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R&D EXPENDITURES AS A DRIVER OF INVESTMENT AND ECONOMIC GROWTH IN KAZAKHSTAN

This article examines the impact of R&D expenditures on capital investment and economic growth in Kazakhstan. R&D spending plays a crucial role in the development of new technologies, the improvement of existing products and processes, and stimulates the advancement of science and human capital. Moreover, active R&D financing is often accompanied by investments in fixed capital, which suggests a potential relationship between the two types of investment. The study aims to assess how R&D expenditures influence capital investment and GDP growth, taking into account potential time-lag effects. The methodological framework of the study is based on a vector autoregression (VAR) model estimated in first differences, which makes it possible to analyze short-term dynamics and lagged effects in the relationships between R&D expenditures, fixed capital investment, and economic growth. The stationarity of the time series was tested using the augmented Dickey–Fuller (ADF) test, while the direction of causal relationships was assessed using Granger causality tests. The results of the VAR model show that changes in R&D expenditures, although they do not have a statistically significant direct effect on changes in capital investment, have a positive impact on changes in GDP growth rates with a one-period lag. In turn, Granger causality tests confirm a unidirectional causal relationship running from changes in GDP growth rates to changes in R&D expenditures. Overall, the results highlight the complexity and time-lag dependence of the interaction between innovation, investment, and growth in Kazakhstan. The theoretical significance of the study lies in refining the mechanisms through which innovation activity exerts short-term effects on economic growth in the context of a developing economy, as well as in identifying the lag-dependent nature of interactions between intangible and tangible investments. The practical significance of the study consists in the possibility of using the obtained results in the formulation of public policy in the areas of innovation development and investment promotion, particularly in the design of R&D support measures that take into account time lags and macroeconomic conditions. The value of the obtained results lies in providing new empirical evidence on the nature of the relationships between R&D expenditures, investment, and economic growth in Kazakhstan, thereby expanding the empirical base of research on innovation-driven growth in emerging economies.

Keywords: R&D expenditures, capital investment, economic growth, VAR model.

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Қазақстандағы инвестициялар мен экономикалық өсудің қозғаушы күші ретіндегі ҒЗТКЖ шығындары

Мақалада ҒЗТКЖ-ға жұмсалатын шығындар және олардың негізгі капиталға салынатын инвестициялар мен Қазақстанның экономикалық өсуіне әсері талданады. ҒЗТКЖ шығындары жаңа технологияларды дамытуда, қолданыстағы өнімдер мен үдерістерді жетілдіруде, ғылым мен адами капиталдың дамуын ынталандыруда шешуші рөл атқарады. Сонымен қатар, ҒЗТКЖ-ны белсенді қаржыландыру негізгі капиталға салынатын инвестициялармен қатар жүреді. Бұл екі инвестиция түрінің арасында өзара байланыс бар екенін көрсетеді. Зерттеудің мақсаты – уақытша лагтың ықтимал әсерлерін ескере отырып, ҒЗТКЖ-ға жұмсалатын шығындардың капитал салымдарына және ЖІӨ-нің өсуіне қалай әсер ететінін бағалау. Зерттеудің әдіснамалық негізі алғашқы айырмаларда бағаланған векторлық авторегрессиялық модель (VAR), бұл ҒЗТКЖ-ға жұмсалатын шығындар, негізгі капиталға салынатын инвестициялар және экономикалық өсу арасындағы өзара байланыстардың қысқа мерзімді динамикасы мен уақыттық лагтық әсерлерін талдауға мүмкіндік береді. Уақыттық қатарлардың стационарлығы кеңейтілген Дики–Фуллер (ADF) тесті арқылы тексерілді, ал себеп-салдарлық байланыстардың бағыты Грейнджер себептілік тесттері көмегімен бағаланды. VAR моделінің нәтижелері ҒЗТКЖ-ға жұмсалатын шығындардағы өзгерістер капитал салымдарындағы өзгерістерге статистикалық тұрғыдан маңызды тікелей әсер

етпегенімен, ЖІӨ өсу қарқынындағы өзгерістерге бір кезеңдік лагпен оң әсер ететінін көрсетеді. Грейнджердің себептілік тесттері ЖІӨ өсу қарқынындағы өзгерістерден ҒЗТКЖ-ға жұмсалатын шығындардағы өзгерістерге қарай бағытталған біржақты себеп-салдарлық байланысты растайды. Зерттеу нәтижелері Қазақстандағы инновациялар, инвестициялар және экономикалық өсім арасындағы өзара әрекеттесудің күрделілігі мен уақытша лагқа тәуелділікті көрсетеді. Зерттеудің теориялық маңыздылығы дамушы экономика жағдайында инновациялық белсенділіктің экономикалық өсуге қысқа мерзімді ықпал ету тетіктерін нақтылауда, сондай-ақ материалдық емес және материалдық инвестициялар арасындағы өзара әрекеттестіктің уақыттық лагтарға тәуелді сипатын айқындауда көрініс табады. Жұмыстың практикалық маңыздылығы алынған нәтижелерді инновациялық даму және инвестицияларды ынталандыру саласындағы мемлекеттік саясатты қалыптастыру барысында, атап айтқанда уақыттық лагтар мен макроэкономикалық конъюнктураны ескере отырып ҒЗТКЖ-ды қолдау шараларын әзірлеуде пайдалану мүмкіндігімен айқындалады. Алынған нәтижелердің құндылығы Қазақстандағы ҒЗТКЖ, инвестициялар және экономикалық өсу арасындағы өзара байланыстардың сипаты жөнінде жаңа эмпирикалық дәлелдер ұсынылуында, бұл қалыптасушы экономикасы бар елдердегі инновацияға негізделген экономикалық өсуді зерттеудің эмпирикалық базасын кеңейтеді.

