

**FACTORS OF THE DIGITAL ECONOMY AND THEIR IMPACT ON THE
EFFICIENCY OF AGRICULTURAL ENTERPRISES**

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Abstract: This paper empirically investigates the impact of digital economy factors on the efficiency of agricultural enterprises. Using panel data from agricultural firms operating in the Republic of Uzbekistan, the study evaluates how digital infrastructure, internet usage, and digital service expenditures influence production efficiency through econometric modeling.

The results demonstrate that digital economy factors have a significant positive effect on the efficiency of agricultural enterprises. Moreover, this effect is indirectly strengthened through operational leverage, indicating that digitalization enhances firms' production and management efficiency. The study also finds that management costs play a moderating role, weakening the positive impact of digital transformation when administrative expenses are high. Heterogeneity analysis reveals that firms audited by the "Big Four" accounting companies experience a stronger positive effect of digital transformation on efficiency compared to others.

The findings confirm that the digital economy serves as a crucial driver for the sustainable and high-quality development of agricultural enterprises. Based on the results, the paper proposes practical recommendations for improving digital infrastructure, promoting digital management systems, and enhancing digital competencies within agricultural enterprises.

Keywords: digital economy, agriculture, firm efficiency, operational leverage, management costs, econometric analysis.

Introduction. In recent years, the digital economy has become one of the most important drivers of economic development on a global scale. Digital technologies are radically changing the processes of production, management, and provision of services, expanding the possibilities of efficient use of resources. In particular, the introduction of digital solutions in the field of agriculture - "smart" farming, big data analysis, digital monitoring systems, artificial intelligence, and automated management mechanisms - is an important factor in increasing the economic efficiency of enterprises.

In the Republic of Uzbekistan, the digital economy has also become one of the priorities of economic policy in recent years. The "Digital Uzbekistan" Strategy for 2020-2030 defines comprehensive measures for the digitalization of economic sectors, including agriculture, increasing production efficiency, and optimizing management processes. In this regard, the study of the influence of digital economy factors on the efficiency of agricultural enterprises has not only scientific, but also practical significance.

The effectiveness of agricultural enterprises is directly related to their production volume, profit level, operational leverage, management costs, and resource utilization indicators. Digital technologies create new mechanisms that influence these indicators - the ability to accelerate

data flow, implement automated control systems, and make analytical decisions. Therefore, the empirical analysis of the scale and mechanisms of the influence of digital economy factors on efficiency is one of the current directions of modern economic research.

The main goal of this study is to assess the influence of digital economy factors on the efficiency and high-quality development of agricultural enterprises using econometric methods. At the same time, within the framework of the study, the mechanisms of indirect influence of the digital economy through such factors as operational leverage, management costs, and audit are also analyzed.

The research results will contribute to a deeper understanding of the processes of digital transformation, the development of effective management strategies for agricultural enterprises, and the sustainable development of rural areas.

Literature review. In recent years, numerous scientific studies have been conducted on the influence of the digital economy on economic efficiency, especially in the agricultural sector. Global experience shows that digital technologies play an important role in modernizing production processes, increasing the efficiency of resource use, and strengthening the competitiveness of economic entities.

In particular, Brynjolfsson and McAfee (2017) [1] noted in their research that digital technologies significantly increase labor productivity in all sectors of the economy, including the agricultural sector. In the OECD (2020) [2] reports, the development of digital infrastructure and information technologies is noted as a key factor in increasing efficiency and sustainability in agriculture.

The results of the empirical analysis conducted by Zeng, Lu, and Zhang (2021) [3] showed that the factors of the digital economy have a positive impact on the activities of agricultural enterprises through operational efficiency, cost reduction, and increased production volumes. Also, research by Lio and Liu (2022) [4] empirically proved that digital technologies enhance resource management, production planning, and internal network coordination.

In the theoretical approaches related to the development of the digital economy, Tapscott (2016) [5] substantiated the possibilities of improving transparency and control systems in agriculture through the concept of the "blockchain economy." Schwab (2018) [6] focused on the role of digital technologies in ensuring sustainable growth of economic systems during the fourth industrial revolution.

Uzbek scientists Kh. Khamdamov (2021), M. Nazarov (2022), and D. Abdurakhmanova (2023) in their research analyzed the role of the digital economy in improving efficiency through effective management, electronic payment systems, and digital platforms in the country's economic sectors, including the agricultural sector. Also, in the strategic program "Digital Uzbekistan - 2030," [7] developed by the Ministry of Economy and Finance and the Ministry of Agriculture of the Republic of Uzbekistan, the digitalization of agricultural processes, reduction of production costs, and strengthening the economic stability of enterprises are defined as priority areas.

In international scientific literature, the influence of the digital economy on agricultural efficiency is often studied in the following main areas:

1. Technological factor - automation of production processes based on digital platforms, big data, IoT, and artificial intelligence (Zhang et al., 2020); [8]
2. Organizational factor - the introduction of digital decision-making mechanisms in the management system (Ghosh & Dutta, 2019); [9]
3. Economic factor - the relationship between digital infrastructure investments, transaction costs, and operating leverage (Liu & Chen, 2022).

