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The Impact of Digitalization and Investment on Agricultural Development in Kazakhstan

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ABSTRACT

Today, digitalization and investment are becoming key drivers of agricultural transformation, but their impact on the agro-industrial sector remains controversial. The study aims to determine how investments in fixed assets, digital literacy, and Internet penetration affect the volume of gross agricultural output in Kazakhstan. The initial data includes panel data from the Bureau of National Statistics of the Republic of Kazakhstan for 2010-2023. The study uses multidimensional linear regression to assess the contribution of each factor (investments in fixed assets, the level of digital literacy, Internet penetration, and the use of mobile phones and computers) to the formation of gross agricultural output. The findings indicate that investments in fixed agricultural assets exhibit a positive but statistically insignificant relationship with agrarian production ($\beta = 4.4474$, $p = 0.2221$). Similarly, mobile phone use and Internet penetration in rural areas do not show a significant correlation with the growth of the agricultural sector. In addition, negative coefficients for digital literacy and Internet activity in rural areas have been identified, which may indicate barriers to introducing digital technologies into the agro-industrial complex. The novelty of this research lies in its empirical evaluation of digitalization's role in agricultural development within a transitional economy, emphasizing the need for targeted policy interventions. The results suggest that investment efficiency, digital skills training, and improved technological adoption should be prioritized to maximize agricultural productivity. Further research is needed to explore long-term investment effects and sector-specific impacts to refine policy recommendations.

KEYWORDS: Agricultural Investment, Agricultural Development, Agribusiness, Digital Economy, Internet Penetration, Digital Literacy

SCSTI: 06.77.35

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1. INTRODUCTION

The modern agro-industrial complex is one of the main sectors of the economy that ensures food security and sustainable development in rural areas. In 2022, agriculture contributed 4.5% of Kazakhstan's GDP, and the number of people employed in the industry amounted to more than 1.2 million (World Bank, 2023). However, traditional agricultural practices face some challenges, including climate change, lack of skilled labor, declining soil fertility, and increasing demands for product quality and safety. For example, according to the World Bank, global food demand will increase by 60% by 2050, requiring new approaches to agricultural management (FAO, 2021). Under these conditions, digitalization becomes a strategic tool to improve agribusiness efficiency, sustainability, and competitiveness. According to the Ministry of Agriculture of Kazakhstan, the industry's digitalization level in 2023 was 30%, with a target of at least 50% by 2025.

Digitalization of agribusiness involves introducing innovative technologies such as artificial intelligence, big data, the Internet of Things (IoT), blockchain, and drone technologies. Such tools enable optimizing processes at all stages of agricultural production - from soil preparation and sowing to harvesting, logistics, and product sales. With their help, it becomes possible to predict yields more accurately, reduce resource costs, improve product quality control, and minimize negative environmental impact (Klerkx & Rose, 2020).

One of the main aspects of digitalization in agribusiness is the application of precision farming technologies. According to FAO (2022), precision farming can increase crop yields by 10-15% and reduce fertilizer and water costs by 20-30%. Through drones, satellite monitoring, and sensor systems, farmers can get up-to-date information on field conditions, soil moisture levels, and fertilizer needs, increasing yields and reducing losses due to adverse weather conditions or misallocating resources.

In addition, digitalization contributes to the transformation of business models in agriculture. Kazakhstan has already launched over 20 digital platforms, such as AgroHub, Smartek, Qoldau, which bring together farmers, suppliers, processors and consumers (Tsoy & Nurbatsin, 2024). The development of agricultural platforms and marketplaces facilitates interaction between producers, suppliers, distributors, and end consumers. Blockchain enables supply chain transparency, while smart contracts automate transaction and settlement processes, reducing transaction costs, increasing trust between market participants, and improving access to international markets (Treiblmaier, 2018).

Another important direction is the development of agricultural robotic systems and automated production, which will increase the efficiency of agricultural processes, reduce labor costs, and minimize the human factor in the management of agro-industrial complexes. McKinsey (2021) predicts that using robots in agriculture could reduce labor costs by 30-50%. Unmanned tractors, harvesters, and drones for applying fertilizers or pesticides can reduce labor costs, improve the accuracy of operations, and reduce environmental impact. Kazakhstan has already introduced more than 50 unmanned tractors and about 200 drones for fertilizer and pesticide application, reducing chemical consumption by 20-25% and improving operational accuracy (Gabdualiyeva et al., 2024). Artificial intelligence and machine learning help analyze large amounts of data and make optimal decisions, which is especially important in climate variability and population growth (Wolfert et al., 2017).

However, successful implementation of these technologies is impossible without industry professionals' appropriate skills and knowledge. Digital literacy is becoming a significant factor in effectively using robotic systems and automated processes. According to OECD research (OECD, 2022), only 40% of farmers in developing countries have a

sufficient level of digital literacy to work with new technologies. In Kazakhstan, about 65% of the rural population has access to the Internet, but the level of digital literacy in agribusiness remains insufficient (Dauliyeva et al., 2022). Lack of knowledge in working with digital tools can be a serious barrier for farmers and agricultural enterprises. In this context, an important aspect is not only the mastery of digital technologies but also the general level of literacy of the rural population, which determines the ability to adapt to new technological realities, perceive innovations, and increase productivity. Lack of knowledge of digital tools can be a serious barrier for farmers and agricultural enterprises. In this context, an important aspect is not only digital skills but also the general literacy level of the rural population. It determines the ability to adapt to new technological realities, perceive innovations, and increase labor productivity.

Additional indicators of agro-industrial complex digitalization are the level of automation of processes, the degree of integration of digital platforms in agriculture, and the availability of digital infrastructure in rural areas. High levels of automation minimize human error and increase productivity, while digital platforms provide access to analytical tools, trading platforms and logistics services. The availability of digital infrastructure, including broadband internet and mobile technology, is fundamental to successfully implementing digital solutions in agriculture.

However, despite the apparent advantages, agribusiness's digitalization presents several challenges. These include the high cost of technology adoption, the need for staff training, the risks of cyber threats, and the lack of infrastructure in rural areas. It is also important to consider the possible social consequences, such as reducing traditional jobs and the need for farmers to adapt to new farming conditions. Government support, investment in research and development of innovations, and the development of educational programs are becoming critical factors in the successful digital transformation of the agribusiness sector.

