysis of these topics is insufficient. These elements are considered separately in studies, which does not fully reflect the complexity of the real economic environment. One of the gaps is the insufficient explanation of the mechanisms of interaction between climate risks, resource management and strategic decisions. In practical conditions, these factors operate in close interaction with each other. Climate risks affect resource allocation, while resource constraints shape strategic choices (Batarseh, 2022). These processes jointly determine the overall performance results of the organisation. On the other hand, there is no single conceptual framework for the integration of artificial intelligence-based approaches into the decision-making process. In most studies, the application of these technologies at the management and policy levels is not sufficiently investigated. At the same time, long-term sustainability issues remain in the shadows for many studies. The primary purpose of this study was to assess the economic and organisational

consequences of climate risks, determine the role of artificial intelligence technologies in decision-making, and elucidate the interaction between resource management and strategic planning. The findings are expected to enhance the quality of management decisions and facilitate the formulation of more sustainable development strategies.

MATERIALS AND METHODS

The study covered the period 2000-2025, allowing for the analysis of both long-term climate trends and climate-related economic risk. Selecting this period ensures data consistency across all variables and enables robust analysis of both historical trends and recent developments in climate-related economic impacts. The study used a scientific framework that combines economic forecasting tools, climate datasets, and models to identify key AI methods. The datasets were used to re-examine the first extreme historical temperature anomalies, precipitation indices, drought systems, NASA GISTEMP, and ERA5. These datasets are managed for global impact, reliability, and methodological safety. They provide long-term and robust products. The empirical material of the study consists of climate indicators and macroeconomic variables, including GDP growth, inflation rates and sectoral production data. In addition, peer-reviewed scientific publications (Ozupek *et al*., 2025; Ayadi *et al*., 2025) on climate-economic interactions, machine learning forecasting and agent-based modeling were analysed to establish the theoretical and methodological basis of the study. In the second stage, several forecasting approaches were applied. Traditional econometric models were used as benchmark methods. ARIMA was chosen for its ability to capture linear time dependencies in economic time series. Multiple regression was used to estimate linear relationships between climate variables and economic indicators. Machine learning methods were applied to take into account nonlinear relationships and complex interactions. Gradient Boosting was applied to capture nonlinear interactions between predictors. Long Short-Term Memory (LSTM) networks were utilised for modelling sequential patterns and long-range dependencies present in the time series. For all the models, training was done using an identical set of data for the period 2000-2023. Uniform preprocessing and estimation methodologies were adopted for ensuring maximum comparability of the results. Root Mean Square Error (RMSE), Mean Absolute Error (MAE), and Coefficient of Determination (R^2) were utilised for measuring model performance (James, 2021). RMSE measures the mean square deviation between the model-predicted and actual values and is calculated using the following formula:

$$RMSE = \sqrt{(1/n \sum (yi - \hat{y}i)^2)}, \quad (1)$$

where, yi – the actual observed value; $\hat{y}i$ – the value predicted by the model; n – the number of observations. MAE measures the average absolute value of the forecast errors, while Coefficient of Determination (R^2) measures the level of variability explained by the model. The formulas for model performance indicators are presented below:

$$MAE = (1/n) \sum |yi - \hat{y}i|. \quad (2)$$

$$R^2 = 1 - (\sum (yi - \hat{y}i)^2 / \sum (yi - \bar{y})^2), \quad (3)$$

where, $\bar{y}$ – the average of the actual values. These metrics were chosen to provide a consistent comparative assessment of forecast accuracy. In particular, the SHAP (SHapley Additive exPlanations) method was applied to determine the contribution of individual climate variables to economic forecasts. This approach reduced the opacity of the model and increased its interpretability. An agent-based economic simulation model was developed as part of the study to assess the macroeconomic outcomes. In this model, firms were represented as adaptive agents that adjust their production levels, labour allocation, and pricing strategies in response to climate shocks. Three risk scenarios (low, medium and high intensity) were constructed based on climate variability indicators. Macroeconomic outcomes such as GDP change, inflation and production loss were generated from the interaction of agents within the simulated environment. Statistical evaluation included accuracy measures, F1 score for classification tasks, mean square error and 95%

confidence intervals to ensure the reliability of the results. Ethical considerations included transparency of algorithmic design, use of publicly available data sources, compliance with data protection standards and efforts to minimise computational energy consumption.

AI-enhanced climate modelling. The prediction models that employ artificial intelligence, machine learning, deep learning, and neural networks have greatly enhanced climate modelling. These models can easily identify temperature patterns, rainfall anomalies, atmospheric pressure fluctuations, and ocean currents with greater speed and accuracy than many other models (Lewis, 2024). Furthermore, artificial intelligence has shown promise in improving short-term forecasts, real-time simulations, and pattern recognition with various variables. The study systematically reviewed over 20 scientific publications, covering both traditional numerical climate models and AI-based forecasting approaches, to define methodological frameworks. The study is based on the NASA climate report (NASA information center, 2023), and an analysis of publicly available statistical sources from Statista (Buchholz, 2023). Global temperature data and related climate variables relevant to this study were obtained from international climate data repositories such as the National Oceanic and Atmospheric Administration (NOAA, 2021), the UN Climate Change Program, NASA (2021; 2024), and the World Meteorological Organization (WMO, n.d.). The analytical procedures applied in the study are consistent with the methodological principles described in the selected sources.

Explainable artificial intelligence in climate models. Explainable AI in climate modelling aims to make complex machine learning systems more transparent and understandable. Rather than acting as "black boxes", explainable models explain how input variables such as greenhouse gas levels, ocean temperatures, or atmospheric conditions affect predictions. By using techniques like feature importance analysis and sensitivity tests, it is possible to identify which factors have the maximum impact on temperature changes or extreme weather occurrences. This improves the reliability of the model and helps in detecting potential bias while ensuring its compatibility with existing physical principles of climate change.

Economic forecasts using artificial intelligence. In this study, artificial intelligence-based economic forecasting methods were used to assess the impact of climate risks on economic indicators. The dynamic and interdependencies between climate variables and macroeconomic indicators can be detected more accurately through such models. Within the framework of economic forecasting, the growth rate of gross domestic product, energy consumption, inflation rate and production indicators by sectors were selected as the main target variables. The independent variables consisted of long-term temperature anomalies, precipitation variability, frequency of extreme weather events and energy-related climate indicators. By including these variables in artificial intelligence models, the economic consequences of climate risks were predicted.

Agent-based climate-environmental economic models. In this study, an Agent-Based Model (ABM) is developed to estimate the macroeconomic impacts of climate variability over the period 2000-2023. While the framework proposed by Y. Mohajerani (2025) provides conceptual guidance, the model implemented here is independently constructed and calibrated using observed climate and economic data. Due to the model structure and agent behaviours, firms act as adaptive agents that adjust their production levels, division of labour, and pricing strategies in response to climate-induced shocks. Households respond to changes in income and prices by changing their consumption patterns. Climate variables are included as exogenous shocks that affect sector productivity and input costs. Micro-level adaptive behaviours are combined to produce macroeconomic outcomes, including changes in GDP, inflation, and output losses. The study simulated low, medium and high levels of climate risk intensity based on observed data from 2000 to 2023. The resulting macroeconomic outcomes of agent responses for each scenario were determined. The proposed methodology comprehensively explains the relationship between climate and the economy, applies artificial intelligence in an interpretable manner, generates practical implications

for policy and decision-making, and models long-term risks. This provides an integrative, applicable, and analytically robust framework that is different from the existing literature.

RESULTS

Analysis of temperature anomalies

As per the analysis of the temperature records from the National Aeronautics and Space Administration (NASA), the Earth has been experiencing a continuous temperature rise since the end of the 19th century (Buchholz, 2023). The rate at which the Earth has been experiencing temperature rise has accelerated since the year 2000, with visualisations depicting the manifestation of the elevation of the Earth's temperature. By the end of December 2020, the Earth experienced a temperature deviation of approximately 1.34°C from the baseline temperature of 1880 to present, which falls within the range of 2-2.5°C experienced in the past decades. Temperature anomalies are observed to have significant amplification during the summer season. In June 2020, it was recorded that the global mean temperature anomaly was around 2.07°C higher than the historical base period, which is beyond the previously recorded temperature anomaly of 1.1°C to 1.6 in past years. The rising temperature anomaly continues into 2023, with the temperature anomaly recorded in June being +2.23°C, thus creating a new record Figure 1.

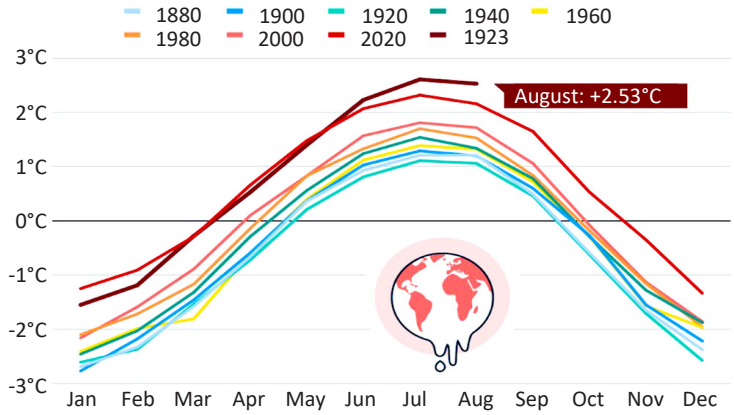

Figure 1. Monthly rate of increase in average temperature (calculated for 1880-2023) in selected years

Source: K. Buchholz (2023)

The summer of 2023, i.e., June-August, marks the period of highest temperature on Earth since systematic temperature recording started in 1880, as per NASA temperature records. This is because the global temperature during these three months of the summer of 2023 was higher than the preceding summer temperature recorded on the Earth's surface. Moreover, as per NASA temperature records, September 2023 marks the highest temperature recorded on Earth and also presents the highest temperature anomaly compared to the long-term average temperature recorded on Earth during September of any given year (NASA information center, 2023). This observation is consistent with the established phenomenon of rising global temperatures on Earth, as per NASA temperature records. The temperature of 2016 was recorded as it marked the highest deviation of average temperature compared to the reference period of 1880-2015. NASA (2021) estimates show that 2016 and 2020 are the two warmest years on record for the Earth's surface. This is similar to what is observed globally with increasing temperatures on Earth and suggests a large risk of global warming and climatic changes, which are at a critical juncture relative to prior periods. The satellite records of NASA also show that there is a rise of 1.28°C in global air temperatures, which is the highest recorded temperature rise since systematic

temperature measurement began in 1880. In 2024, the Earth's average surface temperature reached a record high and was the warmest year since records began in 1880 (NASA, 2024). The average global surface temperature in 2025 was slightly lower than in 2024, but still higher than in previous years (NASA, 2025). According to the WMO (n.d.), 2025 was the third warmest year on record at the Earth's surface, indicating an increasing trend in surface temperatures and very high levels of global warming. The last three years, 2023-2025, were the three warmest years in all eight data sets.

