Economic aspects of Industry 4.0 marketing technologies implementation in the agricultural sector of Ukraine

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► **Abstract.** The study aimed to assess the impact of Industry 4.0 marketing technologies on the efficiency of business processes in the agro-industrial complex of Ukraine in the current market conditions. The study established that Industry 4.0, as a new stage of technological development, radically changes traditional methods of production, business and management by integrating digital technologies with physical processes. With the use of big data, artificial intelligence, and machine learning, agricultural businesses can create accurate customer profiles, develop personalised marketing campaigns, and automate routine tasks such as audience segmentation and forecasting market changes. The study also addressed the impact of the Internet of Things, social media and digital platforms on customer engagement and supply chain management. Innovations in e-commerce and the use of augmented and virtual reality also substantially improve the marketing efficiency of agricultural enterprises. The impact of the war in Ukraine on the introduction of digital technologies in the farming sector was emphasised. While investment in digitalisation declined during the conflict, the war also stimulated the search for innovative solutions, such as the use of drones to monitor fields and technology to improve cybersecurity. The impact of the war on consumer habits and priorities has also necessitated rapid adaptation of marketing strategies. Based on the study, which included a survey

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of 727 enterprises, the level of adoption of Industry 4.0 technologies among large, medium and small enterprises, as well as their plans for further implementation, was determined. The results showed that large enterprises are leading the way in adopting new technologies such as data analytics and artificial intelligence, while small and medium enterprises are just beginning to implement these solutions

▶ **Keywords:** digital transformation; business efficiency; process optimisation; customer interaction; competitive advantages

▶ **Introduction**

The Ukrainian modern agricultural sector is on the verge of significant transformations driven by global digitalisation trends and the transition to Industry 4.0. These trends reflect a new approach to agriculture, where the integration of marketing technologies is becoming a key factor in achieving competitive advantage and ensuring the sustainable development of enterprises. Faced with the challenges of global competition, and the need to improve production efficiency and adapt to climate change, Ukrainian agricultural companies are increasingly looking to the opportunities offered by the latest technologies. The research relevance is determined by the agricultural sector being one of the main sectors of the Ukrainian economy, which provides a significant share of the country's gross domestic product (GDP) and affects its economic stability. At the same time, the application of Industry 4.0 marketing technologies in the agricultural sector remains at an early stage, which requires in-depth analysis and development of practical recommendations for enterprises. The implementation of innovative solutions will not only optimise production and sales processes but also help develop new markets, improve product quality and increase consumer confidence.

The main problem is that most agricultural enterprises in Ukraine do not fully realise the potential of Industry 4.0 marketing technologies, which can lead to a loss of competitiveness in the global market (Davlikanova & Osadchuk, 2022). Challenges such as insufficient digital literacy, lack of financial resources to implement modern technologies, and a shortage of specialists capable of working with new tools are significant obstacles to digital transformation. In addition, there is a need to develop comprehensive strategies that would address the specifics of Ukraine's agricultural sector and promote the effective use of marketing technologies. Industry 4.0 involves the widespread adoption of digital technologies such as artificial intelligence, big data, the Internet of Things, blockchain and other innovations that can radically change approaches to business management (Bodi *et al.*, 2021). In the context of the agricultural sector, these technologies can be used to automate production processes, analyse market data, forecast demand, and develop personalised marketing strategies. The use of such tools increases the accuracy of forecasts, reduces costs and improves customer interaction, which contributes to the competitiveness of enterprises in the global market. The analysis of scientific papers by leading experts in the field of Industry 4.0 implementation in the agro-industrial complex demonstrates that marketing technologies play a critical role in improving the efficiency and sustainability of agricultural enterprises. M. Huang & R.T. Rust (2020) addressed the use of big data and artificial intelligence to personalise marketing strategies. He argued that the integration of

these technologies can improve the accuracy of market forecasts, which in turn helps to optimise production processes and reduce marketing costs. A. Duhinets (2018), in turn, studied the impact of the Internet of Things (IoT) on the automation of marketing campaigns in the agricultural sector. The author noted that IoT makes it possible to track consumer behaviour in real-time.

S. Menon & K. Jain (2024) addressed the role of blockchain technologies in ensuring transparency and trust in agricultural supply chains. Following their opinion, blockchain not only simplifies product tracking but also strengthens consumer confidence in the brand, which is a key factor in the current market environment. I. Ponomarenko *et al.* (2023) also analysed the use of artificial intelligence in marketing analytics, for market segmentation and demand forecasting. J.D. Borrero & J. Mariscal (2022) addressed the impact of digital platforms on the development of agricultural business. They noted that such platforms not only simplify the interaction between businesses and consumers but also provide new opportunities for promoting products on the global market. M.S. Azimi Mahmud *et al.* (2020) studied the impact of automation on the operational efficiency of agricultural enterprises. They noted that the introduction of robotic systems and automated analytical tools into marketing processes can significantly reduce costs and increase productivity. G. Dalmarco *et al.* (2019) emphasised that data security is a necessary element for the successful implementation of Industry 4.0 marketing technologies, as it directly affects customer trust. L. Klerkx *et al.* (2019) highlighted the social aspects of the digitalisation of the agricultural sector, in particular, the impact of new technologies on the level of employment and qualifications of workers. U.O. Nnaji *et al.* (2024) noted that companies that effectively use customer data can significantly increase their competitiveness in the market. E. Raji *et al.* (2024a) studied the impact of the integration of digital tools on management decisions in the agricultural sector.