Thus, the digitalization of the agro-industrial complex is a powerful driver of its development, ensuring increased production efficiency, cost reduction, and improved environmental sustainability. However, the successful implementation of digital technologies requires a comprehensive approach, including infrastructure modernization, government and business support, and the active development of educational and research initiatives. The following sections of this study will discuss key areas of digital transformation of the agro-industrial complex, examples of successful implementation of technologies in different countries, and possible strategies for adapting to the conditions of national agriculture.

The study aims to investigate the impact of economic (investment) and digital (internet, digital literacy, use of technology) factors on agricultural development. Hypotheses were formulated:

H0: The listed factors have no statistically significant effect on the gross output of agriculture.

H1: Rural internet penetration and digital literacy have a meaningful impact on the growth of agricultural production.

H2: Fixed capital investment in agriculture is the primary driver of the increase in gross output.

H3: Use of cell phones and computers in rural areas contributes to the development of the agricultural sector.

2. LITERATURE REVIEW

The introduction of digital technologies and investment in fixed capital is an important direction of agricultural development. However, their impact on the growth of agricultural production remains a subject of academic debate. This review explores the relationship between investment, digital literacy, internet penetration, and agricultural sector development.

Investment in fixed capital is one of the factors that increase agricultural productivity. Studies by Gollin et al. (2002) and Mogues et

al. (2012) show that increased investment in the agricultural sector contributes to infrastructure modernization, adoption of innovative technologies, and yield growth. However, the impact of investment depends on its focus: funds invested in technology and equipment have a more significant impact on productivity than investments in traditional farming practices. Ali et al. (2022) found that digitalization and automation of the agricultural sector contribute to reducing CO_2 emissions through resource efficiency, confirming the need to modernize agriculture through investment.

Digital literacy is becoming one of the main drivers of economic and social development today. The agro-industrial complex s crucial in increasing productivity, optimizing resource management, and enhancing market access for farmers and agrarian enterprises (Kosasih & Sulaiman, 2024). This review explores the significance of digital literacy in agriculture, analyzing its impact on precision farming, access to financial services, knowledge dissemination, and sustainable development. Empirical studies and theoretical approaches are reviewed, illustrating both the benefits and challenges of digital transformation in agribusiness.

One of the main factors influencing the successful implementation of digital technologies in the agricultural sector is farmers' level of digital literacy. Studies by Gong et al. (2024) examine the impact of digital literacy on the efficiency of green production in agriculture. Their study found that farmers with high digital skills are likelier to use digital tools to monitor soil health, manage water resources, and optimize fertilizer application. As a result, their farming operations are more sustainable, reducing the burden on the environment. In addition, the successful implementation of digital solutions requires their availability and the active participation of farmers in the digitalization process. In particular, research shows that those with access to educational resources and government support adapt to new technologies much faster and use them more effectively in their work (Engås et al., 2023).

Precision farming is based on the use of digital tools such as geographic information systems (GIS), remote sensing, and the Internet of Things (IoT) sensors to help optimize agricultural processes (Klerkx & Rose, 2020). In addition, Chang et al. (2023) examined the impact of social media on fertilizer management among farmers in Shaanxi Province of China. They found that digital platforms such as WeChat and Douyin (the Chinese equivalent of TikTok) allow farmers to access up-to-date information on best farming practices, which helps to reduce excessive use of chemical fertilizers and improve soil fertility. The study found that farmers who actively use digital platforms exhibit more environmentally conscious behavior and are willing to adopt innovative agricultural resource management practices.

Also, farmers with high levels of digital literacy are more willing to adopt innovative technologies, which leads to higher yields and reduced negative environmental impact (Wolfert et al., 2017). In Kazakhstan, the issues of digitalization of agriculture are also the focus of scientists' attention. According to a study by Abdullaev et al. (2020), the level of adoption of precision agriculture in Kazakhstan remains insufficient, mainly due to the lack of qualified personnel and limited availability of technology in remote regions. However, government initiatives such as the Digital Kazakhstan program have gradually increased the adoption of innovative agro-technologies.

In addition to adopting precision farming, digital literacy is important in making financial services accessible to agriculture. Mobile banking, digital credit platforms, and blockchain technology make it easier for farmers to obtain finance, facilitating the modernization of production and adopting sustainable practices (Ye et al., 2022). Studies in Kazakhstan show that farmers with basic skills in digital financial instruments are less likely to face credit problems (Dauletkhanova et al., 2023). However, insufficient financial literacy and poor development of digital

infrastructure in rural areas hinder the full utilization of digital payment systems and online lending.

Another important aspect of digitalization is disseminating knowledge and innovation in agriculture. The Internet and mobile applications have radically changed the process of information transfer, providing farmers with up-to-date data on weather conditions, pest control, and best farming practices (Abiri et al., 2023). Kazakhstan is actively developing educational programs to improve the digital literacy of agrarians. According to a study by Myrzakhmetova et al. (2021), the introduction of online courses and webinars has significantly increased the level of digital knowledge of farmers. However, there is an urgent need to localize content into Kazakh and adapt educational programs to the specific conditions of agriculture in the country.

Despite the apparent benefits of digital technologies, their diffusion in the agricultural sector faces many challenges. Key barriers include lack of internet accessibility, lack of educational programs on digital literacy, and farmers' wariness of new technologies (Eastwood et al., 2019). Together, these factors inhibit the digital transformation of agribusiness, reducing the effectiveness of agribusiness modernization. Overcoming these barriers requires a comprehensive approach that includes infrastructure development, educational initiatives, and support for digital solutions at the state level.

In Kazakhstan, a study by Dauliyeva et al. (2022) found that the main barriers to the digitalization of agriculture are the high equipment cost, low training level, and lack of specialized digital solutions for local agrarian conditions. Researchers emphasize that state subsidies and tax incentives are needed to support the digitalization of farms.