From the findings discussed above, it is evident that global warming is still on course as a trend in recent years and that its rate is increasing, especially in 2016, 2019, 2020, and 2023. The findings on temperature changes suggest that the rate of risk is increasing. Such changes have posed a challenge to the economy as well as to natural resources. In this respect, the need to employ AI as well as economic forecasting techniques becomes necessary. This is because the ability of statistical analysis to forecast climate variables accurately is limited. In this respect, the ability of AI-based forecasting techniques to predict climate variables in the study framework was analysed in order to compare the results with the ability of statistical analysis to predict the variables. From the analysis, it can be deduced that the results from the application of machine learning in the study have higher accuracy in the prediction of climate variables.

Model performance and forecast accuracy

Both accuracy indicators and stability criteria were taken into account during model evaluation. In this research, performance metrics such as root mean square error, mean absolute error, and coefficient of determination are used. These performance metrics have been calculated in order to compare the economic forecasting models based on climate variables (Table 1). It is worth noting that all models are based on the same dataset and used the same method of estimation, covering the period from 2000 to 2023.

Table 1. Comparison of model performance (2000-2023)

Model	RMSE	MAE	R^2
ARIMA	0.74	0.61	0.48
Multiple regression	0.69	0.57	0.52
Gradient Boosting	0.41	0.34	0.78
LSTM	**0.36**	**0.29**	**0.84**

Note: the model performance indicators presented in Table 1 were calculated using the RMSE, MAE, and R^2 formulas 1, 2, 3

Source: data generated by the author

Traditional models such as ARIMA and multiple regression, which rely on linear assumptions, were unable to accurately capture sudden temperature changes and extreme weather events, leading to lower forecast accuracy. These models are limited by their linear structure, short memory of past observations, and sensitivity to outliers. Although the addition of non-linear terms or regime-switching terms is possible, this has more limitations in terms of flexibility compared to state-of-the-art machine learning techniques. In contrast, the best performance was achieved by the LSTM model with the following error measures: RMSE = 0.36, MAE = 0.29, and R^2 = 0.84, signifying the ability to model long-range dependencies and complex non-linear relationships in the climate data. This is because it is able to retain memory cells over long periods of time, making it very effective for seasonal and sudden changes. These findings are a testament to those of Z. Zhang *et al.* (2025), who found that LSTM was more effective than linear and tree-based methods for predicting economic indicators based on temperature. However, unlike Z. Zhang *et al.* (2025), this study also proves that it is more effective than Gradient Boosting, showing its potential for accurately predicting financial risks related to climate change and its nonlinear and time-dependent nature.

Analysis of the economic impacts of climate variables (XAI results)

Explainable Artificial Intelligence (XAI) analysis was conducted using the SHAP framework to interpret how individual climate variables influence economic forecasts generated by the LSTM model. SHAP values allow identification of both the magnitude and direction (positive or negative) of each variable's contribution to predicted economic outcomes. The results showed that average temperature increase, precipitation anomalies, and drought duration have the greatest impact on economic forecasts. These findings indicate that climate risks are transmitted to economic systems mainly through temperature and water-resource channels. In this regard, artificial intelligence-based models enable the achievement of higher forecast accuracy. The analysis shows that average temperature increase was the variable that had the greatest impact on model forecasts, with a total impact share of 34%. Precipitation anomalies accounted for 26%; drought duration for 18%; and the number of extremely hot days and humidity levels had relatively lower, but statistically significant, impacts (Fig. 2).

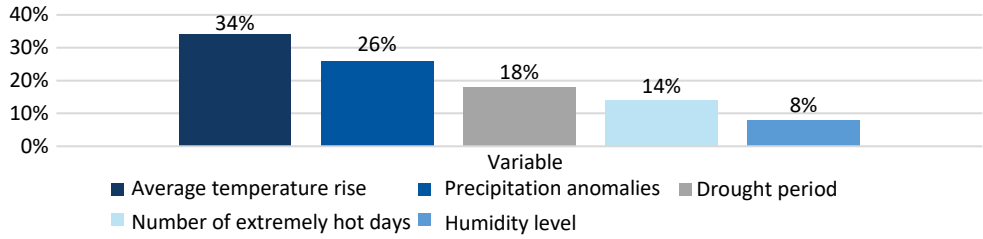

Figure 2. Variables with the main influence (2000-2023)
Source: data generated by the author

The results also corroborate results obtained in prior studies such as E. Ozupek *et al.* (2025) and Z. Zhang *et al.* (2025). At the same time, it is also evident that even though traditional methods and some alternative techniques such as Gradient Boosting are effective in predicting economic indicators that are sensitive to climate change, even better results are obtained when a Long Short-Term Memory Network is applied. The results of the XAI analysis improve model interpretability by clearly quantifying the extent of each predictor's contribution.

Results of the agent-based economic model

The ABM simulation results quantify the macroeconomic impact of climate variability over the period 2000-2023 and demonstrate how sector-specific shocks affect overall economic outcomes. The model presents results for three levels of observed climate risk intensity. The model explains the mechanism of macroeconomic outcomes by simulating the responses of individual economic entities to climate shocks (Azhar *et al.*, 2025). As the intensity of climate risks increases, the following changes are observed in the economic system (Table 2).

As can be seen, low-risk years show moderate GDP declines and limited inflation. This also reflects resilience in the economy when climate shocks are mild. This is because adaptive responses by firms and households mitigate short-term impacts, so output losses are minimal. Medium-risk years highlight the cumulative effects of climate shocks. Cumulative climate shocks reduce agricultural output and increase energy demand, which leads to increased costs and deeper production losses. Although firms adjust partially through division of labour and input substitution, the economy is unable to fully absorb repeated shocks. High-risk years demonstrate structural stress. Severe climate shocks create economic structural stress through decreased agricultural productivity, increased energy costs, and increased supply chain fragmentation. As a result, there is a significant decline in gross domestic product (GDP), and inflation rates increase. For instance, there is a decline in GDP of 5.4%, and inflation rates increase to 4.3%.

Output losses are 7.1%. These findings suggest that severe climate events could create persistent economic vulnerabilities. In general, the findings suggest that climate shocks affect the scale of the economy and price dynamics. Sectoral interventions, along with macroeconomic policy interventions, can reduce vulnerabilities and increase resilience.

Table 2. Macroeconomic outcomes (2000-2023)

Scenario	GDP change	Inflation	Production loss
Low risk	-0.8%	+0.5%	-1.2%
Medium risk	-2.6%	+1.9%	-3.8%
High risk	-5.4%	+4.3%	-7.1%

Source: author's simulation results based on the ABM calibrated for 2000-2023

The results of the study show that artificial intelligence-based models significantly outperform classical approaches in predicting the economic impact of climate variables. Classical studies also noted the decisive impact of temperature increase on economic productivity (Lu, 2023). However, most of the existing literature analyses climate models and economic models separately, presents artificial intelligence methods as a "black box" and does not clearly indicate how the results will be integrated into the decision-making process. The conducted analyses show that climate variables have a direct and measurable impact on economic indicators. It confirms that climate risks, in addition to being an ecological problem, are also a factor of macroeconomic stability. Artificial intelligence models predict these impacts more accurately than classical methods (Sandiponi, 2025). AI methods, on the other hand, make the decision-making process transparent. The results obtained indicate that artificial intelligence models are capable of predicting climate risks 6-12 months in advance, and that climate-informed planning increases the effectiveness of budget expenditure.

The results show that the relationship between climatic variables and economic indicators is non-linear and dynamic. The temperature anomalies have a considerable impact on productivity. The results show that artificial intelligence models can accurately define the relationship While traditional econometric models are based on stable and linear relationships between variables, the LSTM model facilitated the detection of long-term dependencies over time and non-linear impact mechanisms. Since the impact of climate change is gradual and sometimes exacerbated after critical thresholds, data-based models provide more appropriate results. This result indicates the need for methodological transformation in climate risk assessment. From a practical perspective, artificial intelligence-based economic forecasting systems can help form early warning mechanisms and timely assessment of risks, especially in the energy, agriculture, and financial sectors, which can ensure a more optimal allocation of resources. E. Ozupek *et al.* (2025) demonstrates that AI has the ability to identify important climatic factors that lead to the onset of drought, which allows for more reliable early warning systems. This approach allows the results to be interpreted not only from a technical but also from a policy perspective. Improvements made by AI, Figure 3.

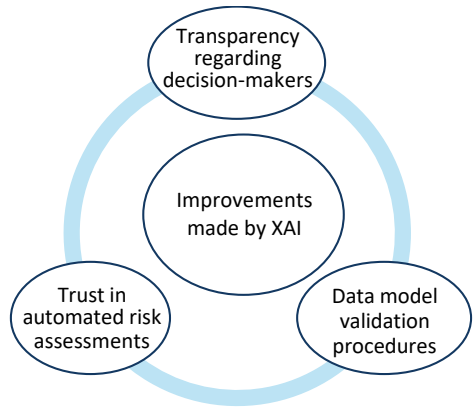

Figure 3. Improvements made by AI
Source: E. Ozupek *et al.* (2025)

Determining the impact of variables through SHAP analysis more clearly shows that climate

factors are a priority risk factor. The results obtained show that climate risks are spread in economic systems not only directly, but also through interaction mechanisms. In particular, the relationship between temperature increase and energy consumption directly affects production costs (Pasqualetto, 2024). This, in turn, increases the price level and inflation. Such chain effects are not sufficiently taken into account in traditional models. Artificial intelligence approaches, on the other hand, can simultaneously process multidimensional interactions between variables. This approach allows for the identification of risks at an earlier stage in the economic decision-making process and the formation of adaptive policy instruments. Thus, artificial intelligence-based economic forecasting both increases analytical accuracy and creates strategic planning opportunities for the systematic management of climate risks.