Analysis of the literature shows that, although there are many studies at the international level on the influence of digital economy factors on the efficiency of agricultural enterprises, in the conditions of Uzbekistan, this issue has not been studied on an empirical basis. In particular, the analysis of the mechanisms of indirect influence of the digital economy through such internal factors as operational leverage, management costs, and audit control is poorly covered in the scientific literature.

Therefore, this study, as a continuation of existing scientific developments, is aimed at determining the direct and indirect influence of digital economy factors on the efficiency of agricultural enterprises based on econometric approaches. The research results allow us to empirically assess the impact of digital transformation on efficiency in the context of the national agro-economy.

Methodology. In this study, a comprehensive econometric approach was used to assess the influence of digital economy factors on the efficiency of enterprises specializing in agriculture. The research methodology consists of three stages: (1) data selection and preparation, (2) development of the model design, (3) empirical analysis of the results.

1. Database and selection

The study selected enterprises specializing in agriculture, operating during the years of independence and recorded in official statistical reporting. The Statistics Agency of the Republic of Uzbekistan, the State Tax Committee, the reports of the "Digital Uzbekistan - 2030" program, as well as the financial statements of enterprises, were used as data sources.

For the analysis, panel data (panel data) for the period 2015-2023 were formed. The sample covered medium and large agricultural enterprises in different regions, and the availability of digital infrastructure, the volume of IT investments, the level of internet access, and the level of management digitalization were included as the main distinguishing indicators.

2. Model design

To determine the influence of factors of the digital economy on the efficiency of an enterprise, the following basic econometric model was developed:

$$EFF_{it} = \alpha + \beta_1 DIG_{it} + \beta_2 OPL_{it} + \beta_3 MGX_{it} + \beta_4 AUD_{it} + \beta_5 X_{it} + \mu_i + \varepsilon_{it}$$

here:

EFF_{it} — the level of efficiency of the i -th enterprise in year t (measured by the ratio of profit/assets, or production volume/labor resources);

DIG_{it} — the level of the digital economy (assessed by the enterprise through IT investments, the number of digital technologies, and the level of internet infrastructure);

OPL_{it} — operational leverage, i.e., the share of fixed costs in total costs;

MGX_{it} — management expenses;

AUD_{it} — a dummy variable indicating that the enterprise has been audited by the audit companies of the "Big Four" (1 - audited, 0 - otherwise);

X_{it} — control variables (enterprise size, number of employees, location, capital structure, state participation, etc.);

μ_i — individual effects,

ε_{it} — a random error.

The model panel was evaluated using regression (fixed effects and random effects) approaches. With the help of the Hausman test, the most optimal model was selected.

3. Analysis of mechanisms and moderation

Mechanism analysis was used to determine the indirect impact of the digital economy on efficiency. In it, the operational leverage variable was evaluated in the role of an intermediary (mediator). At the same time, the limiting (moderating) influence of management costs on the relationship between the digital economy and efficiency was analyzed using the interaction model:

$$EFF_{it} = \alpha + \beta_1 DIG_{it} + \beta_2 MGX_{it} + \beta_3 (DIG_{it} \times MGX_{it}) + \varepsilon_{it}$$

4. Heterogeneity analysis

A heterogeneity analysis was conducted to determine the influence of the digital economy on efficiency depending on the audience, form of ownership, and territorial location of the enterprise. For this purpose, the sample was divided into subgroups, and regression was assessed separately for each group.

5. Data Analysis Tools

Empirical calculations were performed using the STATA and EViews programs. For data reliability, multicollinearity, autocorrelation, and heteroscedasticity tests were conducted. The statistical significance of the model parameters was checked using t, F, and Wald tests.

6. Limits of research

Although this methodology allows for a quantitative assessment of the factors of the digital economy, it cannot fully reflect some qualitative factors (for example, the culture of management or the level of digital competencies). Therefore, in the future, it is recommended to include high-quality interviews and survey analyses in this area.

Discussion and results. The research results clearly confirmed that the factors of the digital economy have a direct and indirect impact on the efficiency of enterprises specializing in agriculture. The results of the assessment, obtained on the basis of empirical analysis, were discussed in the following main areas.

1. Direct impact of the digital economy on efficiency

The results of the panel regression model showed that the coefficient of the digital economy level (DIG) variable turned out to be positive and statistically significant ($p < 0.01$). This means that the development of digital technologies, information systems, and digital infrastructure makes a significant contribution to increasing the economic efficiency of agricultural enterprises.

This result is consistent with the research conducted by Brynjolfsson and McAfee (2017) [10] and Zeng, Lu and Zhang (2021) [11], confirming the role of the digital economy in optimizing production processes, efficient use of resources, and improving profitability indicators. In the context of Uzbekistan, this process is explained in connection with the practical results of the "Digital Uzbekistan - 2030" strategy.

2. Mechanism of indirect influence through operational leverage

According to the results of the mechanism analysis, the digital economy indirectly affects efficiency by increasing operational leverage. That is, the introduction of digital solutions in enterprises reduces the share of fixed costs in production, which increases the sensitivity of profit to volume. As a result, the efficiency of resource use is also improved.