The results of these studies emphasise the importance of implementing Industry 4.0 marketing technologies in the agro-industrial complex of Ukraine to increase its competitiveness and sustainability in the face of global challenges. Despite the significant contribution of previous studies to the development of Industry 4.0 marketing technologies in the agricultural sector, there are still areas that remain insufficiently studied. Little attention was devoted to the integration of marketing technologies with traditional business processes in Ukrainian agricultural enterprises, especially in the context of small and medium-sized companies that have limited resources for digitalisation. The impact of such technologies on socio-economic aspects, including employment and income levels, has also been insufficiently studied.

The study aimed to analyse the integration of Industry 4.0 marketing technologies into the business processes of Ukrainian agro-industrial enterprises, covering various aspects and challenges. The objectives of the study are to identify key barriers and opportunities for integrating Industry 4.0 marketing technologies into business processes; and to study the impact of marketing technologies on the socio-economic indicators of rural areas, on employment and income.

▶ Materials and methods

The study analysed the level of implementation and planning of the use of technologies such as Big Data, artificial intelligence (AI), machine learning, IoT, blockchain and cloud technologies in agribusinesses of various sizes. The research also included a qualitative study of practical cases of marketing technology implementation on the example of large agricultural companies such as Kernel (2019) and MHP (2021). For this purpose, the corporate reports of these companies, which contain detailed information on the implementation of innovative technologies in their business processes, were employed. These reports provided valuable data on the specific technologies that were integrated and the results of their use. This approach was used to capture not only theoretical aspects but also the practical experience of large agricultural enterprises. In addition, an important aspect of the study was the analysis of the impact of military operations in Ukraine on the digitalisation of the agricultural sector. During the war, many businesses were forced to adapt their business processes to ensure sustainability and efficiency.

In 2021, researchers from the Department of Marketing of Odesa Polytechnic National University, together with the analytical group of the National Qualifications Agency, State Employment Service and the Representation of the Friedrich-Ebert-Stiftung Fund, with the support of experts from the Odesa State Academy of Civil Engineering and Architecture, conducted research work. The results of this survey were used to assess the level of adoption of Industry 4.0 technologies, their impact on business processes, and to analyse changes in the marketing strategies of enterprises in the face of current challenges. The study included a quantitative survey of representatives of agricultural, forestry and fisheries enterprises, which included sending questionnaires to the heads of these enterprises. To create the sample, the number of large, medium and small enterprises in the specified industries was initially designated. Based on the similarity in the areas of application and implementation of Industry 4.0 technologies, the sub-sectors were grouped into 6 main categories for the study: crop production, livestock farming, mixed agriculture, forestry, hunting and fishing.

The sample size consisted of 727 enterprises, ensuring an error margin of no more than 3.7% with a 95% confidence level. Companies were selected based on specific criteria. Large enterprises, which have significantly greater financial resources and technological equipment enabling them to implement Industry 4.0 technologies earlier, were fully surveyed, amounting to 43 companies. Medium-sized enterprises were randomly selected, representing 10.5% of the total, as they are also actively implementing innovations. This group comprised 240 medium-sized enterprises. Small enterprises, selected at a rate of 0.93% due to their size and lower innovation activity, totaled 444 businesses.

The survey covered two key multiple-choice questions to assess the state of implementation of Industry 4.0 technologies at various enterprises and their plans, as well as the impact of these technologies on various aspects of their operations. The first question was about the technologies that have already been implemented since the company was founded and those that are planned to be implemented in the short and long term. The second question of the survey: "What transformations (personnel, economic, business processes) has the introduction of new technologies caused?" the questionnaire provided multiple choice answers. All survey participants were informed about how their anonymity is ensured, they know why the survey is being conducted, how the data they provide will be used, and the risks involved. The research was conducted following the rules of the The Declaration of Helsinki (1975).

▶ Results

Industry 4.0, also known as the Fourth Industrial Revolution, represents a new era in technology development that is transforming traditional methods of production, business and management. Unlike previous phases of industrial revolutions that focused on mechanisation, electrification and automation, Industry 4.0 integrates digital technologies with physical processes, creating smart systems that can autonomously respond to changes and optimise operations in real-time. Industry 4.0, as the latest stage of technology development, is fundamentally changing not only production processes but also the marketing strategies of enterprises. In this context, marketing is becoming more integrated, personalised and data-driven, allowing businesses to better understand consumer needs and quickly adapt to market changes. One of the key characteristics of marketing technologies in Industry 4.0 is their ability to collect and analyse large amounts of data. Thanks to modern analytical tools, companies can obtain detailed information about consumer behaviour, preferences, demographics, and even emotional reactions to certain products (Lin *et al.*, 2020). This data can be used to create highly accurate customer profiles and develop personalised marketing campaigns, which significantly increases their effectiveness. AI and machine learning allow automating routine tasks such as audience segmentation, creating personalised offers, and optimising marketing campaigns. Thanks to AI, companies can predict changes in the market and adapt their strategies to new conditions, which gives them a significant advantage over competitors.

In the context of Industry 4.0, marketing technologies also have a significant impact on customer interaction. Modern digital marketing platforms allow for a dialogue with customers through various channels, such as social media, messengers, email. This creates a new level of interaction, where the client becomes an active participant in the process, not just a consumer of a product or service. Feedback from customers is used to improve the quality of goods and services, as well as to create new products that best meet their expectations. The use of cloud technologies is also becoming an important aspect of marketing

in Industry 4.0. They allow storing and processing large amounts of data, providing quick access to information from anywhere and at any time (Misra *et al.*, 2022). This allows companies to be more flexible and adaptive, as well as to respond quickly to changes in the market situation. In the context of agribusinesses, digital innovations play a crucial role in transforming marketing activities, increasing their efficiency and contributing to the development of sustainable business models. The use of modern technologies allows agribusinesses not only to improve customer interaction but also to optimise all stages of the marketing process – from market research to product promotion and sales management (Ievoli *et al.*, 2019). One of the most significant areas is the use of big data for market analytics. In the agriculture sector, data can be collected from numerous sources, such as climatic conditions, yields, changes in raw material prices, consumer behaviour, and even social media (Lioutas *et al.*, 2019). Using this data, businesses can more accurately forecast demand, adjust their products to meet market needs and increase profitability by optimising costs.