DISCUSSION

The results of this study are consistent with the results of a number of contemporary scientific studies examining the impact of climate change on the economy. While Y. Mohajerani (2025) shows that high-emission scenarios generate long-term inflationary pressures and supply chain disruptions, this study empirically confirms these mechanisms for the period 2000-2023. Unlike Y. Mohajerani, the current model incorporates interpretable AI to measure the impact of climate variables and generates explicit macroeconomic measures for GDP, inflation, and output losses. M. Azhar *et al.* (2025) examined the impact of climate change on GDP and inflation in developing countries and found that climate shocks lead to a decrease in economic growth and an increase in inflation. The results of this study also show that climate-related risks affect price increases, especially through a decrease in production in the agricultural sector. However, although M. Azhar *et al.* (2025) uses the panel regression method from a methodological point of view, this study simulates the formation of macroeconomic outcomes through agent-based modelling (ABM) based on the interaction of agents at the micro level. A study by T. Ehlers *et al.* (2025) also examined the impact of climate and weather events on various sectors of the economy and showed that climate risks lead to a decrease in production and an increase in prices. These results are consistent with the results of the current study. However, the authors' study is based on models based on global empirical data used by the Bank for International Settlements. Studies focused on the agricultural sector also show similar results. T. Yusifzada (2024) showed that climate variability is one of the main factors affecting the increase in agricultural prices and empirically substantiated this relationship using a climate condition index. The results of this study also support this idea with a different methodological approach and show that climate shocks cause an increase in food prices. Although T. Yusifzada (2024) uses an index-based empirical approach, this study models agent behaviour and the mechanism of cost transmission throughout the economic system. Recently, studies on the application of artificial intelligence technologies in climate risk assessment have also been widespread. For example, M.K. Khan *et al.* (2023) showed that the application of artificial intelligence technologies in enterprises helps to manage climate risks more effectively. This study also confirms that artificial intelligence-based models play an important role in the analysis and forecasting of climate risks. However, M.K. Khan *et al.* (2023) focused more on risk management at the organisational level, using statistical and machine learning approaches based on empirical data to evaluate the impact of AI implementation on enterprise performance. A study by Y. Wang *et al.* (2025) found that machine learning models performed better than traditional methods in predicting climate risks. While this result is consistent with the results of the current study, the authors used a binary machine learning approach. The results of this study show that the LSTM model provided the highest prediction performance, with a coefficient of determination (R^2) of 0.84. In general, in the existing literature, the economic impacts of climate change have been mainly investigated through either empirical macroeconomic analyses or artificial intelligence-based forecasting methods. This study presents an integrative approach that combines agent-based modelling and machine learning methods to more broadly explain the mechanism of climate risk transmission to the economic system.

The findings are consistent with the recommendations of the UN Technology Mechanism on Climate Change. A new technical paper published by the Technology Implementation Committee (TIC) of the UNFCCC Technology Mechanism explores how AI can serve as a powerful enabler of climate action in developing countries, which are most vulnerable to climate impacts (UNFCCC, 2025). TIC Chair Dietram Oppelt presented the Committee's latest technical paper at the AI for Good Summit in Geneva. The paper, developed in partnership with the United Nations Industrial Development Organization and supported by the Korea International Cooperation Agency, is part of the Technology Mechanism's ClimateAction initiative. It provides a comprehensive guide to policymakers, practitioners, and researchers on the opportunities, risks, and challenges of using artificial intelligence in the mitigation and adaptation of climate change in developing countries (UNFCCC, 2025). There is considerable potential in AI technologies to mitigate greenhouse gas emissions. This is particularly true in minimising energy wastage, optimising energy consumption and distribution, and identifying areas where there is excessive emission in industrial processes. The AI energy management system has the potential to improve the grid, forecast energy demand, and optimise the use of renewable energy sources such as wind and solar energy.

A number of strategic actions are needed to maximise the benefits of using AI in climate action in developing countries (UNFCCC, 2025). First, it is important to increase investments in infrastructure development and programs aimed at building capacity in the field of AI in order to bridge the digital divide. This approach can create conditions for strengthening local experts and expanding technological capabilities. At the same time, improving the quality of climate data is of great importance to support the development and application of AI models. To this end, it is recommended to establish more advanced data collection mechanisms and expand open data initiatives. In addition, it is necessary to form appropriate regulatory frameworks to ensure transparency and accountability in the application of AI technologies. These frameworks can contribute to strengthening AI governance within the framework of the UN Framework Convention on Climate Change. Another important direction is to build AI systems based on inclusive approaches, which would allow for the elimination of problems such as social inequality and a more equitable distribution of the benefits of climate action. Finally, when implementing AI technologies, special attention should be paid to the efficient use of energy and water resources, and the development of resource-saving and sustainable technological solutions should be encouraged. This approach can help ensure the long-term sustainability of AI systems.

Global near-surface temperature records come from land-based surface meteorological stations as well as from ship-based, buoy-based, and satellite-based observations over the ocean. According to scientific evidence, continued global warming will lead to changes in the intensity, frequency, geographic extent, and duration of extreme weather occurrences. Likewise, AI can be used to optimise the flow of traffic, thereby reducing fuel consumption. In addition, there are promising opportunities for adapting to the effects of climate change with the use of AI (Ayadi *et al.*, 2025). For instance, AI can be used to improve the efficiency of early warning systems for extreme weather occurrences like hurricanes, floods, and droughts (Camps-Valls *et al.*, 2025). In addition, AI-based urban resilience planning can help to elucidate the vulnerabilities of urban infrastructure and optimise land use. Moreover, with the integration of satellite images, AI can aid in biodiversity conservation, water sustainability, and land restoration activities (Jain, 2023). Although the results of this study are reliable, there are certain limitations (UNFCCC & UNIDO, 2025). These limitations include data limitations, model sensitivity, structural simplification, and time constraints. First, it should be noted that the data used are mainly global in scale. It is possible that climate-economic dynamics at the regional and local levels may differ. Second, AI models are sensitive to hyperparameters, so models built with different parameters may produce different results. Agent-based models do not fully reflect real economic behaviour and do not take into account some social factors. Due to time constraints, the model mainly covers short- and medium-term impacts. Long-term

(50-100 years) climate impacts cannot be captured in this study. If there is a lack of inclusiveness in the development of algorithms, there is a possibility of further deepening inequalities. Besides, the energy and water requirements of AI systems are sustainability concerns, especially in regions where there are already existing resource constraints. Limited digital infrastructures, including unreliable internet connectivity, limited computing capacity, and limited human capacity, hinder the development of AI systems. Moreover, developing countries often experience difficulties related to accessing quality and comprehensive climate information, which is essential for creating artificial intelligence models and for informing robust and quality-based decision-making. Without quality information sharing and cybersecurity mechanisms, there is a likelihood of inaccurate information emanating from AI outputs. However, it is important to note that these challenges and limitations do not in any way affect the results' accuracy but, instead, require a more in-depth understanding of the same. It is possible for future research to incorporate alternative models and approaches, such as causality, in order to become more effective. Separately, examining the impact of climate risks on financial stability and capital flows could be considered a promising direction.

CONCLUSIONS

The primary aim of this study was to examine the economic and organisational consequences of climate risks, identify the role of artificial intelligence in the process, and clarify the interaction between the management of resources and strategic planning in relation to climate risks. The study findings show that the objectives were fully realised through the integration of agent-based economic modelling, sophisticated machine learning, and artificial intelligence techniques. The findings point to the fact that climatic factors, such as increased temperatures, inconsistent precipitation, and drought periods, have a quantified effect on macroeconomic performance. Using scenario analysis to examine the period between 2000 and 2023, it is evident that increased risk intensity in climatic factors is linked to lower GDP levels, high inflation rates, and production losses in different sectors. Agriculture is identified as the most susceptible sector to climatic factors due to its direct exposure to temperature and water risks, while the energy sector reflects the effects of climatic factors in terms of increased costs. These dynamics confirm the structural link between environmental stress and economic vulnerability.

Model comparison further shows that deep learning methods outperform traditional econometric approaches in forecasting climate-related economic outcomes. The superior performance of the LSTM model indicates that nonlinear and time-dependent relationships between climate and economic variables require more flexible analytical frameworks. The use of explainable artificial intelligence techniques provided greater transparency through the quantification of the relative importance of each of the climate indicators on the economic forecasts, thus improving the overall reliability of the results. In conclusion, this study shows that the integration of artificial intelligence with economic forecasting has a significant positive impact on the assessment of climate risks, thus improving the robustness of strategic planning. Future studies need to be conducted to extend the cross-country comparison, include the incorporation of firm-level data, and examine the long-term transition risks under different climate policy scenarios. The improvement of the quality of the data, the ethics of AI, and coordination are important to fully exploit the benefits of the technological progress.

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CONFLICT OF INTEREST

The author declares no conflict of interest related to this study.