Analysis of scientific research shows that digital literacy, internet penetration, and investment in agriculture are key factors in the modernization of the agro-industrial complex. However, their impact depends on the quality of infrastructure, the level of training of farmers, and the availability of financial resources. In Kazakhstan, despite increased investment and internet penetration, the effect of digitalization remains limited due to low levels of digital literacy and poorly developed digital infrastructure. Future research should consider the impact of long-term investments and the need to develop educational programs focused on farmers and the rural population.

3. RESEARCH METHODS

The study uses a quantitative approach to analyze the impact of investment, internet penetration, digital literacy, and digital technologies in rural areas on the volume of gross agricultural output in Kazakhstan. Using a quantitative method allows for an objective assessment of the existing relationships between variables and the identification of significant factors influencing the development of the agricultural sector. The study is based on secondary data collected from official statistical sources, including the Bureau of National Statistics of the Republic of Kazakhstan. The analysis covers the period from 2013 to 2023, which allows for assessing long-term trends, identifying stable relationships, and identifying possible structural changes in the industry.

Python, which provides powerful statistical and visualization tools, was used to analyze the data and build regression models. In particular, the following libraries were used.

The research methodology includes several stages, shown in Figure 1.

Description of the research stages:

Stage 1. Descriptive analysis of macro-economic indicators The first stage of the study includes an analysis of the main macroeconomic indicators of the agro-industrial complex of Kazakhstan. During this stage, the share of agriculture in the gross domestic product and gross value added is considered, which makes it possible to determine the importance of the industry in the country's economy. The gross agricultural output is also analyzed, covering both crop production and animal husbandry.

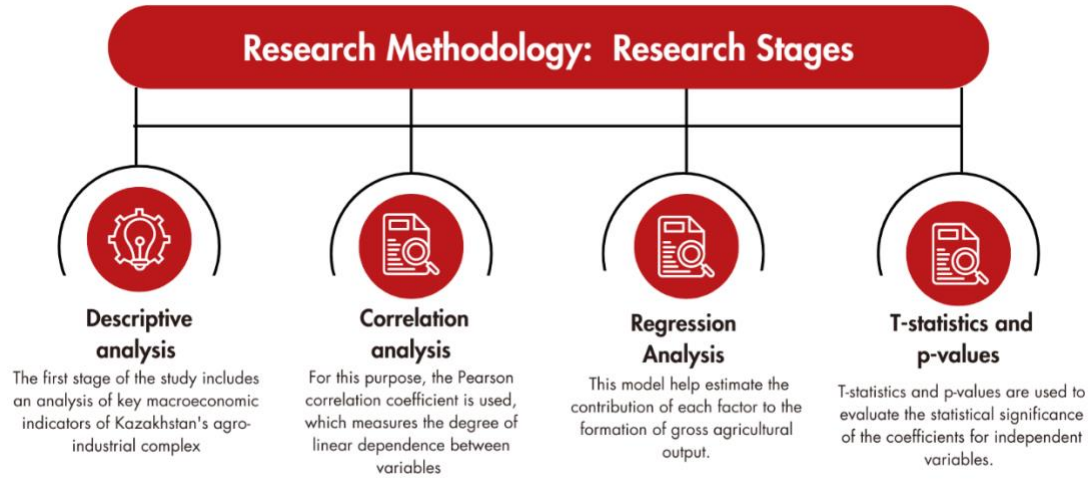

FIGURE 1. The steps of analysis

Note: compiled by authors

Another important aspect is the level of investment in fixed assets of agriculture, which reflects the scale of financing of the industry and the potential for its further development. This analysis helps identify the main trends related to agricultural production and determine the sector's structure.

Stage 2. Correlation analysis determines the strength and direction of the relationship between the dependent and independent variables at this stage. For this purpose, the Pearson correlation coefficient is used, which measures the degree of linear dependence between variables (see Table 1).

TABLE 1. Indicators for analysis

Code	Indicator	Category
Dependent variable		
GO_AP	Gross output of agricultural products (services), mln KZT	The economic factor
Independent variables		
Inv_AP	Investments in fixed assets, mln KZT	The economic factor
Mob_us_r	Percentage of mobile phone users in rural areas, %	The digitalization factor
%_Com	Percentage of computer users aged 6-74 years, %	The digitalization factor
Hh_Int	Share of rural households with Internet access from home, %	The digitalization factor
Dig_lit	The level of digital literacy of the population, %	The digitalization factor
Int_us_r	Percentage of Internet users aged 6-74 in rural areas, %	The digitalization factor

Note: compiled by authors

Correlation analysis reveals the degree of relationship between gross agricultural output and key economic and digital factors, which contributes to a deeper understanding of the impact of digitalization and investment on the development of Kazakhstan's agro-industrial complex.

Stage 3. Multiple regression model, to analyze the relationship between variables. This model help estimate the contribution of

each factor to the formation of gross agricultural output.

The regression model is specified as follows formula (1):

$$GO\_AP = \beta 0 + \sum_{i-1}^{6} \beta_i X_i + \epsilon \qquad (1)$$

where:

β0 – the free term of the equation;

βi – regression coefficients for each independent variable;

Xi – vector of independent variable;

ϵ – accidental model error.

This regression model captures the linear relationship between agricultural output and key economic and digitalization-related factors. The main purpose of the model is to determine which of these factors have a statistically significant impact on agricultural production and to what extent. Stage 4. T-statistics and p-values are used to evaluate the statistical significance of the coefficients for independent variables. F-statistics help to determine whether the model explains a significant part of the variation in the dependent variable. Confidence intervals (95%) are used to assess the reliability of regression coefficients.

The proposed methodology provides a comprehensive analysis of the factors influencing the development of agriculture in Kazakhstan. The applied research approach allows us to obtain objective and reliable results that can serve as a basis for developing recommendations on the digitalization and modernization of the country's agro-industrial complex.