Artificial intelligence is also having a significant impact on the marketing of agricultural companies. Thanks to machine learning algorithms, companies can automate processes such as market segmentation, targeted campaign development, and sales forecasting. This allows them to respond quickly to changes in consumer preferences and market conditions, which is especially important in times of instability caused by, for example, climate change or global crises. The IoT opens new opportunities for precise supply chain management and transparency at all stages of production. This is especially true for agribusinesses, where product quality often depends on factors such as weather conditions, storage and logistics. Thanks to IoT, companies can monitor all these aspects in real-time, which not only improves product quality but also better informs consumers about the conditions of its production, thereby increasing brand trust (Yue *et al.*, 2021). Social media and digital platforms are becoming an important communication channel for agribusinesses, especially in a globally competitive environment. Using these platforms, companies can interact directly with their customers, gather feedback and respond quickly to market demands. Digital platforms also allow companies to expand their markets by entering new geographical regions and attracting new consumers. Innovations in e-commerce are also playing a significant role, as it is becoming an important part of the marketing activities of agribusinesses. Online sales allow agribusinesses to expand their customer base by offering products directly to consumers (Dash *et al.*, 2021). This not only increases sales but also contributes to the loyalty of customers who value convenience and accessibility.

Augmented reality (AR) and virtual reality (VR) are finding their way into the marketing of agricultural enterprises, allowing for interactive product presentations and virtual tours of farms. This is particularly relevant for premium products, where demonstrating the production process and quality assurance plays an important role. With AR and VR, consumers can "visit" the farm where their products are grown, which creates a deeper emotional connection with the brand (Bowen & Morris, 2019).

Blockchain technologies are also becoming an important element of digital innovation in the marketing of agricultural enterprises. They ensure transparency and security of transactions, which is important for maintaining trust between all market participants – from producers to end consumers. In addition, blockchain allows tracking the entire supply chain of products, which is especially important for organic and environmentally friendly products, where proof of compliance with quality standards plays an important role (Lin *et al.*, 2020). The digitalisation of the Ukrainian agricultural sector is an important process aimed at increasing the productivity, efficiency and competitiveness of agricultural enterprises. However, despite certain achievements, the level of digitalisation in the Ukrainian agricultural sector remains uneven and requires significant improvement. This process has faced new challenges since the beginning of the Russian invasion of Ukraine, which has added even more difficulties in achieving sustainable development in the sector. One of the key indicators that characterise the level of digitalisation is the use of modern technologies to manage production processes and analyse data.

Ukrainian agribusiness companies such as Kernel (2019) and MHP (2021) demonstrate impressive examples of how they have implemented marketing technologies to improve the efficiency of their business processes and strengthen their market positions. Kernel, one of the largest agro-industrial holdings in Ukraine, is implementing various marketing technologies to improve its management and communication processes. One of the main drivers is digital marketing, including the use of analytical platforms to collect and process data. The company uses business intelligence systems to study market trends, the competitive environment and consumer preferences. This supports informed decision-making, the development of targeted advertising campaigns and the optimisation of marketing strategies. For example, Kernel implements loyalty programmes and personalised advertising campaigns, focusing on the individual needs of customers. The company actively uses social media to promote its brand and interact with the audience. This includes publishing information about company news, environmental initiatives and product innovations. The use of marketing process automation platforms, such as customer relationship management (CRM) systems, helps to effectively manage customer and partner relations.

MHP (former Myronivsky bread product), one of the leaders in the Ukrainian poultry and feed market, is also actively implementing marketing technologies to improve its competitiveness. One of its key practices is the use of digital platforms to expand market opportunities. The company uses online marketing to promote its products both domestically and internationally. This includes search engine optimisation (SEO), content marketing, brand reputation management and online advertising. MHP implements integrated marketing campaigns that combine online and offline channels. For example, the company uses social media management tools to keep in touch with end users and inform them about new products, promotions and special offers. This helps to create a positive brand image and increase brand awareness. In addition, MHP invests in technology to analyse data

and market trends, which allows the company to adapt its strategies to changing market conditions. The use of analytical tools determines the effectiveness of advertising campaigns, identifies new business opportunities and optimises marketing costs. At the same time, small and medium-sized farms face financial constraints, a lack of skilled labour and insufficient access to modern technology. As a result, they may be at the stage of implementing basic digital solutions, such as electronic resource records or simple financial management software. These farms are not yet ready to implement complex analytical systems or automation. State support for the digitalisation of the agricultural sector remains fragmented. Despite government initiatives to provide subsidies and grants, their scope and accessibility to small and medium-sized farmers are limited. The low level of digital literacy among farmers also hampers the widespread adoption of new technologies. In addition, poor infrastructure, especially in rural areas, including poor access to the internet and modern communications, hinders digitalisation.