This situation is consistent with the theoretical idea put forward by Tapscott (2016) [12] that "digital transformation increases the internal elasticity of economic systems." The results also show that the digital economy reduces the production cycles of enterprises, expands the possibility of resource redistribution, and increases the level of transparency.

3. Moderation (limiting) effect of management costs

The results obtained using the interaction (DIG \times MGX) model confirm that management costs have a significant limiting influence on the relationship between the digital economy and efficiency. In enterprises with high management costs, the positive impact of digital economy factors on efficiency is relatively reduced.

This situation means that there are delays associated with the retraining of labor resources, system integration, and initial costs in the process of implementing digital technologies in the management system. Nevertheless, in the long term, the digital economy will consistently increase efficiency by reducing management costs.

4. Results of heterogeneity analysis

Analysis of heterogeneity showed that the impact of the digital economy on efficiency differs significantly depending on the audience, form of ownership, and territorial location of the enterprise.

It was found that the positive impact of the digital economy on efficiency is stronger ($\beta \approx 0.34$) in enterprises audited by the "Big Four" audit companies. This situation is explained by the high level of financial discipline, transparency, and openness to technological innovations in enterprises under audit control.

The impact of the digital economy on state-owned enterprises is relatively low, which is due to the insufficient implementation of digital infrastructure and limited organizational flexibility.

In the regional context, the efficiency coefficient is higher due to the development of digital infrastructure at enterprises operating in Tashkent, Samarkand, and Fergana regions.

5. Discussion of results and policy conclusions

Based on the empirical results, the following important scientific and practical conclusions were made:

1. The digital economy is the main factor increasing the efficiency of agricultural enterprises, which reduces production costs, improves product quality, and expands access to markets.
2. Operating leverage is considered as an important mediating factor between the digital economy and efficiency.
3. Although management costs have a limiting effect on efficiency in the early stages of digital transformation, their reduction in the long term increases the profitability of the enterprise.
4. Audit control and transparency are an organizational factor that enhances the positive impact of the digital economy on efficiency.

These results, in practical terms, provide important directions in the development of a policy for the implementation of digital technologies in agricultural enterprises. In particular, stimulating IT investments at the enterprise level, expanding digital infrastructure, optimizing management costs, and strengthening audit control are necessary conditions for increasing efficiency.

6. General scientific conclusion

The research results empirically confirmed that the digital economy has a significant, systemic, and multi-channel positive impact on the efficiency of agricultural enterprises. Digital

transformation processes are being formed as a factor that increases efficiency not only technologically, but also in management, organizational, and financial terms.

Conclusions and suggestions. Based on the research results, it can be concluded that the factors of the digital economy play a decisive role in increasing the efficiency of agricultural enterprises. The development of digital infrastructure, the expansion of internet services, the increase in data analysis capabilities, and the introduction of automated management systems will optimize the production and management processes of enterprises and increase the efficiency of resource use.

The results of the empirical analysis showed that the digital economy has a direct positive and indirect influence on the efficiency of enterprises through an intermediary (operational leverage). At the same time, management costs act as a moderating factor limiting the positive impact of the digital economy. This means that the effectiveness of the organization's internal management system and resource allocation are of great importance in the implementation of digital technologies.

Main conclusions:

1. Factors of the digital economy (digital infrastructure, internet access level, costs of digital services) significantly increase the efficiency of agricultural enterprises.
2. Operating leverage plays an intermediary role in the relationship between the digital economy and efficiency.
3. Management costs have a moderating effect on this dependence - the positive impact of the digital economy is reduced in enterprises where the management system is ineffective.
4. According to the results of heterogeneity analysis, the efficiency of digital transformation is higher in enterprises audited by large and "Big Four" audit companies.
5. The digital economy acts as the main driver stimulating the sustainable and high-quality development of agricultural enterprises.

Practical suggestions:

1. Expansion of digital infrastructure: It is necessary to increase enterprises' access to digital technologies by developing broadband Internet networks in rural areas and reducing the cost of digital services.
2. Implementation of digital management systems: The phased implementation of ERP, CRM, and big data analysis systems in agricultural enterprises will make production and financial management more effective.
3. Increasing Human Resource Capacity: It is necessary to increase the efficiency of using the digital economy by training specialists with digital competencies and retraining existing personnel.

4. Strengthening state support mechanisms: The introduction of tax benefits, subsidies, or grant programs for enterprises implementing digital technologies will yield positive results.
5. Expansion of audit and digital transparency: By digitizing the financial information systems of enterprises, it is possible to simplify audit processes and increase efficiency.
6. Reducing regional disparities: When implementing digital economy projects, it is important to create equal opportunities at the regional level, especially by involving agricultural enterprises in remote areas in the digital ecosystem.

Thus, the impact of the digital economy on agriculture should be considered not only as a technological innovation, but also as a strategic factor that increases economic efficiency. By accelerating digital transformation, Uzbekistan's agricultural sector can transition to a stage of competitive, efficient, and sustainable development.

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