4. FINDINGS AND DISCUSSIONS

Kazakhstan has significant agricultural potential, contributing to developing a more diversified and inclusive economy. The key advantage of the country's agricultural sector is its vast territory with low population density and a large amount of agricultural land. The total area of agricultural land reaches about 217 million hectares, of which about 35 million hectares is arable land, and fallow land is about 13 million hectares. Due to geographical peculiarities and uneven distribution of land resources, the agrarian specialization of the regions varies significantly. Thus, crop production is predominantly developed in the north of the country, as well as in the east and south. The central regions are oriented towards extensive livestock farming, while in the south-eastern part of the country, a mixed type of agriculture prevails.

Figure 2 shows that the share of agriculture in the GDP structure varies between 4.3 and 5.4%, demonstrating relative stability with small fluctuations.

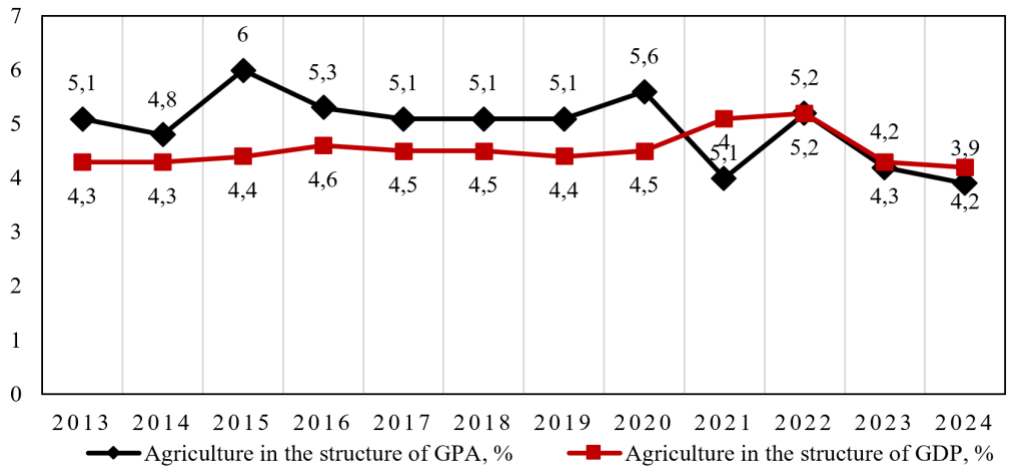

FIGURE 2. Agriculture in the structure of GDP and GVA, %

Note: compiled by authors

The highest value was noted in 2020, and amounted to 5.4%, and in 2024 there was a decrease to 4.2%. And the share of agriculture in the structure of gross value added (GVA, %), in contrast to GDP, had more pronounced fluctuations. In 2015, it reached 6%, then there was a decrease to 5.1% in 2019, but in 2020 there was an increase to 5.6%. However, after 2022, the value dropped to 3.9% in 2024, indicating a drop in agriculture's contribution to total value added. The general trend shows a decrease in the importance of agriculture in the economy in recent years, especially after 2020. The reason may be related to labor productivity in agriculture, as outdated machinery is used in Kazakhstan, and there is a shortage of qualified personnel.

Figure 3 reflects the dynamics of Kazakhstan's agricultural sector over the period 2013-2023, demonstrating changes in gross output, as well as in the structure of the industry, where crop production and animal husbandry occupy different shares.

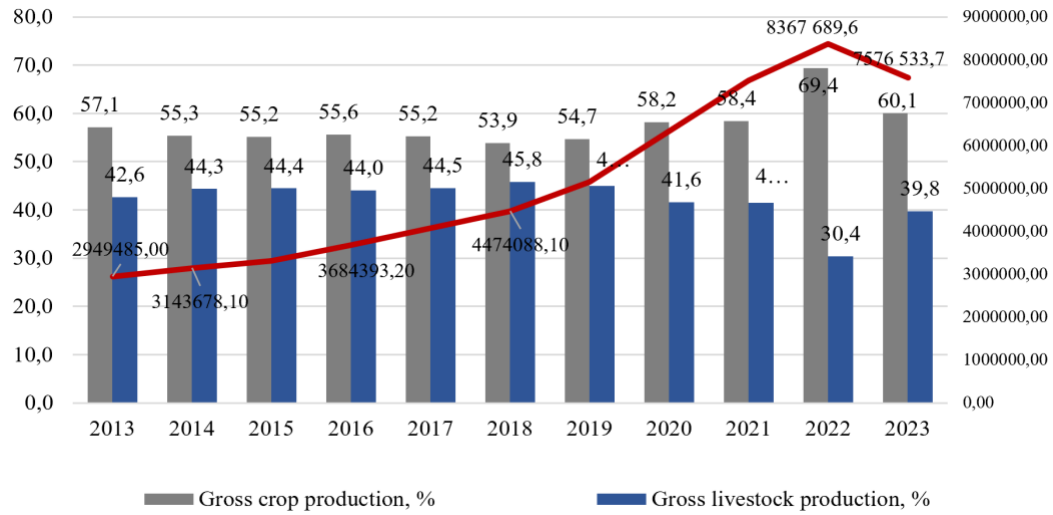

FIGURE 3. Gross agricultural product in the context of animal husbandry and crop production

Note: compiled by authors

In general, there is a steady increase in gross agricultural production: if in 2013 the volume amounted to 2.94 trillion tenge, then by 2022 it reached 8.37 trillion tenge, which indicates a more than twofold increase. However, in 2023, there was a decrease to 7.58 trillion tenge, which may be due to a number of factors, such as worsening weather conditions, price fluctuations on world markets or changes in the agricultural policy of the state. In addition to the general growth of agricultural production, there is a significant change in its structure. The share of crop production, which was 57.1% in 2013, has shown a downward trend over the following years, reaching 39.8% in 2023. This reduction is especially noticeable after 2022, when the share of crop production fell sharply from 69.4% to 39.8%, due to changes in acreage, dry periods, falling yields or rising production costs. At the same time, animal husbandry shows relative stability, maintaining a share of 41-45% until 2021, but in 2022 it decreased to 30.4%, and in 2023 it increased sharply to 60.1%, indicating possible crisis phenomena such as feed shortages, epidemiological threats, rising prices for livestock products, this could lead to temporary difficulties in the sector, and then to its recovery.