The war in Ukraine has significantly worsened the situation. It destroyed infrastructure, especially in the areas of active hostilities, making it difficult for many farmers to operate. The loss of internet access in some regions has made it impossible to use digital technologies to manage fields, supply chains or exchange data with partners. The war has also reduced investment in the agricultural sector, including investment in digitalisation. In the face of high uncertainty, businesses are allocating resources to ensure safety and survival, leading to the postponement of modernisation plans. However, the war has also stimulated the search for innovative solutions. Agribusinesses that continue to operate are making greater use of drones to monitor fields and collect information, as well as remote technologies to reduce their physical presence in the field. The rise in cyber threats during the war has pushed businesses to pay more attention to cybersecurity. The war has also changed consumer behaviour and priorities, requiring agribusinesses to quickly adapt marketing strategies and make greater use of digital platforms to stay connected with customers, especially in international markets. In 2021, a study was conducted on the implementation of Industry 4.0 technologies and their impact on the transformation of enterprises in the agriculture, forestry and fisheries sectors of Ukraine (Fig. 1).
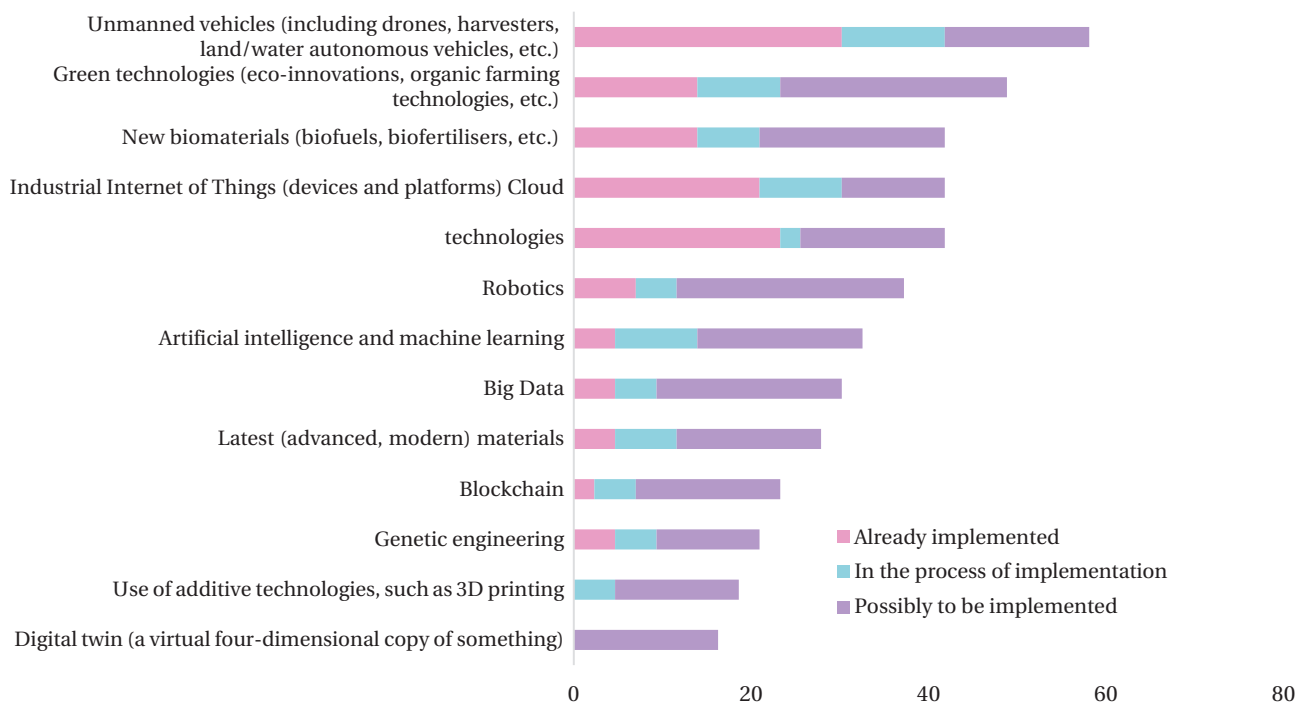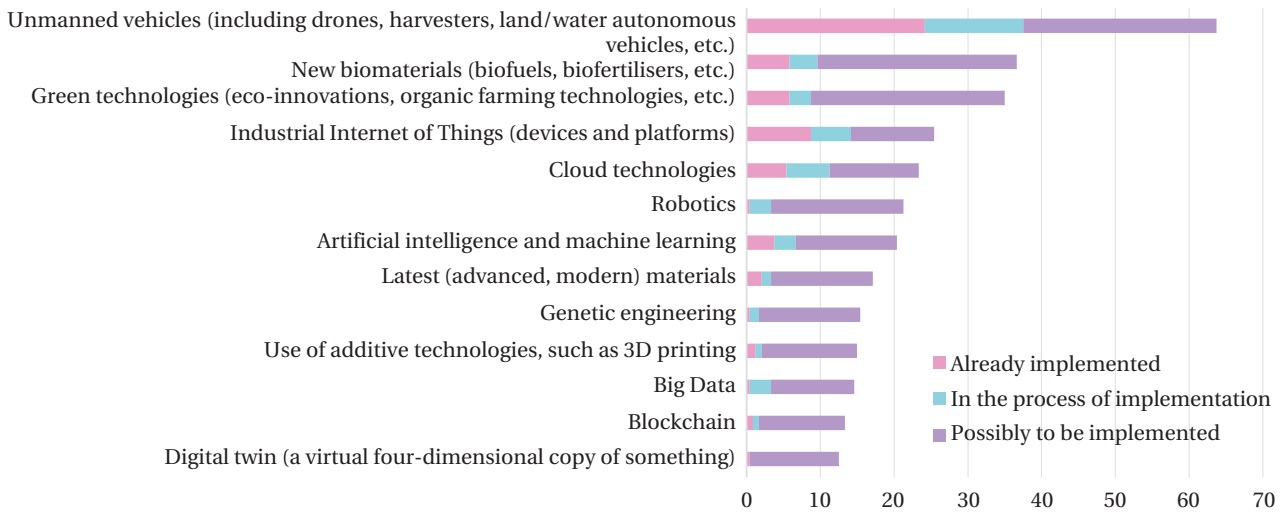