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Штучний інтелект та економічні прогнози в управлінні кліматичними ризиками

Анотація. Фізичні, фінансові та системні ризики, пов'язані зі зміною клімату, продовжують зростати в економіках усього світу. У міру того як частота та інтенсивність кліматичних ризиків посилюються, стандартним інструментам прогнозування стає дедалі складніше адекватно враховувати складні еколого-економічні взаємодії. Метою цієї статті було детально дослідити роль штучного інтелекту (ШІ) та економічного прогнозування в управлінні кліматичними ризиками. Дослідження продемонструвало, що ідентифікація та прогнозування екстремальних погодних явищ суттєво покращуються завдяки використанню кліматичних моделей на основі ШІ. Пояснюваний штучний інтелект забезпечує додаткову прозорість, оскільки дає змогу аналітикам і політикам краще розуміти чинники, що впливають на прогнози, сформовані моделями посух, повеней і хвиль спеки. У поєднанні з моделями економічного прогнозування ШІ забезпечує проведення комплексних симуляцій того, як кліматичні виклики поширюються через ланцюги постачання, ринки праці, енергетичні мережі та фінансові системи. Попри ці переваги, моделювання на основі ШІ має низку обмежень, зокрема дефіцит даних, обмежену узагальнюваність результатів, а також етичні питання, пов'язані з прозорістю, енергоспоживанням і нерівністю. У дослідженні зроблено висновок, що інтеграція ШІ з економічним прогнозуванням формує надійну міждисциплінарну основу для оцінювання кліматичних ризиків, формування політики та розроблення адаптаційних стратегій. Водночас ефективність такого підходу залежить від удосконалення систем управління, розвитку інфраструктури даних і відповідального впровадження технологій. Практична значущість дослідження полягає у можливості більш точного та раннього оцінювання впливу кліматичних змін на економічні системи. Отримані результати є особливо актуальними для прогнозування та управління ризиками в енергетичному, аграрному та фінансовому секторах

Ключові слова: машинне навчання; пояснювальний штучний інтелект; агентно-орієнтовані моделі; кліматична політика; економічна стійкість; інновації

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The role of innovative entrepreneurship in the modernisation of agricultural enterprises in Ukraine

Abstract. The purpose of this study was to substantiate the role of innovative entrepreneurship in increasing the efficiency and financial sustainability of agricultural enterprises in Ukraine in the context of military and macroeconomic challenges. The research methodology was based on an empirical approach using structural-logical, comparative-dynamic, statistical-dynamic, interval, descriptive, trend, technological-functional, and institutional-comparative analysis, generalising analysis of sources and case studies of the activities of an agricultural enterprise. The results of the study showed an increase in the share of innovatively active agricultural enterprises from 6.2-6.5% in 2020 to 7-8% in 2024-2025, despite the reduction in total capital investments in 2022. It was found that fuel level trackers and machine condition monitoring systems were used in approximately 70% of farms, while linear navigation and field dynamics analysis systems

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were used in about 60%. In 2021-2023, about 3.1 million hectares were processed using drones, and in 2024-2025 – up to 1 million hectares annually. Differentiated input of resources ensured an increase in yield by 4-22%. Analysis of the activities of Myronivsky Hliboproduct showed the restoration of operating margins to 11-12% and an increase in earnings before interest, taxes, depreciation and amortisation to 16-17% in 2023-2024. Comparison with Poland, Slovakia, Hungary and Romania showed that in these countries 5-10% of the funds of the second pillar of the Common Agricultural Policy of the European Union are directed to innovative areas with a level of development of 70-85%, which ensures an increase in productivity by 15-30% and profitability by 20-40%. The practical significance of the study lies in the possibility of using its results by agricultural enterprises to justify decisions on the implementation of innovations

Keywords: technological renewal; agribusiness; innovation activity; investment; transformations; resilience

INTRODUCTION

Structural changes in the Ukrainian economy are deepening due to wartime challenges, global instability and the transformation of agri-food markets. This brings the task of updating the production and management models of agricultural enterprises to the forefront. In conditions of limited access to capital, rising costs, logistical disruptions and heightened risks, the effectiveness of traditional development mechanisms is diminishing, intensifying the need for entrepreneurial approaches that focus on implementing new technologies, business solutions and organisational practices. Low resource efficiency, significant volumes of unrealised by-products, and dependence on linear resource use models constrain the renewal of production and management processes, reducing the economic resilience of enterprises. V. Shebanin *et al.* (2024) analysed these issues, examining the implementation of circular economy principles as a tool for reducing costs, increasing profitability, and strengthening socio-economic effects through the reuse of resources, the development of bioenergy solutions, and the formation of closed production cycles. Their results demonstrated that applying circular approaches optimises material and energy resources, creates additional employment and improves the performance of agricultural enterprises.

The instability of the economic environment, caused by wartime risks, inflationary pressures, and fluctuations in resource prices, makes long-term planning and investment activity difficult, as well as hindering the reproduction of the production potential of agricultural enterprises at the regional level. O. Khrystenko *et al.* (2025) used regression analysis, econometric modelling and a scenario approach to forecast the development of the agricultural sector under conditions of economic instability. Their study revealed crop yields, the structure of sown areas and investment activity to be highly sensitive to changes in macroeconomic factors, particularly inflation levels and fuel prices. It also revealed a limited potential for production recovery under unfavourable scenarios. A.S. Poltorak *et al.* (2023) examined the relationships between food security indicators. Based on a correlation-regression analysis of data from 113 countries, they demonstrated a statistically significant correlation between the economic accessibility of food and the extent to which agricultural production adheres to sustainable development principles. The results showed that in countries with high purchasing power, these relationships are stable and economically significant. However, under medium and low levels of food accessibility, they lose statistical strength, which limits the possibility of universally applying such models.

The fragmented implementation of innovations, the weak integration of technological, organisational, and socio-economic solutions, and the limited coherence between improving production efficiency and enhancing the development conditions of rural areas, constrain the comprehensive renewal of agricultural enterprises. V. Mamchur & G. Studinska (2023) focused on forming a model of innovative development within the national resilience system.

They substantiated the need to combine technological, institutional, organisational, and marketing innovations to increase productivity, expand value chains, strengthen export potential, and improve socio-economic living conditions. Their results showed that systematically implementing a package of innovations can ensure a synergistic effect on economic performance and sustainable development. They also emphasised the role of state reforms and institutional prerequisites in initiating such changes. However, low innovation activity, the predominance of imitative technological solutions, and dependence on imported equipment limit improvements in productivity, competitiveness, and the sustainability of agricultural enterprises. Against this backdrop, V.V. Antoshchenkova & M.O. Peresada (2023) emphasised the pivotal role of innovation in agricultural production. They substantiated the impact of technological advancements, mechanisation, and biotechnological solutions on enhancing crop yields, improving resource efficiency, and transforming production models. Notably, they examined these aspects through the lens of Cochrane's "treadmill" theory. The study demonstrated that, while innovations contribute to growth in labour productivity and economic performance, they also generate risks of overproduction, price pressure and the displacement of small producers when development is primarily oriented towards scale and price. N. Kovalenko & Y. Malakhova (2025) focused on the strategic management of innovation activity. They substantiated the need to form an organisational-economic mechanism that combines the assessment of innovation potential, the definition of an innovation strategy, and phased control over the results of its implementation. Their analysis confirmed that integrating strategic management and innovation processes has a positive impact on productivity, cost efficiency, and the competitiveness of enterprises in times of economic instability.

Entrepreneurial activity develops under conditions of complex interaction between formal and informal institutions, unequal access to financial and organisational resources, and increased sensitivity to macroeconomic and social transformations. I. Deineha *et al.* (2021) examined these issues, focusing on analysing the institutional environment for small and medium-sized enterprises. The authors concluded that the effectiveness of entrepreneurial activity is determined by the quality of state regulation, the availability of financial support instruments, the coherence of institutional mechanisms, and the stability of economic rules. T. Sus *et al.* (2023) classified financial models to ensure innovative development. They analysed combinations of self-financing, budgetary support, cluster and cooperative mechanisms. They also proposed a methodology to assess the influence of financing on regional innovation potential. The results obtained demonstrated differentiation among regions according to the level of financial support for innovation, as well as the dependence of innovation activity on the structure of attracted resources.

Meanwhile, existing studies have primarily focused on macro-level environmental and methodological aspects. However, the entrepreneurial mechanisms for initiating, scaling and commercialising innovations, and their impact on modernising business and management models in the agricultural sector, remain insufficiently explored. This study aimed to determine the influence of innovative entrepreneurship on updating production and management processes in Ukrainian agricultural enterprises. To this end, two objectives were set: to analyse the implementation of digital, technological and organisational innovations in Ukrainian agricultural enterprises between 2020 and 2025; and to evaluate the effect of innovative entrepreneurship on production performance indicators, crop yields and the financial resilience of Ukrainian agricultural enterprises.

MATERIALS AND METHODS

This empirical study aimed to analyse the dynamics of innovative and economic processes in Ukrainian agricultural enterprises between 2020 and 2025. This time period was chosen due to the intensification of digitalisation in the agricultural sector and changes in operating conditions after 2022, enabling dynamic analysis. To evaluate the structure of implemented innovations and the level of automation of production processes, a structural-logical analysis of data from Yu. Makovey (2025) on the application

of Agriculture 4.0 approaches in Ukrainian agricultural enterprises was used. This made it possible to categorise the use of drones, Global Positioning System (GPS) satellite navigation systems, automated data collection systems, and digital platforms for managing production operations, and to determine their role in the production cycle.

A comparative-dynamic approach was used to study the volumes of state, concessional and grant funds directed towards innovation in the agricultural sector, with a particular focus on the implementation of state support programmes. The credit programme "5-7-9%", which financed investment and modernisation projects for agricultural enterprises in 2020-2025, was examined in detail. Sources used included V. Khvorostyaniy (2020) and State Support for Farmers in 2025 (2024). The dynamics of capital investment in Ukrainian agriculture and the proportion of investment directed towards innovation between 2020 and 2025 were examined using statistical and dynamic analyses, as well as interval analyses of indicators of total capital investment and investment in innovation, and their respective shares in the financing structure. These analyses were based on secondary sources such as Investments in the Agricultural Sector of Ukraine (n.d.) and S.Yu. Sokoliuk *et al.* (2025). This approach identified structural shifts in the investment priorities of agricultural enterprises during a period of limited access to capital.

The practices of differentiated fertiliser application, the use of drones, and precision approaches in crop production were studied using a technological-functional approach. A comparative assessment of the level of automation of production operations was carried out based on the Ukraine Digitalisation Index (2025) and V. Polishchuk (2025). This made it possible to establish a relationship between digital technologies and the efficiency of agrotechnological processes. To evaluate the outcomes of production during the implementation of digital solutions, a descriptive analysis of crop harvesting indicators in 2025 was conducted (Ukraine completed the harvest..., 2025). The impact of innovative entrepreneurship on the performance of agricultural enterprises was assessed economically using a case study of Myronivsky Hliboproduct (MHP), which was selected as a representative example due to the scale of its production activities, the systemic nature of innovation implementation, and the availability of open financial and operational information (MHP SE, 2024; 2025). The analysis examined the full-scale implementation of precision farming and the introduction of the innovative "Biogas 5.0" programme, which aims to decarbonise production, utilise by-products, and form closed energy-resource cycles. This enabled the economic impact of innovation on the enterprise's production and financial activities to be evaluated (MHP innovation programme, 2021).