Thus, the agricultural sector continues to show growth in value terms, but its structure is significantly transformed. The decline in the

share of crop production combined with the instability of the livestock sector may indicate structural problems requiring intervention.

Figure 4 shows the dynamics of investments in fixed assets of agriculture for the period 2013-2023.

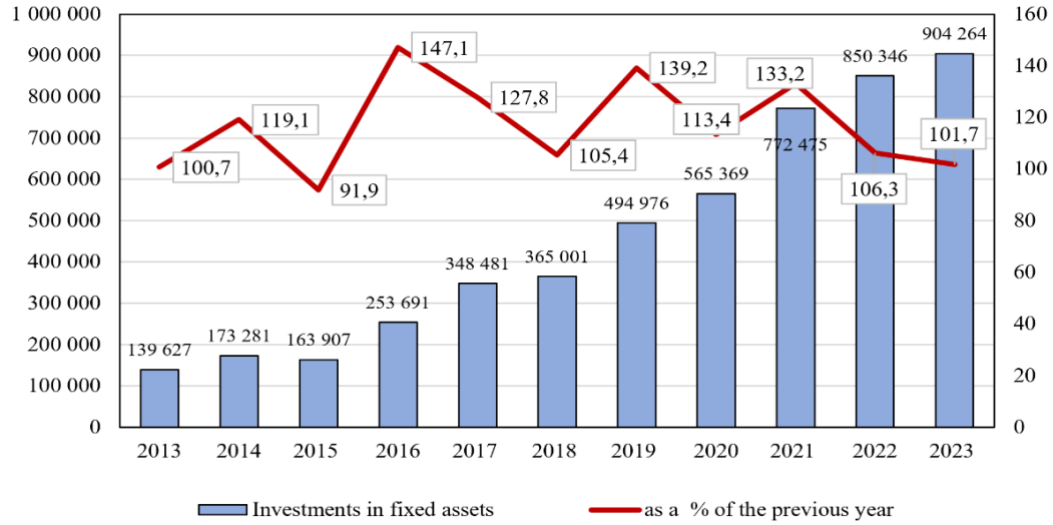

FIGURE 4. Investments in fixed capital of agriculture, mln. KZT

Note: compiled by authors

In general, there is a tendency towards an increase in investment volumes, which indicates a gradual increase in investments in the agricultural sector. If in 2013 the volume of investments amounted to 139.6 billion tenge, by 2023 this figure has increased more than sixfold, reaching 904.2 billion tenge, which indicates the increasing role of investments in the development of agriculture. However, the dynamics of investment growth is uneven, which is reflected in the percentage change compared to the previous year. In 2014, there was a significant increase in investments (119.1% compared to 2013), but in 2015 the growth rate decreased to 91.9%, indicating possible financial or institutional constraints. In 2017, there was a sharp jump in investment, amounting to 147.1% compared to the previous year, which may be due to government support programs, the introduction of new technologies and increased investor interest. However, the following years were characterized by volatility, where, despite the growth in absolute investment values, the growth rate showed fluctuations.

In 2019, investment growth was 139.2%, but then decreased to 113.4% in 2020, which could be due to the impact of the COVID-19 pandemic, disruption of supply chains and a decrease in business activity. In 2021, a significant increase in investments was recorded, reaching 772.4 billion tenge, but in 2022 the rate of increase slowed to 106.3%, which may indicate that the existing mechanisms for supporting the sector are approaching the limit of effectiveness. Despite a slight decrease in growth rates in 2022-2023, the total volume of investments continues to grow, which indicates continued interest in agricultural development and strengthening of its investment base.

The agricultural sector demonstrates a steady increase in investments in fixed assets, but their growth is cyclical, due to changes in macroeconomic conditions, the availability of credit resources, government support programs and the level of technological modernization. Fluctuations in investment growth reflect changes in the sector's financing strategy, including the impact of external factors such as

climate conditions, global economic crises, and changes in agricultural policy. In the long term, maintaining positive investment dynamics will be crucial for increasing agricultural productivity, introducing innovative technologies, and increasing the competitiveness of the agricultural sector.

Summing up the analysis, Kazakhstan's agro-industrial complex is showing growth, but is facing a number of structural challenges. The share of agriculture in GDP is declining, reaching 4.2% in 2024, reflecting its slowdown. Although the gross output of agricultural products more than doubled from 2013 to 2022, in 2023 it decreased to 7.58 trillion tenge due to unfavorable conditions and price instability. Structural changes are manifested in a decrease in the share of crop production to 39.8% in 2023, while livestock production, after a recession in 2022, increased to 60.1%. Investments in fixed assets have increased more than sixfold in a decade, but their pace remains unstable. Technological modernization, qualified personnel and effective government support are needed to ensure the sustainable development of the sector.

Next, a correlation analysis was performed, presented in the form of a heat map, which demonstrates the degree of relationship between the various indicators.

Figure 5 describes the indicators which have strong positive relationships, which is confirmed by high correlation values, 0.91 and higher, respectively.