Figure 1. Implemented technologies and technologies that may be implemented at large enterprises, %
Source: compiled by the authors based on Kernel (2019)

Figure 1 illustrates the level of adoption and the potential for further use of Industry 4.0 technologies in large enterprises. Large enterprises are leading the way in technology adoption: about 50% of them have already integrated or plan to integrate green technologies; about 40% are actively working on the introduction of new biomaterials, the industrial Internet of Things, cloud technologies and robotics. In terms of marketing technologies, innovations such as Big Data, artificial intelligence machine learning, and blockchain are key to improving the effectiveness of marketing strategies. They allow for more accurate market analysis, forecasting consumer behaviour and optimising marketing campaigns in real-time. Most of the technologies are in the process of active implementation, which indicates their prospects for further development. Cloud technologies also play an important role in creating flexible marketing tools, allowing for faster adaptation to changes in market conditions. Although some of these

technologies have already been implemented, a significant number are in the process of being implemented or have the potential for future use, indicating that this area is actively developing at large enterprises (Fig. 2).

Figure 2. Implemented technologies and technologies that may be implemented at medium enterprises, %
Source: compiled by the authors based on Kernel (2019)

Figure 2 shows the level of adoption and prospects for the development of Industry 4.0 technologies in medium-sized enterprises. About 35% of medium-sized enterprises have already implemented or are planning to implement new biomaterials and green technologies; about 25% are working on the implementation of the industrial Internet of Things and cloud technologies. In terms of marketing technologies, it is important to pay attention to Big Data, Blockchain, artificial intelligence and machine learning, as well as cloud technologies, where they have already been partially implemented or are in the process of being implemented, which indicates that medium-sized enterprises are beginning to realise their importance for increasing competitiveness. The use of these technologies allows for more effective market analysis, personalised marketing campaigns, optimised advertising costs, and improved customer experience. However, adoption remains at an early stage, indicating significant potential for further development in this area (Fig. 3).
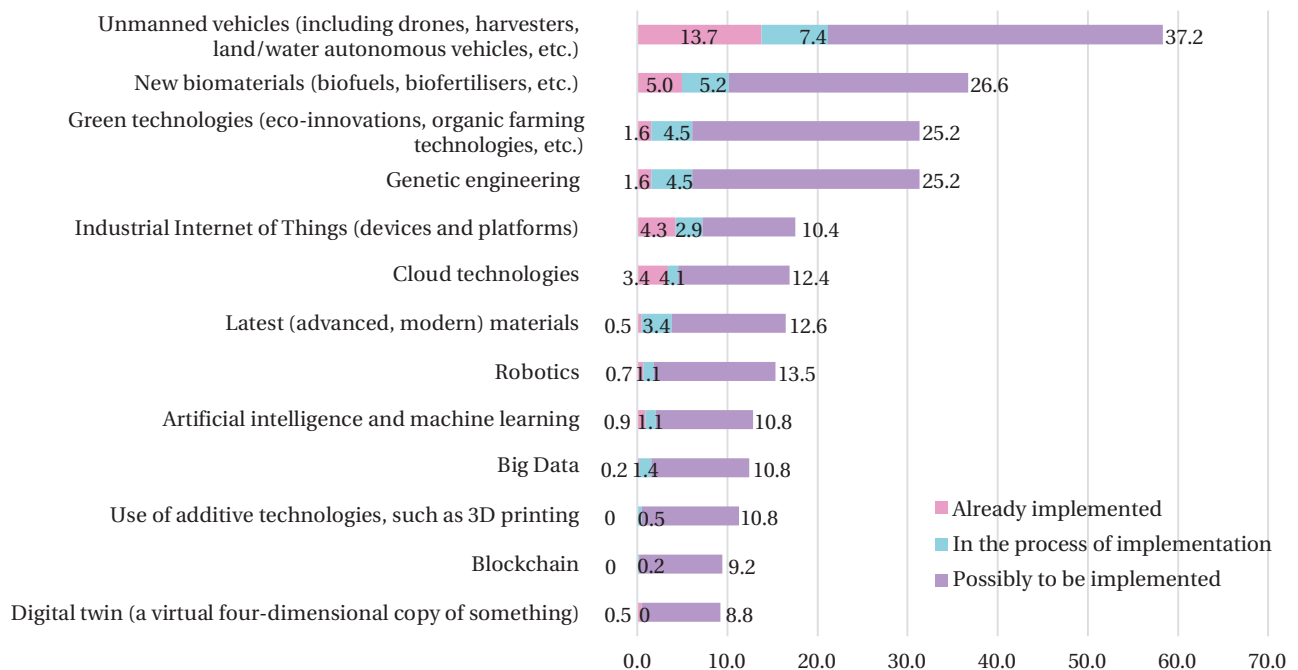
Figure 3. Implemented technologies and technologies that may be implemented at small enterprises, %
Source: compiled by the authors based on Kernel (2019)

Figure 3 shows the adoption and possible development of Industry 4.0 technologies in small enterprises. About 35% of small businesses have already integrated or are planning to introduce new biomaterials and green technologies; about 17% are working on the introduction of the industrial Internet of Things, cloud technologies, new materials and robotics. In terms of marketing technology, these technologies have not yet been implemented in small businesses, but their potential remains significant. Big Data and artificial intelligence can significantly improve the accuracy of marketing decisions, allowing small businesses to better understand the market and customers, while cloud technologies provide access to analytical tools and marketing platforms without significant investment.