Түйін сөздер: ҒЗТКЖ шығындары, негізгі капиталға салынатын инвестициялар, экономикалық өсу, VAR моделі.

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Расходы на НИОКР как драйвер инвестиций и экономического роста Казахстана

В статье анализируются затраты на НИОКР и их взаимосвязь с инвестициями в основной капитал и экономическим ростом Казахстана. Расходы на НИОКР играют решающую роль в развитии новых технологий, улучшении существующих продуктов и процессов, стимулируют развитие науки и человеческого капитала. Кроме того, активное финансирование НИОКР сопровождается вложениями в основной капитал, что предполагает существование взаимосвязи между двумя типами инвестиций.

Цель исследования – оценить, как расходы на НИОКР влияют на капиталовложения и рост ВВП с учетом потенциальных эффектов временного лага. Методологической основой исследования является векторная авторегрессионная модель (VAR), оцененная в первых разностях, что позволяет проанализировать краткосрочную динамику и лаговые эффекты взаимосвязей между расходами на НИОКР, инвестициями в основной капитал и экономическим ростом. Стационарность временных рядов проверялась с использованием расширенного теста Дики–Фуллера (ADF), а направленность причинно-следственных связей оценивалась с помощью тестов причинности Грейнджера. Результаты VAR-модели показывают, что изменения в расходах на НИОКР хотя и не оказывают статистически значимого прямого влияния на изменения в капитальных вложениях, они положительно влияют на изменения темпов роста ВВП с одноперiодным лагом. В свою очередь, тесты причинности Грейнджера подтверждают одностороннюю причинно-следственную связь от изменений темпов роста ВВП к изменениям в расходах на НИОКР. В целом результаты подчеркивают сложность и зависимость от временного лага взаимодействия между инновациями, инвестициями и ростом в Казахстане. Теоретическая значимость исследования заключается в уточнении механизмов краткосрочного воздействия инновационной активности на экономический рост в условиях развивающейся экономики, а также в выявлении лагозависимого характера взаимодействия между нематериальными и материальными инвестициями. Практическая значимость работы состоит в возможности использования полученных результатов при формировании государственной политики в сфере инновационного развития и инвестиционного стимулирования, в частности при разработке мер поддержки НИОКР с учетом временных лагов и макроэкономической конъюнктуры. Ценность полученных результатов заключается в предоставлении новых эмпирических свидетельств о характере взаимосвязей между НИОКР, инвестициями и экономическим ростом в Казахстане, что расширяет эмпирическую базу исследований инновационно-ориентированного роста в странах с формирующейся экономикой.

Ключевые слова: затраты на НИОКР, инвестиции в основной капитал, экономический рост, VAR-модель.

Introduction

In modern conditions of increasing competition in international markets and intensive development and implementation of advanced innovative technologies in world markets, Kazakhstan faces an urgent need to develop a new approach to managing the national economy. The strategic goal of the Republic of Kazakhstan is the need to achieve high-quality and sustainable economic growth leading to an increase in people's living standards based on strengthening business competitiveness, technological modernization, improving the institutional environment and minimizing negative impacts on nature, which is consistent with the UN Sustainable Development Goals. In this regard, the domestic economy remains in constant need of investment resources necessary for the development of the real sector. Particular emphasis should be placed on building sustainable infrastructure to foster industrialization and innovation through increased R&D spending.

The Concept for the Development of Higher Education and Science in the Republic of Kazakhstan for 2023-2029 notes the need for a phased increase in R&D costs from all sources to 1% of GDP. This measure aims to enhance is the global competitiveness of Kazakh science and its contribution to solving national-level applied challenges. It should be borne in mind that according to international standard definitions adopted in the economy of the Republic of Kazakhstan, domestic R&D expenditures are synonymous with R&D results (MSHE RK, 2022).

An analysis of internal R&D costs in terms of funding sources shows that the state remains the main investor in scientific research. It accounts for more than 60% of the costs. The share of own funds, which can be considered as investments of entrepreneurs, decreases annually (Akorda, 2024). The demand for R&D remains at a very low level due to the fact that it is not being brought to a state where this knowledge can be used in economic activities and in production. Less than 15% is invested in research and development aimed at creating new materials, products, processes, devices, services, systems or methods and their further improvement.