The integration of artificial intelligence into production and management processes was analysed using a functional-analytical approach, illustrated by MHP's transition to the SAP S/4HANA Enterprise Resource Planning (ERP) platform and the introduction of digital ecosystems for personnel and business process management, Myronivsky Hliboproduct for You (MHP4U, n.d.). This made it possible to evaluate the impact on controllability, analytical decision support, and operational efficiency. The economic impact of the innovation in 2025 was evaluated through statistical analysis of crop production results, focusing on yield and harvest volume indicators presented in MHP received a record... (2025). This analysis revealed the impact of technological solutions on enterprise productivity. The financial performance of innovative entrepreneurship was examined through a dynamic financial analysis of revenue, operating profit, adjusted EBITDA, and margin levels from 2020 to 2025, based on official financial reports from MHP SE (2024 and 2025). This analysis revealed changes in the enterprise's financial resilience over time. Trend analysis of financial indicators in the post-shock period (2023-2025) was carried out using data from the official financial reports "Financial results for the first quarter ended 31 March 2025" and "Unaudited financial results for the first quarter ended 31 March 2024", identifying changes in operational efficiency and profitability under conditions of digitalisation and automation of management processes.

A comparative analysis was carried out using institutional-comparative and structural

analyses to examine innovative approaches to the modernisation of agricultural enterprises in Ukraine and neighbouring European Union countries (Poland, Slovakia, Hungary and Romania). The analysis was conducted according to the following criteria: land-use structure, the level of innovation activity within agricultural enterprises, and access to financial resources. The countries were selected due to their proximity to Ukraine, similar natural and climatic conditions, and participation in the Common Agricultural Policy (CAP) (Agriculture and Rural Development, n.d.). The analysis was conducted using data from Eurostat (2022) and M. Teryukhanova (2025). The institutional conditions for developing innovative entrepreneurship were evaluated by analysing the European Union's Common Agricultural Policy, particularly its second pillar, Pillar II (Rural Development), and the European Innovation Partnership for Agricultural Productivity and Sustainability (EIP-AGRI) mechanism. This made it possible to determine the role of supranational instruments in stimulating innovation. In the case of Ukraine, national programmes supporting innovative entrepreneurship in the agricultural sector were analysed, including the "5-7-9%" preferential credit programme, as well as the eRobota (n.d.) and Own Business... (2025) grant instruments. International initiatives were also examined, including the USAID Agricultural and Rural Development Programme and the Food and Agriculture Organization of the United Nations (FAO) programme. Analysing these programmes made it possible to evaluate how agricultural enterprises in Ukraine access financial resources, innovation instruments and technological support, and how this compares with the mechanisms operating within the European Union's Common Agricultural Policy.

A comparative index approach based on data from E. Francica (2025) was used to analyse the level of innovation among agricultural enterprises in EU border countries, which made it possible to identify their position within the structure of innovation development in the European Union. The economic impact of innovative entrepreneurship and the influence of the EU's environmental policies were evaluated through an analysis of generalising empirical studies and strategic documents, such as the European Green Deal and Farm to Fork. This allowed for comparing entrepreneurial incentives, regulatory constraints, and innovation outcomes in the agricultural sector, using data from V. Choudhary *et al.* (2025) and I. Tomashuk *et al.* (2025).

RESULTS

Analytical characteristics of innovation and modernisation processes in agricultural enterprises in Ukraine

From 2020 to 2025, the innovation activity of Ukrainian agricultural enterprises developed amid limited access to financial resources, wartime risks, and shifting investment priorities. This resulted in a gradual increase in the proportion of entities engaged in innovation. The proportion of enterprises introducing innovations increased from 6.2-6.5% in 2020 to 7-8% in 2024-2025 (Kalina *et al.*, 2025). This trend was primarily driven by digital and technological solutions aimed at optimising costs, improving the precision of production operations, and adapting production to labour shortages. Within the structure of implemented innovations, elements of precision agriculture predominated, particularly the use of drones, GPS satellite navigation systems and automated data collection and processing. However, the number of agricultural enterprises using drones and automated solutions remained largely confined to large farms, accounting for around 10-12% as of 2025. Meanwhile, the actual scale of use of such technologies remained stable: approximately 3.1 million hectares were treated with drones in 2021-2023, whereas the area treated was estimated at up to 1 million hectares annually in 2024-2025 (Makovey, 2025). This reflects the concentration of innovative technology use in enterprises with large land holdings and greater investment capacity.

The automation of production processes and the use of artificial intelligence tools were selective in nature. Around 12% of agricultural enterprises used algorithms for fertiliser application planning and yield forecasting. By contrast, auxiliary digital solutions became more widespread, with fuel level trackers and systems for monitoring the location and technical condition of machinery being used on around

70% of farms and linear navigation systems and field dynamics analysis systems being applied on around 60%. Automatic sprayers (used by around 34% of enterprises) and Real-Time Kinematic (RTK) high-precision positioning technologies (used by around 52%) remained less widespread, due to the high investment required for such solutions (Makovey, 2025).

The volume of state, concessional and grant funding directed towards innovation in the agricultural sector fluctuated unevenly between 2020 and 2025. In 2020, the total amounted to around UAH 4.0 billion, which was used to compensate for the cost of machinery and to develop horticulture and livestock farming (Khvorostyaniy, 2020). In 2021, funding increased to UAH 5.0 billion due to the expansion of the "5-7-9%" credit programme (PrivatBank, n.d.). In 2022, support declined to UAH 4.5 billion, with funding being reallocated to cover wartime risks and land demining. In 2023, funding increased to UAH 5.4 billion, with approximately UAH 1.5 billion directed towards stimulating private investment in modernisation. In 2024, funding reached UAH 6.0 billion, with a focus on developing irrigation systems and providing grants for greenhouse projects. In 2025, funding was estimated to be between UAH 4.7 and 6.0 billion, including per-hectare subsidies and financing for demining and land reclamation (State support for farmers in 2025, 2024). Figure 1 presents the dynamics of capital investment in Ukraine's agriculture and the share of funds directed towards innovative technologies in 2020-2025.

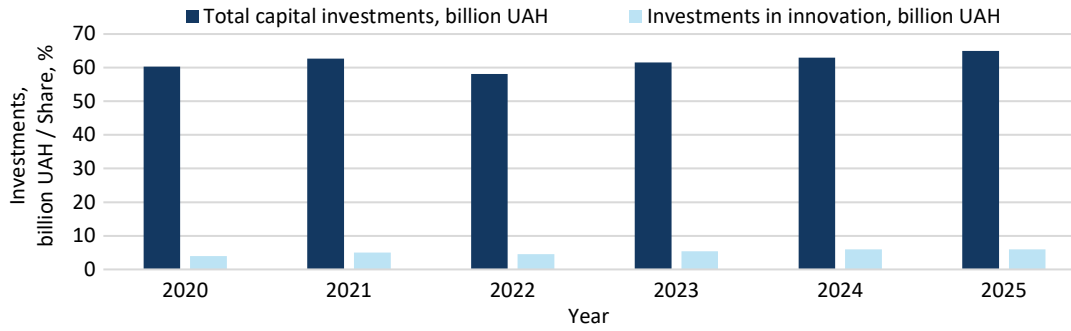

Figure 1. Dynamics of capital investment in Ukraine's agriculture and the share of investment directed towards innovation in 2020-2025

Source: compiled by the authors based on S.Yu. Sokoliuk *et al.* (2025), Investments in the agricultural sector of Ukraine (n.d.)

According to the presented data, the highest total capital investment volume was recorded in 2021 (UAH 62.7 billion), while the lowest was observed in 2022 (UAH 58.1 billion). The maximum share of investment in innovation was recorded in 2024 (9.5%), while the minimum was in 2020 (6.6%). The concentration of minimum values in 2022, followed by an increase in the share of innovation investment up to 2025, indicates a shift in the investment priorities of agricultural enterprises towards technological renewal, despite limited recovery in the overall volume of capital investment. From 2020 to 2025, wartime restrictions, climatic fluctuations and accelerated digitalisation transformed the structure of production operations in Ukrainian agricultural enterprises, as reflected in changes to soil cultivation, sowing, fertiliser application and harvest organisation technologies, and a gradual shift in the balance between manual and machine-automated operations. In soil cultivation, the transition from traditional ploughing to mini-till, no-till and strip-till systems was driven by the need to retain moisture, reduce erosion and cut fuel costs. Technologically, this was accompanied by the increased use of combined units and wide-span machinery, reducing the number of fields passes and improving resource efficiency. The partial automation of tillage operations mainly occurred through the use of GPS navigation during chisel ploughing and discing, covering approximately half of the cultivated area

in large enterprises. However, full automation remained limited due to the high investment required for the necessary technology (Khablak & Arakelyan, 2021).

From 2020 to 2025, fertiliser application shifted from mass to localised application with variable rates, based on precision agriculture tools and algorithmic recommendations. By 2025, mineral fertiliser consumption had increased by 20% compared to 2024, reaching 3.42 million tonnes over eight months. This was accompanied by an increasing emphasis on differentiated application. Automation of fertiliser and crop protection product application was one of the most advanced areas of technological development: sectional application and variable rates were employed by around 78% of innovative farms (Polishchuk, 2025). The use of drones and spot-treatment approaches improved operational precision; however, the extent to which they were adopted differed substantially depending on enterprise scale and technological equipment. Automatic sprayers with advanced analytical functions were adopted less widely (by around 40-50% of enterprises), while autonomous, operator-free machinery remained largely at the pilot project stage in large companies (10-20%) (Ukraine Digitalisation Index, 2025).