At the same time, the low level of adoption indicates certain barriers, such as limited resources or lack of relevant skills, which require further attention to realise the marketing potential of Industry 4.0 in small businesses. The next aspect of the Industry 4.0 survey concerned the transformations that their introduction causes. 74% of respondents believe that new technologies will improve the efficiency of their company; 27% expect an increase in sales; 18% of respondents predict a reduction in the number of employees and an increase in the need for investment. There are significant differences in expectations of efficiency gains by business size, indicating that larger businesses are adopting more technology and experiencing more transformation as a result of its implementation (Fig. 4).

Transformations from the introduction of technology	Size of enterprises		
	Large	**Medium**	**Small**
Increase in sales volumes	38	23	28
Improving the efficiency of the enterprise	85	79	70
Reducing the number of employees	29	16	19
Increase the existing number of employees	0	4	2
Maintaining the existing number of employees, subject to replacement with employees in demand	21	15	14
Increase in the number of employees	9	5	2
Increased need for investment to acquire expensive	21	15	19
Increased spending on cyber security	6	4	4
Increased maintenance costs for complex systems	9	11	12
Changes in the form of employment of employees	21	12	10
Changes in the structure of the company, the number of divisions, and the direction of their activities	32	13	8

Figure 4. Transformations expected by enterprises
from the introduction of Industry 4.0 technologies by enterprise size, %
Source: compiled by the authors based on Kernel (2019)

Large enterprises expect significant improvements in operational efficiency (85%) and sales (38%), indicating their desire to make the most of new technologies to optimise marketing processes and expand their markets. This reflects their ability to integrate advanced marketing tools, such as Big Data analytics and the use of artificial intelligence, to improve targeting and personalisation. Small and medium enterprises (SMEs) also expect to increase efficiency (79% and 70% respectively) but with lower expectations of increased sales (23% and 28%). This indicates that they are just beginning to use Industry 4.0 marketing technologies, focusing on internal processes and cost optimisation. However, these businesses recognise the need for investment (19% of small businesses), indicating that they are ready to further develop and implement new marketing technologies to achieve competitive advantage.

The war in Ukraine has a potentially significant impact on the adoption and use of digital technologies in agricultural enterprises, which will certainly affect the data presented in the previous tables. The priorities of agricultural enterprises have changed significantly during the war. While they used to focus on implementing innovative technologies to increase efficiency and expand markets, they may now be forced to postpone or reconsider their investments in digital solutions. The main goal may be to ensure the safety of production, preserve existing facilities and recover from destruction. War causes economic difficulties, including reduced financial resources and limited investment. Agribusinesses may have to redirect their budgets to reconstruction and urgent needs, which will affect their ability to introduce new technologies. In an environment of volatility and risk, there may be a growing need for solutions to manage risks, better monitor resources and ensure the sustainability of production processes. This may lead to an increase in demand for safety and sustainability technologies, which may shift the focus from marketing innovations to technical and operational solutions. The introduction of marketing technologies in the agricultural sector has significant potential to change the structure of employment and social services in rural

areas. On the one hand, the automation of marketing processes and the use of digital platforms may lead to a reduction in the need for some traditional roles, such as sales agents or distributors. However, on the other hand, the emergence of new technologies is creating new jobs that require specific knowledge and skills in digital marketing, data analytics, online platform management, and customer support (Peter & Dalla Vecchia, 2021). This opens up opportunities for young professionals in rural areas who can gain new skills and knowledge while staying in their communities. Instead of migrating to cities to find work, they can work locally, contributing to the preservation and development of rural communities. In addition, increasing digital literacy in rural areas can promote social inclusion and engage local people in global economic processes.

By using digital tools for market analysis and product promotion, small farmers and craft producers can access wider markets, including international markets. This contributes to the development of small and medium-sized enterprises, the creation of new jobs, and increased incomes for the local population. However, this process requires government support and investment in education and infrastructure. Marketing technologies also contribute to the development of regional branding. Regions with unique natural conditions or traditional production practices can use these advantages to create brands that are recognisable at the national and international levels (Egieya *et al.*, 2023). This increases the added value of products and helps to attract investment in the development of the regional economy. In the context of global climate change, marketing technologies play an important role in ensuring the sustainable development of agricultural enterprises. One of the key areas is the use of technology to promote environmentally friendly and organic products. Modern consumers are increasingly paying attention to the environmental friendliness of products, so agricultural companies that implement sustainable practices can gain competitive advantages in the market. Thanks to marketing technologies, agrarians can communicate more effectively with consumers, informing them about the environmental benefits of their products, sustainable use of resources, and responsible business practices (Matzembacher & Meira, 2019). This not only increases demand for such products but also encourages other businesses to adopt sustainable practices that reduce their environmental impact.

Overall, modern technology opens up new opportunities to optimise business processes, improve product quality and expand markets. However, to realise these benefits, agricultural businesses need to carefully consider several key aspects and strategies. One of the key elements of Industry 4.0 is big data and analytics. Agribusinesses need to integrate data management systems that allow them to collect, store and analyse information about production, product quality, market conditions and consumer preferences (Rivera *et al.*, 2020). This can be achieved through the implementation of enterprise resource planning (ERP) and CRM systems, which help automate business processes and improve customer interaction. The use of analytical platforms allows agricultural enterprises to make more informed decisions, forecast demand and adapt their strategies to changing market conditions.

Digital marketing is an effective instrument for promoting the products of agricultural enterprises. It is recommended to implement comprehensive marketing campaigns that include SEO, content marketing, social media and email marketing. Businesses should actively use social media to communicate with end users, promote products and increase brand awareness. Content marketing, in particular, can include blogging, posting on news platforms and creating video content to help raise awareness of products and branding.