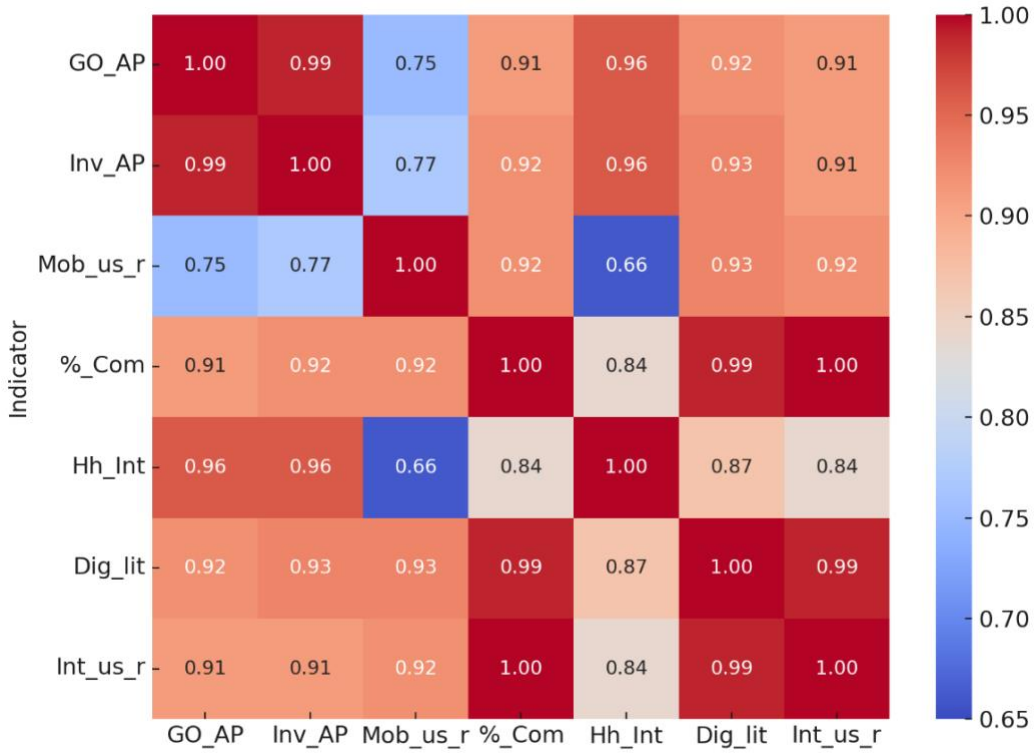

FIGURE 5. Correlation matrix

Note: compiled by authors

Thus, GO_AP and Inv_AP show an almost complete correlation (0.99), which may indicate a close relationship between the level of investment in agriculture and its gross output. Indicators such as the proportion of mobile phone users in rural areas (Mob_us_r) and the proportion of rural households with Internet access from home (Hh_Int) have less

pronounced connectivity (0.66), which may indicate the presence of additional factors affecting their relationship. It can also be noted that digital literacy (Dig_lit) and the level of Internet access (Int_us_r) are almost identical in terms of the degree of connection with other variables, reflecting the high level of digital integration and dependence on infrastructure. In addition, %_Com (the proportion of computer users) shows a significant correlation (over 0.99) with digital literacy and Internet users, which underscores the importance of digital technologies in economic activity. In general, the presented analysis indicates a high degree of interconnectedness between investments, digital skills and infrastructure development, which confirms the need for an integrated approach to their development.

Table 2 shows the results of regression analysis, which demonstrate the absence of a statistically significant influence of the studied factors on the dependent variable, which is confirmed by the high P-values of all independent variables (above 0.05) .

TABLE 2. Regression analysis result

Variable	Coefficient	Standard Error	t-Statistic	P-Value	95% CI (Lower)	95% CI (Upper)
Intercept	-12,371,360	23,395,370	-0.5288	0.6249	-77,327,310	52,584,590
Inv_AP	4.4474	3.0785	1.4446	0.2221	-4.10	12.99
Mob_us_r	18,417.85	40,214.20	0.4580	0.6707	-93,234.66	130,070.4
%_Com	371,529.4	563,178.5	0.6597	0.5455	-1,192,105	1,935,164
Hh_Int	122,363.2	80,007.7	1.5294	0.2009	-99,773.8	344,500.2
Dig_lit	-217,847.4	248,059.2	-0.8782	0.4294	-906,570.2	470,875.5
Int_us_r	-122,229.5	417,590.0	-0.2927	0.7843	-1,281,645	1,037,186

Note: compiled by authors

Although investments in agriculture (Inv_AP), rural mobile users (Mob_us_r), and household Internet access (Hh_Int) have positive coefficients, their impact remains statistically insignificant. The highest coefficient (371.529.4) is observed for a variable reflecting the proportion of computer users (%_Com), but its P-value (0.5455) indicates a weak relationship. At the same time, digital literacy (Dig_lit) and the share of rural Internet users (Int_us_r) show negative coefficients, but their high P-values (0.4294) and (0.7843). The high uncertainty of the estimates and wide confidence intervals, for example, for %_Com from -1,192,105 to 1,935,164, indicate possible model problems such as multicollinearity or insufficient number of observations.

Table 3 shows the results of hypothesis testing.

TABLE 3. Hypothesis testing results

Hypothesis	Expected Effect	Coefficient	t-Statistic	P-Value	Result
H1	Positive	-217,847.4 (Digital Literacy) -122,229.5 (Internet Usage in Rural Areas)	-0.8782 -0.2927	0.4294 0.7843	Rejected (P > 0.05)
H2	Positive	4.4474	1.4446	0.2221	Rejected (P > 0.05)
H3	Positive	18,417.85 (Mobile Usage in Rural Areas) 371,529.4 (Computer Usage)	0.4580 0.6597	0.6707 0.5455	Rejected (P > 0.05)
H0	No effect	-			Not Rejected (All P-values > 0.05)

Note: compiled by authors

Based on the regression results, none of the independent variables showed a statistically significant effect on agricultural output (all p-values > 0.05). This suggests that internet penetration, digital literacy, mobile and computer usage, and investment in fixed assets do not strongly influence agricultural production growth in the analyzed data. The null hypothesis (H0) is not rejected, meaning no statistical evidence supports the alternative hypotheses (H1, H2, and H3).

4. DISCUSSION

The regression analysis results indicate that investments in fixed agricultural assets, internet penetration, digital literacy, and the use of digital technologies in rural areas do not have a statistically significant impact on agricultural output in Kazakhstan. This finding contrasts with numerous studies that emphasize the transformative role of digitalization and capital investment in agriculture. However, it aligns with research suggesting that the effectiveness of these factors is contingent on additional conditions, such as the level of infrastructure development, the efficiency of policy implementation, and the capacity of farmers to adopt and utilize new technologies effectively.

Empirical studies by Gollin et al. (2002) and Mogues et al. (2012) underscore the crucial role of capital investment in enhancing agricultural productivity, particularly in developing economies. Contrary to these findings, the present study reveals no significant relationship between investment in fixed agricultural assets and agricultural output, which may suggest that either the level of investment remains insufficient to drive substantial productivity gains or that financial resources are not being effectively allocated to key productivity-enhancing assets such as modern machinery, irrigation systems, and precision farming technologies. Moreover, in Kazakhstan, where large-scale agribusiness enterprises coexist with smallholder farms, it is plausible that investments are disproportionately concentrated in specific subsectors, thereby limiting their overall contribution to the agricultural sector's growth.