Despite constraints related to security and the accessibility of certain land plots, harvesting in 2025 ensured production volumes of 57.6 million tonnes of cereals and 17.3 million tonnes of oilseeds, with an average cereal yield of 5.08 t/ha. The use of telemetry and machinery monitoring systems within the structure of harvesting operations expanded to approximately 70% of large farms, making it possible to control work execution, fuel consumption and machine operating modes while reducing response time to process deviations. The trajectory of modernisation was uneven over the years: in 2023, precision agriculture solutions accounted for around 22% of the market, while algorithms for fertiliser application planning accounted for around 12%. In 2024, 70-80% of innovative enterprises automated key production processes such as sowing, applying inputs and harvesting. In 2025, leading companies such as Kernel (n.d.) and UkrLandFarming (n.d.) had automated over 80% of their operations through the use of RTK navigation, telematics, drones and analytical platforms (Ukraine completed the harvest..., 2025). In summary, the structural changes in the production operations of Ukrainian agricultural enterprises between 2020 and 2025 manifested as a technological shift towards resource-saving tillage systems, an increased share of highly precise sowing and material input application, a stronger role for telemetry in harvesting processes and clear differentiation in the pace of modernisation between enterprises of different sizes and investment capacities.

Economic assessment of the impact of innovative entrepreneurship on the performance of agricultural enterprises

From 2020 to 2025, the implementation of innovative entrepreneurial solutions in Ukrainian agricultural enterprises was accompanied by noticeable changes in production and financial performance indicators. These solutions included elements of precision agriculture, automated technological processes, and digital production management tools, primarily used by large farms and, to a lesser extent, medium-sized ones. One of the key channels through which innovation exerted economic influence was crop yield. Using agrochemical soil analysis, field zoning, satellite monitoring and differentiated input application rates ensured yield increases ranging from 4% to 22%, depending on the crop and regional conditions. At Industrial Milk Company (IMC), for example, the average maize yield in 2021 was 10.55 t/ha, compared to an average of 7.42 t/ha in Ukraine, reflecting differences in nutrient management and technological operations. In 2025, more than 81 thousand tonnes of sunflower were harvested from 24.8 thousand hectares, yielding 3.3 t/ha; meanwhile, the average sunflower yield in Ukraine was 1.83 t/ha (IMC, n.d.).

Between 2020 and 2025, agricultural holding company MHP implemented an innovative entrepreneurial model, in which digitalising production and management processes became a key instrument for ensuring operational resilience and financial performance (MHP SE, 2024; 2025). Rather than being integrated as separate technological projects, innovations were incorporated as a component of the business model,

directly influencing the cost structure, profitability, and the company's ability to adapt to external shocks. The central element of MHP's innovative transformation was the large-scale adoption of precision agriculture. All cultivated land was mapped digitally, and electronic field maps, records of agrotechnological operations, yield indicators and agrochemical soil condition data were created. As part of its sustainable development strategy, MHP began introducing the innovative "Biogas 5.0" programme in 2020, which is aimed at decarbonising production and achieving carbon neutrality. This programme integrates biogas and biomethane technologies with systems for utilising organic waste, producing renewable energy and organic fertiliser, and reducing greenhouse gas emissions. MHP began implementing biogas projects before the introduction of the European Green Deal, establishing industrial biogas complexes to partially supply energy to the company's agro-industrial facilities. The transition to the "Biogas 5.0" concept also involves developing biomethane production technologies and integrating green hydrogen solutions. This creates a closed energy-resource cycle and expands the company's opportunities to participate in European climate and energy markets (MHP innovation programme, 2021).

From 2020 to 2025, MHP consistently integrated artificial intelligence (AI) tools into its production and management processes as part of its innovative entrepreneurial approach and digital transformation strategy. According to management estimates, investments in AI projects reached the break-even point during the implementation period of 2020-2021: the net economic effect in 2024 was in the region of hundreds of thousands of US dollars, and the expected effect in 2025 exceeded USD 1 million. The digital transformation of management, particularly the transition to the SAP S/4HANA ERP platform (Business Evolution, n.d.), formed the institutional basis for scaling AI solutions and ensured the standardisation of financial, production, logistics and sales processes. In 2024, MHP's investment in innovation exceeded UAH 900 million, one of the highest figures among Ukrainian companies. The implementation of digital projects was carried out by a team of around 350 specialists. Practical applications of AI included optimising poultry production by analysing large volumes of production data, automating climate control in poultry houses and forecasting crop yields. These solutions ensured lower operating costs and improved resource efficiency, enabling the company to achieve measurable financial results despite high levels of macroeconomic and wartime uncertainty (MHP innovation programme, 2021).

In developing the company's information technologies and digital ecosystems, one of the key steps was creating and implementing proprietary technological solutions adapted to the specifics of the agricultural and food business. These solutions include the Smart Technology Assistant (Smart TA), an adaptive system that supports decision-making in poultry farming at every stage of the production cycle, from planning to the automated control of essential rearing factors. Another example is the Data Model for Meat Processing (DMMP), an artificial intelligence-based model designed to optimise meat yield from specific anatomical parts of poultry and improve the consistency of quality indicators for finished products. As part of the digital transformation, the MHP4U (n.d.) recruitment ecosystem was also developed. This integrated various digital platforms and data analysis tools to manage the processes of attracting, selecting and developing personnel. Using these solutions ensured greater coherence between production and management processes, reduced transaction costs, and minimised the impact of human error, thereby increasing the company's operational efficiency (Lopokha, 2025). The economic effect of innovation in crop production was reflected in higher yield indicators. In the 2025 season, MHP harvested over 2 million tonnes of produce from a 330,000-hectare area, accounting for over 90% of the planned area. Wheat yield reached 7.7 t/ha, compared to 7.2 t/ha in 2024. Projected maize yield was estimated at 8.7 t/ha and sunflower yield at around 3 t/ha. These results demonstrate the maintenance of high productivity despite wartime risks and restricted access to some land (MHP received a record...., 2025).

The financial results of the MHP agricultural holding were achieved amid high levels of

macroeconomic and operational uncertainty, resulting from the impact of the pandemic, the war in Ukraine, logistical constraints and currency fluctuations. In this context, investments in digitalisation, production process automation and analytical management platforms were incorporated into the company's operational model as part of the transition to a "digital agricultural holding". To assess the economic impact of innovative entrepreneurship at MHP, the dynamics of key financial indicators in the first quarter of 2020-2025 was analysed (Table 1).

Table 1. Dynamics of MHP's key financial indicators in 2020-2025 (Q1)

Indicator	Years						Growth rate	
	2020	2021	2022	2023	2024	2025	2025/2020, %	2025/2024, %
Revenue, USD million	443	436	553	746	719	779	75.8	8
Gross margin, %	21	19	16	19	24	–	–	–
Operating profit, USD million	47	50	9	84	84	60	27.7	-28.6
Operating margin, %	11	11	2	11	12	8	-27.3	-33.3
Adjusted EBITDA (net of IFRS 16), USD million	90	83	43	117	119	111	23.3	-6.7
EBITDA margin (net of IFRS 16), %	20	19	8	16	17	14	-30.0	-17.6
Net profit/(loss), USD million	-174	33	-108	49	16	32	–	100
Net margin, %	-39	8	-20	7	2	–	–	–
Wartime costs, USD million	–	–	26	6	10	–	–	–
Share of export revenue, %	–	–	–	70	63	–	–	–

Source: compiled by the authors based on MHP SE (2024; 2025)

As shown in Table 1, 2021 was characterised by relatively stable financial parameters in MHP's operations. The operating margin was 11%, the EBITDA margin was 19%, and the net margin was 8%. These values can be considered the baseline level of performance for an innovation-oriented agricultural model under wartime-free conditions. The highest revenue volume during the analysed period was recorded in 2025 at USD 779 million, exceeding the 2020 figure by 75.8% and the 2024 figure by 8%. Meanwhile, the maximum gross margin (24%) and adjusted EBITDA (USD 119 million) values were observed in 2024, reflecting the peak of recovery in operational efficiency after the crisis period. However, in 2022, there was a sharp deterioration in financial indicators: the operating margin fell to 2%, the lowest value for the period, the EBITDA margin declined to 8%, and the net financial result became negative at USD -108 million. The lowest profitability indicators and a substantial reduction in earnings were precisely recorded in 2022, reflecting the impact of wartime costs (USD 26 million), foreign exchange losses and disruptions to production and logistics processes. From 2023 to 2024, MHP demonstrated an improvement in operational efficiency, with operating profit rising to USD 84 million and EBITDA increasing to USD 117-119 million. Net profit in 2025 amounted to USD 32 million, double the 2024 figure. However, a decline in the operating margin to 8% (-33.3% compared to 2024) and a reduction in the EBITDA margin to 14% were also recorded in 2025, indicating weakening margins despite maintained overall revenue growth. Thus, the dynamics of the indicators for 2020-2025 reflect a significant downturn in 2022, which was the lowest point of the financial cycle. This was followed by a recovery in 2024-2025, during which the highest revenue and profitability values were achieved. Comparing 2021 with the period 2023-2025 confirms that, after the wartime shock of 2022, innovative entrepreneurship at MHP acted as an economic stabiliser, ensuring the recovery of profitability and revenues, and maintaining financial resilience.

From 2020 to 2025, innovative entrepreneurship played a role in modernising agricultural enterprises in Ukraine. Implementing precision agriculture, automating production operations and introducing digital management systems increased productivity, made more efficient use of resources and enabled more controllable production processes. These changes

were most evident in large agricultural companies, where innovations were integrated into the business model rather than implemented as isolated technological solutions. The case of the MHP agricultural holding showed that systematic digitalisation and automation enabled production and financial resilience to be preserved under wartime and macroeconomic constraints. Innovative entrepreneurial solutions acted as an adaptive mechanism, ensuring the recovery of operational efficiency and stabilising financial results after external shocks. Overall, innovation in the agricultural sector not only raised productivity, but also became an element of enterprises' long-term economic resilience.

Comparative analysis of innovative approaches to the modernisation of agricultural enterprises in Ukraine and EU neighbouring countries

The European Union's border countries – Poland, Slovakia, Hungary and Romania – directly border Ukraine to the west and south. The border lengths are 542 km with Poland, 98 km with Slovakia, 137 km with Hungary and 614 km with Romania. Following the Union's enlargement, these borders became part of the EU's external frontier. The agricultural sectors of these countries are characterised by fragmented land use, family farming and the consolidation of land among medium and large-scale producers. In such circumstances, innovative entrepreneurship serves as a means of not only increasing productivity, but also of adapting agricultural enterprises to the EU's environmental, technological, and market requirements (Teryukhanova, 2025).