Automating marketing processes reduces the time and resources spent on routine tasks for agricultural businesses. Marketing automation platforms can be used to manage advertising campaigns, segment audiences, manage email campaigns and conduct campaign analytics. This ensures more efficient use of marketing budgets and improves campaign results through accurate targeting and personalisation. For the successful implementation of marketing technologies, it is important to invest not only in the technology itself but also in staff training. Businesses need to provide their employees with the necessary knowledge and skills for new systems and technologies. This can include regular training sessions, seminars and educational programmes. In addition, it is important to have digital marketing and analytics specialists who can help develop and implement strategies. Continuous evaluation of the effectiveness of implemented technologies is critical. Agribusinesses should regularly analyse the results of their marketing campaigns, use the data to adjust strategies and implement new solutions depending on changes in market conditions and consumer needs. The use of key performance indicators (KPIs) helps to identify weaknesses and improve results. Thus, the implementation of Industry 4.0 marketing technologies in agricultural enterprises is a complex but important process. The use of data analytics, digital marketing, process automation, investment in training, performance measurement and support for sustainable development help agricultural enterprises adapt to modern market requirements, improve their competitiveness and ensure sustainable development in the face of global change.

► **Discussion**

The results of the study of the implementation of Industry 4.0 technologies in the Ukrainian agricultural sector have shown that these innovations can significantly transform the agricultural business while posing new challenges to enterprises. Industry 4.0 envisages the integration of modern digital technologies into all aspects of production and management, which has the potential to increase the efficiency, transparency and sustainability of the agricultural sector. E.D. Lioutas *et al.* (2019) investigated the impact of big data on the marketing strategies of agricultural enterprises. Their findings support the conclusion that big data contributes to more accurate market segmentation and personalisation of marketing campaigns. E. Raji *et al.* (2024b) emphasise that enterprises that actively use big data analytics demonstrate better financial performance and increased competitiveness. The current results in this regard coincide with the findings, confirming the effectiveness of big data in modern marketing strategies of agricultural enterprises.

Industry 4.0 technologies have significant potential to transform marketing approaches in the agricultural sector. Big data, artificial intelligence and blockchain can radically change the approach to market segmentation, targeted marketing and supply chain management (Lipych *et al.*, 2023). The use of big data allows agricultural businesses to analyse consumer behaviour and predict market trends with greater accuracy, which in turn allows them to develop more personalised and effective marketing campaigns. Artificial intelligence can automate complex processes such as audience segmentation and optimisation of advertising campaigns (Shtovba, 2023). Blockchain, for its part, can provide greater transparency in supply chains, which is critical for marketing strategies focused on environmental and social responsibility. A. Subeesh & C. Mehta (2021) investigated the impact of artificial intelligence on the automation of production processes in large agricultural holdings. Their findings highlight that AI technologies can reduce operating costs and increase the efficiency of enterprise management. However, in contrast to the current study, the authors note that AI has not yet been widely implemented in small and medium-sized enterprises due to high costs and a lack of knowledge among managers. This underscores the existence of a gap between large and small enterprises, which was also found in the current study, but less emphasised.

G. Mirabelli & V. Solina (2020) analysed the impact of blockchain technologies on supply chain transparency in the agricultural sector. Their findings show that blockchain adoption is effective in ensuring transparency and increasing consumer confidence, especially in the context of exports. They highlight the importance of blockchain technologies for the marketing of environmentally friendly products. The current study confirms these findings, especially concerning the potential of blockchain to increase transparency and sustainability of marketing strategies. However, the introduction of such technologies in the agricultural sector faces several serious challenges. One of the key constraints is the lack of digital literacy among agricultural workers, especially in small and medium-sized enterprises. While large agricultural holdings, such as Kernel and MHP, are actively implementing the latest technologies, small and medium-sized enterprises often lack the resources to do so. This leads to a significant part of the agricultural sector being left out of the digital transformation. A. Rejeb *et al.* (2022) investigated the impact of the IoT on the efficiency of agricultural enterprise management. In their work, they emphasise that the introduction of IoT allows farmers to significantly optimise production processes, through automated monitoring of soil conditions, weather conditions, and plant health. A. Rehman *et al.* (2022) note that the use of IoT helps to increase yields and reduce the cost of agricultural work, especially in large agricultural holdings. Compared to the current results, the findings confirm the significant role of IoT in improving the efficiency of agricultural enterprises. However, the current findings also show that SMEs face challenges in implementing IoT due to high initial investments and a lack of necessary infrastructure.

The war in Ukraine has created additional barriers to the adoption of Industry 4.0 technologies in the agricultural sector (Semenenko *et al.*, 2023). The destruction of infrastructure, interruptions in internet access and general economic instability have forced many agricultural businesses to rethink their priorities and postpone investments in digital technologies (Stender *et al.*, 2024). At the same time, changing market conditions and the need to ensure business security and sustainability have created a demand for new technological solutions that can help businesses adapt to new realities. M. Gupta *et al.* (2020) investigated the impact of various factors on the digital transformation of the agricultural sector, including cybersecurity. Their study showed that external risks have pushed businesses to actively implement cybersecurity measures to protect critical data. A. Sridhar *et al.* (2022), in turn, noted the growing demand for remote management and monitoring. They emphasised that remote solutions have become key tools for agricultural enterprises during crises, ensuring the continuity of operations even in unforeseen situations. The results of these authors confirm the importance of data security and integration of remote technologies, which coincides with the findings of the current study. On the other hand, their research is more focused on specific aspects of digital transformation, such as cybersecurity and remote management, while the current study covers these issues more broadly.