Similarly, despite the theoretical advantages of digitalization, the study does not confirm a statistically significant impact of internet penetration and digital literacy on agricultural output. While research by Engås et al. (2023) suggested that access to digital technologies in rural areas can improve market access, reduce transaction costs, and enhance productivity, these benefits may not yet be fully realized in Kazakhstan's agricultural sector. One possible explanation is that, although internet penetration is increasing, its application for agricultural purposes remains limited. Many farmers may not actively utilize digital tools for market monitoring, financial management, or precision farming, constraining the anticipated productivity gains. Furthermore, Kosasih and Sulaiman (2024) highlighted the persistence of the digital divide in rural regions, where older farmers demonstrate lower levels of technology adoption, which may further explain the insignificant impact observed in this study.

Additionally, the findings do not support the hypothesis that the use of mobile phones and computers in rural areas significantly contributes to agricultural development. While previous highlights the role of mobile technologies in facilitating access to market information and financial services, thereby increasing efficiency, the results of this study suggest that, in Kazakhstan, mobile phone usage in rural areas may still be predominantly limited to communication purposes rather than business-oriented applications. Furthermore, low digital literacy levels, particularly among older generations, maybe a barrier to effectively utilizing digital tools in agricultural operations, further limiting their potential impact.

Several factors may explain the lack of statistically significant results. First, investments in agriculture typically exhibit a time lag before yielding measurable

productivity gains. The observed period of analysis may not fully capture the long-term effects of capital investments, and future studies could benefit from applying lagged models to address this limitation. Second, while internet penetration continues to expand, insufficient training, inadequate digital infrastructure, and resistance to technology adoption may hinder its effective integration into agricultural processes. Policymakers should, therefore, not only focus on increasing internet accessibility but also prioritize initiatives to enhance digital skills and provide targeted incentives for farmers to integrate technological innovations into their production activities.

Furthermore, the structural characteristics of Kazakhstan's agricultural sector may also influence the effectiveness of investments and digitalization. The sector is characterized by a dual structure comprising large agro-industrial enterprises alongside smallholder farms. The impact of technological advancements and capital investment may vary significantly between these groups, with larger enterprises having greater capacity to adopt and implement modern agricultural technologies. At the same time, small-scale farmers may face barriers related to financial constraints and limited access to resources. Future research should, therefore, consider heterogeneous effects, particularly by analyzing whether digitalization and investment policies disproportionately benefit large-scale farms over smallholders.

In light of these findings, policymakers should focus on improving the efficiency of investment allocation in agriculture, ensuring that resources are directed toward productivity-enhancing assets and technological advancements. Moreover, digitalization efforts must extend beyond increasing internet access to fostering a comprehensive digital transformation strategy that includes training programs, targeted incentives, and infrastructural development. While previous studies emphasize the potential of digitalization and investment in driving agricultural growth, the results of this study indicate that, in the case of Kazakhstan, these factors have not yet yielded statistically significant effects, highlighting the need for complementary measures to unlock their potential fully.

5. CONCLUSION

This study was aimed at analyzing the impact of economic and digital factors on the development of agriculture in Kazakhstan, where the main focus was on investments in fixed assets, digitalization and their potential contribution to the formation of gross agricultural product. The literature review revealed that investments in agriculture are traditionally considered as a key factor in increasing productivity, but their effectiveness depends on the direction of investments. Research shows that the most significant effect is achieved by financing technological innovations, upgrading infrastructure, and training personnel, whereas a simple increase in capital investment does not always lead to an increase in agricultural production.

The empirical results of the study, based on data from 2013-2023, revealed that investments in fixed assets did not have a statistically significant impact on agricultural production, which may be explained by the long-term nature of their impact, uneven resource allocation and possible inefficiency of their use. The penetration of the Internet and the level of digital literacy also did not demonstrate a significant relationship with the growth of agricultural production, which indicates that access to digital technologies alone does not guarantee their effective use in the agricultural sector. In addition, the use of mobile phones and computers in rural areas did not turn out to be a significant growth factor, which is probably due to insufficient digital involvement of farmers and the underdeveloped ecosystem of digital services in agriculture.

The results obtained allow us to conclude that a simple increase in investments and the spread of digital technologies without parallel development of infrastructure and educational initiatives does not lead to the expected effect.

In this regard, it is necessary to reconsider approaches to the development of agriculture and the digitalization of the agricultural sector, ensuring a more targeted use of resources. Main recommendations include improving investment efficiency through priority financing of technological modernization and productivity improvement, developing digital literacy of farmers through the introduction of educational programs, improving the digital infrastructure of rural areas with an emphasis on providing broadband Internet and affordable digital services, creating financial incentives for the introduction of digital technologies in the agricultural sector, including subsidies, tax incentives and grants, as well as monitoring and evaluating the effectiveness of government initiatives in this area.

Given these findings, policymakers should adopt a more comprehensive approach to agricultural development by ensuring that investments are effectively allocated to productivity-enhancing assets such as modern machinery, irrigation, and precision farming technologies. Additionally, digitalization efforts should focus on expanding internet access, improving digital literacy, and promoting the practical application of technology in agricultural production. Future research should explore the long-term effects of investment, sector-specific impacts, and the interaction between digitalization, investment, and government policies. By addressing these challenges, Kazakhstan can better leverage its agricultural potential to enhance economic diversification and sustainable rural development.

Limitations

The study's limitations stem from data constraints. The short observation period may not fully reflect the effects of long-term investment and digitalization. Structural differences within the agricultural sector were not considered, potentially masking varying impacts. Additionally, unobserved factors like regional policies and financial access could influence results. Future research should address these gaps for a more comprehensive analysis.