The land-use structure in EU border countries influences the pace and character of innovation implementation. In Romania, for example, over 90% of farms have an area of less than 5 hectares, whereas in Hungary it is around 65%. In Poland and the Baltic States, meanwhile, it is small and medium-sized family farms that predominate. Conversely, in Slovakia and in parts of Poland and Romania, large farms control between 50% and over 90% of agricultural land (Eurostat, 2022). This asymmetry leads to differing access to financial resources, technologies and knowledge, shaping the dual nature of innovative entrepreneurship: large-scale investment in large cooperatives and agricultural companies, and slow, fragmented innovation among small family farms. A similar land-use structure can be observed in Ukraine, albeit with a higher degree of land concentration in large agricultural enterprises. Of the approximately 39 thousand commercial agricultural enterprises, over half have a land bank of less than 100 hectares, yet they use only around 3.8% of agricultural land. In contrast, enterprises with an area of over 1,000 hectares represent a smaller numerical share, yet they control over 70% of the total land area. In particular, farms with a land bank of 1,000-5,000 hectares account for nearly half of the total area, while enterprises with over 5,000 hectares control more than a quarter (Régnier & Catallo, 2024). Thus, as in EU border countries, Ukraine's small and medium-sized entities dominate numerically, while large producers control the majority of land resources, directly affecting the scale of investment and the nature of innovation activity.

The institutional basis for developing innovative entrepreneurship in the agricultural sectors of EU border countries is the EU's Common Agricultural Policy (CAP) (Agriculture and Rural Development, n.d.), specifically its second pillar (Rural Development) (Granier & Sgueo, 2016). During the 2023-2027 programming period, Pillar II will be the main source of funding for innovation, digitalisation, and sustainable development, offsetting the limited private investment in research and development. On average, 30% of Pillar II budgets are allocated to innovative, environmentally oriented measures, while expenditure on research and development (R&D) accounts for around 1.3% of gross domestic product (GDP) (Agriculture and Rural Development, 2025).

In Ukraine, state and international support programmes aimed at modernising production, developing infrastructure and irrigation, and supporting small and medium-sized agricultural producers perform a functionally similar role to that of Pillar II. Examples include the "5-7-9%" preferential credit programme (PrivatBank, n.d.), the eRobota (n.d.) grant scheme and the Own Business... (2025) grant scheme, as well as the USAID Agricultural and Rural Development Programme (2025) and the FAO's (n.d.) programme. These instruments provide financing

for technological renewal, the development of cooperation, irrigation and processing, and partially compensate for the limited access to private investment experienced by agricultural enterprises. As in EU border countries, under such conditions, the land-use structure forms an asymmetric model of innovative entrepreneurship, with large agricultural enterprises serving as the main adopters of large-scale technological and digital solutions and small and medium-sized farms introducing innovations selectively and in a fragmented manner.

The most widespread Pillar II instruments are Measure 4 (investment in physical assets), Measure 6 (business development and young farmers), and Measure 16 (cooperation, European Innovation Partnership for Agricultural Productivity and Sustainability (EIP-AGRI)) (EU CAP Network, n.d.). In Poland and Romania, investment measures under Measure 4 account for 25-40% of European Agricultural Fund for Rural Development (n.d.) financing, which stimulates the introduction of precision agriculture technologies, digital management systems and the automation of production processes. In the Baltic States and Slovakia, Measure 16 occupies a notable share in the funding structure, reaching 15-25% of Pillar II, ensuring the creation of EIP-AGRI operational groups, the development of innovation clusters, and the testing of agri-tech solutions in pilot projects. Overall, 5-10% of national CAP strategic plans in the border countries are directly oriented towards innovation, while the fund absorption rate amounts to 70-85% (Agriculture and Rural Development, 2025). The level of innovation among agricultural enterprises in the European Union's border countries – Poland, Slovakia, Hungary, Romania and the Baltic States – remained below or close to the EU average, as confirmed by the data of the 2025 European Innovation Scoreboard (indexed to the EU average in 2018 = 100). In particular, Poland demonstrated an innovation performance index of around 80-85 points, Hungary 75-80 points, and Slovakia 70-75 points, which placed these countries in the group of moderate innovators. The lowest indicators among the analysed border countries were recorded in Romania and Bulgaria, where the innovation performance index stood at approximately 45-50 points and 55-60 points respectively, corresponding to the category of emerging innovators. These values differed markedly from those of the EU "core" countries, where the innovation performance index exceeded 130-150 points (in particular in Sweden, Denmark and the Netherlands). The Baltic States were characterised by internal differentiation in innovation development. Estonia showed an index of around 120 points, exceeding the EU average and approaching the group of strong innovators, which reflected its high level of digitalisation and the development of innovation infrastructure. At the same time, Lithuania and Latvia remained in the group of moderate innovators, with figures of approximately 95-100 points and 85-90 points respectively (Francica, 2025). In Ukraine, the level of innovation among agricultural enterprises is also characterised by moderate values, though with a more pronounced asymmetry according to farm size. The systematic use of digital and technological solutions is typical of only 15-25% of agricultural enterprises. At the same time, around 40-50% of large agricultural companies use precision agriculture tools, Internet of Things (IoT) solutions, drones and big data analytics, whereas medium-sized farms mainly implement basic digital tools (mobile applications, monitoring sensors) at a level of around 20%, and among small producers the share using innovative technologies does not exceed 10%, being concentrated primarily in biotechnological solutions and the use of new hybrids (Sukhorukova, 2024). The aggregate digitalisation index of Ukraine's agricultural sector in 2025 was estimated at around 38%, which is lower than the figures for most EU border countries; however, the expected expansion of state and donor support programmes creates the preconditions for this figure to rise to around 50% in the medium term (Ukraine Digitalisation Index, 2025). Thus, the comparison of Ukraine with the European Union's border countries shows that, in terms of overall innovation performance, the Ukrainian agricultural sector is approaching the group of moderate innovators; however, unlike the EU countries, where innovation activity is more evenly distributed across farm categories, in Ukraine innovations are concentrated primarily in large agricultural companies, while medium-sized and small

producers remain constrained in their access to capital-intensive technologies.

The economic impact of innovative entrepreneurship in agricultural enterprises in EU border regions is reflected in increased productivity, reduced costs and greater profitability. On farms that have adopted precision agriculture technologies and digital management tools, productivity growth amounts to 15-30%, while expenditure on fertilisers, plant protection products, and water is reduced by 10-25%. Consequently, the net profitability of such enterprises increases by 20-40% in large cooperatives and medium-sized farms. For small family farms, the economic impact is smaller (8-15%), due to the limited production scale and high initial costs (Choudhary *et al.*, 2025; Tomashuk *et al.*, 2025). In Ukraine, the positive economic impact of innovative entrepreneurship is constrained by the low proportion of innovation-active agricultural enterprises, which amounted to around 7–8% in 2024. Under these conditions, productivity growth of 15-30% is mainly recorded among innovative enterprises, whereas the overall contribution to gross domestic product at the level of the agricultural sector as a whole is estimated at 8-10%. The most pronounced economic effect is observed in large agricultural companies, where yield increases of 20-25% per hectare are ensured by the introduction of precision agriculture, artificial intelligence tools, and Internet of Things systems, while expenditure on fertilisers, fuel, and material resources is reduced by 15-20% (Kalina *et al.*, 2025). An additional economic effect is generated through the export channel. The introduction of innovative crops, particularly highly productive hybrids and organic products, contributed to a 10-15% increase in foreign currency earnings in 2024 (Ukraine Digitalisation Index, 2025). Thus, compared with EU border countries, Ukraine's channels for the economic effects of innovative entrepreneurship are structurally similar, but characterised by lower enterprise coverage and greater concentration of results in large agricultural holdings.

The EU's environmental requirements, particularly the provisions of the European Green Deal (n.d.), Farm to Fork strategy (n.d.) and the Nitrates Directive (Council Directive 91/676/EEC, 1991), provide an additional stimulus for innovative entrepreneurship. The requirement to reduce the use of pesticides and mineral fertilisers creates demand for precision agriculture technologies, bioenergy, and digital monitoring systems. Within the CAP, eco-schemes and Pillar II measures allocate 25-40% of resources to supporting green innovations, creating new entrepreneurial opportunities while simultaneously raising barriers to entry for traditional small farms. Innovative entrepreneurship in agricultural enterprises in the border countries of the European Union is developing in the context of fragmented land use, family farming and limited access to private investment. In such circumstances, institutional support within the framework of the EU Common Agricultural Policy is key to innovation development, particularly through Pillar II mechanisms, EIP-AGRI and EAFRD funds, which offset the structural limitations faced by small and medium-sized farms. Although there is a persistent gap in innovation performance between the EU "core" countries and the border countries, implementing digital and environmentally oriented solutions ensures productivity growth, cost reduction and higher profitability for agricultural enterprises, particularly medium-sized farms and cooperatives. Thus, innovative entrepreneurship in EU border countries plays an adaptive and stabilising role, promoting the gradual convergence of the agricultural sector with European technological and environmental standards.

DISCUSSION

The intensification of wartime risks, restricted access to resources, and tightening regulatory requirements in the agricultural sector necessitate reconsidering the role of digitalisation, innovation, and entrepreneurial practices in modernisation processes and ensuring development resilience. In both this study and the work of H. Wang *et al.* (2025), digitalisation was interpreted as a fundamental driver of agricultural modernisation, capable of improving efficiency, accelerating the innovation process and supporting sustainable development. At the same time, H. Wang *et al.* focused on the macro-regional dimension, examining the digitalisation of agricultural circulation through

integral indices and the spatial effects between regions in China. In contrast, this study considered digital and innovative entrepreneurial solutions in terms of how Ukrainian agricultural enterprises adapted to wartime risks and resource constraints. This shifted the focus from regional dynamics to internal production and managerial transformations. A similar logic can be seen in the approach of Y. Wei & C. Sutunyarak (2025), albeit with a different emphasis. Both studies recognised innovation and digital tools as key factors in improving the performance of agricultural enterprises and overcoming structural constraints. However, Y. Wei & C. Sutunyarak primarily interpreted innovative development through the lens of a digitally inclusive financial system, considering financial constraints to be the central intermediary mechanism influencing the innovative activity of Chinese agricultural companies. In this study, however, innovative entrepreneurship was interpreted much more broadly as a comprehensive strategy for modernising production and management processes in wartime. Taking a broader comparative approach, it was found that the study by X. Meng *et al.* (2024) shared the view that innovation and digital technologies are key drivers of change in the agricultural sector. X. Meng *et al.*, however, focused on the educational and institutional dimension of change, analysing the training of new professional farmers and the development of digital competencies. In contrast, this study considered human capital not as an independent object of analysis, but as part of a broader entrepreneurial logic aimed at renewing production models and enhancing the productivity and resilience of Ukrainian agricultural enterprises.