The introduction of Industry 4.0 technologies not only affects the economic efficiency of agricultural enterprises but also has significant social implications. Automation and digitalisation may lead to job losses in traditional roles, especially in rural areas where the agricultural sector is the main source of employment. However, at the same time, there is a demand for new skills, which creates employment opportunities for young IT and digital professionals. S. Rolandi *et al.* (2021) examined the impact of digital transformation on the social sphere, on employment in rural areas. They conclude that automation and digitalisation can lead to significant job losses, especially among unskilled workers. This result is fully consistent with the current study, which also highlights the risks associated with the loss of traditional jobs in the agricultural sector. From an economic development perspective, the introduction of digital marketing technologies can open up new markets for small and medium-sized enterprises (Shahini *et al.*, 2023). This, in turn, contributes to revenue growth and can support the development of local economies. Digital platforms provide small businesses with access to global markets, enabling them to compete with larger players. N.T. Loan *et al.* (2023) focused on the impact of digital platforms on export opportunities for small and medium-sized agricultural enterprises. They note that digital platforms provide small enterprises with access to international markets, which contributes to revenue growth and business expansion. These findings are in line with current findings on the role of digital technologies in expanding market opportunities for small enterprises, confirming the importance of digital innovation for their development.

Industry 4.0 has significant potential to transform the Ukrainian agricultural sector. However, several issues need to be overcome to realise this potential. These include insufficient investment in digital infrastructure, a

lack of digital skills among employees, and the absence of a comprehensive digital transformation strategy at the state level. To successfully implement marketing strategies based on Industry 4.0 technologies, agricultural enterprises need to more actively implement digital solutions, invest in staff training, and use government support. It is also important to develop infrastructure that will provide reliable access to the Internet even in remote regions.

▶ **Conclusions**

The study analysed the adoption of Industry 4.0 technologies and their impact on the transformation of marketing strategies of Ukrainian agribusinesses. The study showed that Industry 4.0 is a crucial factor in improving marketing strategies through the introduction of analytical platforms, AI, Big Data and other advanced technologies. These technologies allow agribusinesses not only to optimise decision-making processes but also to better understand consumer needs and quickly adapt to changes in the market.

Agricultural enterprises such as Kernel and MHP demonstrate positive examples of implementing marketing technologies to improve the efficiency of business processes and strengthen their market position. However, small and medium-sized farms face financial constraints and insufficient access to modern technologies. Further government support and investment in education and infrastructure development are needed to ensure the sustainable development of the agricultural sector. The study also examines the impact of the war in Ukraine on the processes of digital transformation of the agricultural sector. It is noted that the war has created new challenges, such as the destruction of infrastructure and reduced investment in digitalisation, which complicates the process of introducing modern technologies. However, these same conditions have also encouraged businesses to look for innovative solutions, such as the use of drones to monitor fields and remote technologies to reduce physical presence in the fields.

The study findings highlight the need for government support and investment in the development of digital infrastructure, especially for small and medium-sized enterprises, to ensure a more even adoption of Industry 4.0 technologies. In addition, the importance of staff training for the effective use of new systems and technologies was highlighted as a critical factor for the successful digital transformation of Ukrainian agricultural sector. A limitation of this study is the focus on large and medium-sized enterprises, which may not fully reflect the situation in small agricultural enterprises. Further research should include an analysis of the adoption of marketing technologies in small agricultural enterprises and their impact on economic sustainability in the context of post-war reconstruction.

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▶ **Conflict of interest**

None.

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Економічні аспекти впровадження маркетингових технологій Індустрії 4.0 в агропромисловому комплексі України

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► **Анотація.** Дане дослідження було направлене на аналіз впливу маркетингових технологій Індустрії 4.0 на ефективність бізнес-процесів в агропромисловому комплексі України в умовах сучасного ринку. Встановлено, що Індустрія 4.0, як новий етап технологічного розвитку, радикально змінює традиційні методи виробництва, бізнесу та управління, інтегруючи цифрові технології з фізичними процесами. Завдяки використанню великих даних, штучного інтелекту та машинного навчання, аграрні підприємства отримують можливість створювати точні профілі клієнтів, розробляти персоналізовані маркетингові кампанії та автоматизувати рутинні завдання, такі як сегментація аудиторії і прогнозування змін на ринку. Дослідження також розглядало вплив Інтернету речей, соціальних медіа та цифрових платформ на взаємодію з клієнтами і управління ланцюгами постачання. Інновації в електронній комерції та використання розширеної і віртуальної реальності також відіграють важливу роль у підвищенні ефективності маркетингу агропідприємств. Особливу увагу приділено впливу війни в Україні на впровадження цифрових технологій у аграрному секторі. В умовах конфлікту інвестиції в цифровізацію зменшилися, проте війна також стимулювала пошук інноваційних рішень, таких як використання дронів для моніторингу полів і технологій для підвищення кібербезпеки. Вплив війни на споживацькі звички та пріоритети також зумовив необхідність швидкої адаптації маркетингових стратегій. На основі проведеного дослідження, яке включало опитування 727 підприємств, визначено рівень впровадження технологій Індустрії 4.0 серед великих, середніх та малих підприємств, а також їхні плани щодо подальшого впровадження. Результати показали, що великі підприємства є лідерами у впровадженні нових технологій, таких як аналітика даних та штучний інтелект, тоді як середні та малі підприємства лише починають реалізовувати ці рішення

► **Ключові слова:** цифрова трансформація; ефективність бізнесу; оптимізація процесів; взаємодія з клієнтами; конкурентні переваги