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REFERENCES

Abdullaev, K., Irmulatov, B., Komarov, A., & Nugis, E. (2020). Precision agriculture in the north of Kazakhstan. *Journal of Agricultural Science, 2*(31), 115–121. https://doi.org/10.15159/jas.20.25

Abiri, R., Rizan, N., Balasundram, S. K., Bayat Shahbazi, A., & Abdul-Hamid, H. (2023). Application of digital technologies for ensuring agricultural productivity. *Heliyon, 9*(12), e22601. https://doi.org/10.1016/j.heliyon.2023.e22601

Ali, R., Ishaq, R., Bakhsh, K., & Yasin, M. A. (2022). Do agriculture technologies influence carbon emissions in Pakistan? Evidence based on ARDL technique. *Environmental Science and Pollution Research, 29*(28), 43361–43370. https://doi.org/10.1007/s11356-021-18264-x

Chang, F., Liu, L., Wang, Y., Liu, J., & Bai, X. (2023). Impact of social networks on fertilizer use efficiency in China: Evidence from kiwifruit production in Shaanxi province. *Environmental Science and Pollution Research, 30*(45), 101841–101857. https://doi.org/10.1007/s11356-023-29508-3

Dauletkhanova, Zh. D., Alpysbayev, K. S., & Abeldinova, Zh. S. (2023). The use of digital technologies in the agro-industrial sector in Kazakhstan. *Central Asian Economic Review, 1*, 111–121. https://doi.org/10.52821/2789-4401-2023-1-111-121

Dauliyeva G.R., Erezhepova A.A., Bakytzhan S.S. (2022). Қазақстан республикасының ауыл шаруашылығындағы цифрлық жүйелер: жетістік векторы[Digital systems in agriculture of the Republic of Kazakhstan: a vector of success]. *Problems of AgriMarket, 2,* 6-63. https://doi.org/10.46666/2022-2.2708-9991.05

Eastwood, C., Klerkx, L., Ayre, M., & Dela Rue. (2019). Managing socio-ethical challenges in the development of smart farming: From a fragmented to a comprehensive approach for responsible research and innovation. *Journal of Agricultural and Environmental Ethics, 32*, 741–768. https://doi.org/10.1007/s10806-017-9704-5

Engås, K. G., Raja, J. Z., & Neufang, I. F. (2023). Decoding technological frames: An exploratory study of access to and meaningful engagement with digital technologies in agriculture. *Technological Forecasting and Social Change, 190*, 122405. https://doi.org/10.1016/j.techfore.2023.122405

FAO. (2021). The Future of Food and Agriculture: Trends and Challenges. *Food and Agriculture Organization of the United Nations*. https://www.fao.org/3/i6583e/i6583e.pdf

FAO. (2022). Digital Agriculture: Enabling the Transformation. *Food and Agriculture Organization of the United Nations*. https://www.fao.org/digital-agriculture

Gabdualiyeva, R., Melekova, A., Jakupova, A., & Bazarova, B. (2024). Digitalization of the agricultural sector in Kazakhstan. *BIO Web of Conferences, 82*, 05038. https://doi.org/10.1051/bioconf/20248205038

Gollin, D., Parente, S., & Rogerson, R. (2002). The role of agriculture in development. *American Economic Review, 92*(2), 160–164. https://doi.org/10.1257/000282802320189177

Gong, S., Sun, Z., Wang, B., & Yu, Z. (2024). Could Digital Literacy Contribute to the Improvement of Green Production Efficiency in Agriculture? *SAGE Open, 14*(1). https://doi.org/10.1177/21582440241232789

Klerkx, L., & Rose, D. (2020). Dealing with the game-changing technologies of agriculture 4.0: How do we manage diversity and responsibility in food system transition pathways? *Global Food Security, 24*, 100347. https://doi.org/10.1016/j.gfs.2019.100347

Kosasih, A., & Sulaiman, E. (2024). Digital transformation in rural settings: Unlocking opportunities for sustainable economic growth and community empowerment. *Journal of Sustainable Tourism and Entrepreneurship, 5*(2), 129–143. https://doi.org/10.35912/joste.v5i2.2278

McKinsey. (2021). Agriculture's Connected Future: How Technology Can Yield New Growth. *McKinsey & Company*. https://www.mckinsey.com/industries/agriculture/our-insights/agricultures-connected-future-how-technology-can-yield-new-growth

Mogues, T., Yu, B., Fan, S., & McBride, L. (2012). The impacts of public investment in and for agriculture: Synthesis of the existing evidence. ESA Working Paper No. 12-07, Agricultural Development Economics Division, FAO.

Myrzakhmetova, A. Zh., Khlebnikov, I. D., & Momosheva, N. K. (2021). The Kazakhstani experience in developing information literacy among youth. *Bulletin of Karaganda University. Series: History. Philosophy, 2*(102), 107–116. https://doi.org/10.31489/2021HPh/107-116

OECD. (2022). The Digital Transformation of Agriculture: How to Ensure Inclusive Adoption. *Organisation for Economic Co-operation and Development.* https://www.oecd.org/agriculture/digital-transformation-agriculture

Treiblmaier, H. (2018). The impact of the blockchain on the supply chain: A theory-based research framework and a call for action. *Supply Chain Management, 23*(6), 545-559. https://doi.org/10.1108/SCM-01-2018-0029

Tsoy, A., & Nurbatsin, A. (2024). Analysis of the Level of Agricultural Development in Kazakhstan: Identifying Agro-Hubs. *Eurasian Journal of Economic and Business Studies, 68*(3), 141–154. https://doi.org/10.47703/ejebs.v68i3.425

Wolfert, S., Ge, L., Verdouw, C., & Bogaardt, M. J. (2017). Big data in smart farming – A review. *Agricultural Systems*, *153*, 69-80. https://doi.org/10.1016/j.agsy.2017.01.023

World Bank. (2023). Kazakhstan Economic Update - Shaping Tomorrow: Reforms for Lasting Prosperity. The World Bank Group. https://www.worldbank.org/en/country/kazakhstan/publication/economic-update-winter-2023-24

Ye, F., Ouyang, Y., & Li, Y. (2023). Digital investment and environmental performance: The mediating roles of production efficiency and green innovation. *International Journal of Production Economics*, *259*, 108822. https://doi.org/10.1016/j.ijpe.2023.108822

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