While there was a similarity in theoretical positions, there was a difference in analytical scale compared to the work of X. Xu & K. Zhang (2025). In both studies, innovation and entrepreneurial activity were considered essential for transitioning the agricultural sector to new, higher-quality development models. However, X. Xu & K. Zhang worked at the macro level, assessing the influence of rural entrepreneurship on the formation of "new qualitative productive forces" in China through technological innovation, industry integration, and spatial effects. In the present study, however, the focus was on micro- and meso-level processes where innovative entrepreneurship acted as an instrument for renewing the production and management practices of specific agricultural enterprises amid wartime risks. Further comparison with Y. Pan *et al.* (2024) revealed a shared interpretation of innovative entrepreneurship as a factor in agricultural modernisation. At the same time, Y. Pan *et al.* concentrated on a macro-regional analysis of China, paying attention to the spatial spill over effects of farmers' entrepreneurship and its influence on rural development. In contrast, the present study considered innovative entrepreneurship through the lens of the internal transformation of Ukrainian agricultural enterprises, emphasising the strengthening of financial resilience and the adaptation of business models to wartime challenges.

A comparison with the work of M. Gao *et al.* (2025) revealed a mutual recognition of innovation as a pivotal element in the sustained modernisation of the agricultural sector. Meanwhile, M. Gao *et al.* focused on green and digital macro-level transformations, examining them through the lens of environmental efficiency, structural shifts, and the political and institutional mechanisms of sustainable development. Against this background, the present study stands out for its practical focus: it interprets innovative entrepreneurship as a mechanism for renewing the production and management processes of Ukrainian agricultural enterprises with the aim of enhancing productivity and financial resilience in wartime and in the face of resource constraints. A comparison with the study by J. Wang & L. Zhang (2024) revealed a shared vision of the role of digital technologies in agricultural modernisation, while also highlighting different analytical perspectives. J. Wang & L. Zhang primarily considered digital transformation through the lens of the regulatory environment and environmental requirements, analysing the effect of combining digitalisation and environmental regulation on the quality of innovation development in the sector. In contrast, the present study shifted the focus from sectoral and regulatory effects to individual agricultural enterprises in Ukraine. Here, innovative entrepreneurship was interpreted as a practical instrument for renewing managerial

and production processes, as well as strengthening financial resilience amid wartime risks.

The transition from territorial to financial and institutional aspects of innovation was clearly evident when compared with A. Mavluda's work (2025). While both studies recognised the importance of investment and modernisation as prerequisites for improving enterprise performance, the logic of analysis differed substantially. A. Mavluda focused on the macro- and meso-economic mechanisms that support the real sector, particularly the role of financial markets, bank lending, and investment indicators. In the present study, however, financial resources were considered a consequence of entrepreneurial decisions, and digital technologies were viewed as a means of directly influencing the productivity and financial resilience of Ukrainian agricultural enterprises operating in wartime and under resource constraints. In comparison with the approach of N. Chaparro-Banegas *et al.* (2024), the environmental dimension of innovative transformation became central. While both studies recognised innovation as a key factor in strengthening the resilience of the agricultural sector, N. Chaparro-Banegas *et al.* focused on eco-innovation in the Spanish agri-food sector, emphasising environmental sustainability and compliance with EU policies. In contrast, the environmental component in the present study was not considered an independent objective, but was integrated into the broader logic of innovative entrepreneurship, which aimed to modernise production and management processes, and ensure financial resilience in the face of heightened risks.

Another dimension of innovative transformation emerged when the study by J.M. García-Gallego *et al.* (2025) was considered. Both approaches recognised the role of digital solutions and new business models in overcoming the structural limitations of agricultural development. However, J.M. García-Gallego *et al.* focused specifically on e-marketplace platforms as a means of integrating small-scale producers into value chains. They analysed the barriers to implementation and commercial acceptability of such models in Spain. By contrast, the present study considered innovative entrepreneurship much more broadly as a comprehensive strategy for the technological and managerial renewal of Ukrainian agricultural enterprises, extending beyond platform solutions to encompass the entire business management system. The final perspective in the comparative analysis was shaped by a comparison with the work of J.M. Ortiz-Villajos (2024), which differed fundamentally in terms of its time horizon and methodology. While both studies recognised innovation as a fundamental factor in economic development, J.M. Ortiz-Villajos analysed innovation activity within long-term historical dynamics, tracing the wave-like nature of innovation among Spain's business elites from 1870 to 1970. By contrast, the present study considered innovation in a contemporary crisis context, where digital and technological solutions served an applied function by ensuring the adaptation of Ukrainian agricultural enterprises to wartime risks and preserving their financial resilience.

The comparative analysis revealed variations in the interpretation of the mechanisms through which digitalisation and innovation influence the development of the agricultural sector, influenced by the selection of analytical level and research focus. In a number of studies, macro-, regional, financial or environmental approaches predominated, whereas internal entrepreneurial processes were considered only indirectly. This study emphasised the innovative entrepreneurship of agricultural enterprises as a mechanism for renewing production and management processes, and for adapting to wartime risks and resource constraints. This outlined the micro- and meso-level dimensions of innovative transformations.

CONCLUSIONS

The present study demonstrated that, between 2020 and 2025, innovative entrepreneurship became one of the key factors in the modernisation of Ukrainian agricultural enterprises amid wartime risks, macroeconomic instability, and restricted access to financial resources. During this period, the proportion of agricultural enterprises actively engaged in innovation increased from 6.2-6.5% in 2020 to 7-8% in 2024-2025. This reflects the gradual strengthening of the role of digital and technological solutions in agricultural

production, despite the general decline in investment activity in 2022. At the same time, innovations were predominantly adaptive in nature, aimed at reducing costs, compensating for labour shortages, and improving the controllability of production processes. The technological modernisation of Ukrainian agricultural enterprises was characterised by asymmetry in terms of the scale and depth of implementation. Around 70% of farms used fuel level trackers and machinery condition monitoring systems, around 60% used linear navigation systems and field dynamics analysis systems, and only around 12% used artificial intelligence algorithms. Capital-intensive precision agriculture tools remained concentrated among large agricultural companies; the proportion of enterprises that systematically used drones was estimated at 10-12%, while the proportion that used RTK navigation was around 52%. Between 2021 and 2023, approximately 3.1 million hectares were treated using drones, compared to up to 1 million hectares annually between 2024 and 2025, indicating the concentration of innovation among entities with greater investment capacity.

The economic results of implementing innovations confirmed their positive impact on productivity and financial performance. Using agrochemical soil analysis, field zoning and differentiated resource application ensured yield increases ranging from 4% to 22%, depending on the crop. The MHP case study showed that, after the operating margin fell to 2% and the EBITDA margin to 8% in 2022, the company had restored these figures to 11-12% and 16-17%, respectively, by 2023-2024, while maintaining a positive net financial result in 2025. This confirms the stabilising role of innovative entrepreneurship. A comparative analysis of countries bordering the European Union showed that innovative approaches to modernising agricultural enterprises are implemented under fundamentally different institutional conditions. In Poland, Hungary, Slovakia and Romania, the EU Common Agricultural Policy plays a key role, with around 30% of Pillar II funds directed towards innovation and environmentally oriented measures. In these countries, the share of innovation funding within Pillar II amounts to an average of 5-10% of national strategic plans, while the fund absorption rate reaches 70-85%. Consequently, farms that have adopted digital and precision technologies have achieved a 15-30% increase in productivity and a 20-40% rise in net profitability, which substantially surpasses the average performance of Ukrainian enterprises. One limitation of the study is its use of aggregated data and cases of large agricultural enterprises, which restricts the applicability of the results to small and medium-sized farms. Further research should focus on micro-level econometric analysis, taking into account institutional and regional constraints.

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Роль інноваційного підприємництва в модернізації аграрних підприємств України

Анотація. Метою даного дослідження було обґрунтування ролі інноваційного підприємництва у підвищенні результативності та фінансової стійкості аграрних підприємств України в умовах воєнних і макроекономічних викликів. Методологія дослідження ґрунтувалася на емпіричному підході із застосуванням структурно-логічного, порівняльно-динамічного, статистично-динамічного, інтервального, описового, трендового, технологічно-функціонального, та інституційно-порівняльного аналізу, узагальнюючого аналізу джерел та кейс-стаді діяльності аграрного підприємства. Результати дослідження показали зростання частки інноваційно активних аграрних підприємств з 6,2-6,5 % у 2020 році до 7-8 % у 2024-2025 роках, попри скорочення загальних капітальних інвестицій у 2022 році. Встановлено, що трекери рівня пального та системи моніторингу технічного стану машин застосовувалися приблизно у 70 % господарств, тоді як системи лінійної навігації та аналізу динаміки поля – у близько 60 %. У 2021-2023 роках із використанням дронів було оброблено близько 3,1 млн гектарів, а у 2024-2025 роках – до 1 млн гектарів щорічно. Диференційоване внесення ресурсів забезпечувало приріст урожайності на 4-22 %. Аналіз діяльності «Миронівського хлібопродукту» засвідчив відновлення операційної маржі до 11-12 % та зростання прибутку до сплати відсотків, податків, амортизації та зносу до 16-17 % у 2023-2024 роках. Порівняння з Польщею, Словаччиною, Угорщиною та Румунією показало, що у цих країнах на інноваційні напрями спрямовується 5-10 % коштів другого стовпа Спільної аграрної політики Європейського Союзу при рівні освоєння 70-85 %, що забезпечує приріст продуктивності на 15-30 % і рентабельності на 20-40 %. Практичне значення дослідження полягає у можливості використання його результатів аграрними підприємствами для обґрунтування рішень щодо впровадження інновацій

Ключові слова: технологічне оновлення; агробізнес; інноваційна активність; інвестиції; трансформації; стійкість

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