As you know, Kazakhstan ranks 78th in the Report on the Global Innovation Index for 2024, having demonstrated good results in the field of online government services, utility models and e-participation. However, in terms of investment in R&D, the result deteriorated by 5.1% compared to 2022 (WIPO, 2024). Despite the increase in R&D costs, the science intensity of GDP has not changed in recent years, remaining at the level of 0.12–0.14%. Consequently, the expansion of investment support for R&D and innovation is one of the key problems in Kazakhstan, which underlines the relevance of the topic of this study.

This study examines the impact of R&D investment on two key areas: first, on capital investment; and second, on the economic growth of Kazakhstan. On the one hand, R&D investments can directly influence economic growth through the introduction of new technologies, increased productivity, innovation, and so on. Therefore, R&D investment can be considered a driver of economic growth. On the other hand, R&D investments are often made alongside capital investments, as companies that actively invest in new technologies and products also tend to invest in equipment, production facilities, and other fixed assets. This suggests that R&D investment may influence the dynamics of capital investment. In this regard, it is appropriate to examine the relationship between R&D investment and capital investment, as well as between R&D investment and economic growth.

Literature review

The study of the problems of investment and its effective use has always been in the focus of economic science, since it is investments that affect the deepest foundations of economic activity, determining the pace of economic growth of a country. Therefore, investment policy deserves special attention in economic policy, which is a crucial component in the process of managing the country's economy.

A deeper theoretical understanding of the R&D–growth nexus is provided by endogenous growth theory, which explicitly models technological progress as the outcome of purposeful investment in knowledge. In Romer's seminal model (1990), R&D expenditure increases the stock of ideas, which are characterized by non-rivalry and increasing returns. As firms invest in research, they enhance the productivity of both labor and capital, generating sustained economic growth. In this framework, R&D not only stimulates innovation but also raises the marginal productivity of private investment.

A complementary perspective is offered by the Schumpeterian model of (Aghion & Howitt, 1992), where economic growth arises through "creative destruction". Firms engage in R&D to produce better-quality technologies that replace outdated ones, and

this process drives long-term productivity improvements. In such models, the incentives to invest in research depend critically on expected returns, market structure, and institutional quality. Thus higher innovation effort increases the frequency of technological upgrading, enhances competitiveness, and fuels broader investment flows.

Research on R&D at the national and regional levels mainly focuses on its economic effectiveness. However, the issue of the driving forces of innovation is ignored. Works by Jaffe (1989), Bottazzi & Peri (2003), Crescenzi et al. (2007), Wang et al. (2016), Rodriguez-Pose (1999) and Bilbao-Osorio & Rodriguez-Pose (2004) demonstrate that investments in R&D stimulate both the generation of new knowledge and economic growth. At the same time, territorial specifics play a key role. Researchers Ginevicius R. (2023), Arana Barbier (2023), Mudronja et al (2019), Wynn et al. (2022) have deepened the study of the role of investment in R&D in the economic development of individual regions and industries. (Wang et al., 2016) have shown the strong impact of economic infrastructure development on the quality of innovation in China's provinces. In addition, localized and interregional knowledge spillovers constitute a key mechanism through which R&D activity affects productivity and economic growth (Jaffe, 1989; Bottazzi and Peri, 2003), (Crescenzi et al., 2007) found significant differences in the reasons for patenting between the United States and Europe, which underscores the importance of taking into account territorial features when studying innovation processes.

Huseynli's article (2023) examines the impact of investment in R&D on accelerating economic growth in several countries in the Central Asian region. Kazakhstani authors (Nurmaganbetov& Tugushev, 2024). In their research, they analyze the current state and prospects of investment in research and development (R&D) in Kazakhstan's high-tech sectors, as well as consider barriers hindering investment growth. (Seitkan et al., 2024) assessed the impact of R&D costs on various aspects of innovation activity in Kazakhstan, such as the share of innovative products in GDP and the cost of product and process innovations. The results confirm the importance of R&D investments for economic growth.

A closer examination of Kazakhstan's national innovation system reveals institutional features that significantly shape the effectiveness of R&D investment. (Sadyrova et al., 2021) note that innovation processes in Kazakhstan are constrained by weak linkages between science and industry, limited private-sector demand for innovation, and underdeveloped commercialization mechanisms. Despite increasing state support, these structural issues reduce the transformative impact of R&D expenditures.

According to Baxultanov et al. (2022), Kazakhstan's R&D landscape is characterized by low research intensity, the predominance of public funding, and an uneven distribution of scientific resources. The authors emphasize that fragmented innovation infrastructure and inefficient resource allocation hinder the conversion of R&D inputs into measurable innovation outputs.

The broader institutional trajectory is also important. (Danabayeva & Shedenov, 2015) argue that Kazakhstan's transition toward a knowledge-based economy requires not only greater investment in science but also deeper institutional reforms to strengthen coordination among government, business, and academia. Their work highlights limited technological absorption capacity within firms as a persistent barrier.

More recent studies underline the relevance of the innovation ecosystem approach. (Nauryzbaeva et al., 2024) show that although Kazakhstan has expanded its innovation support structures– technology parks, accelerators, grant programs– the regulatory environment remains inconsistent, and coordination between ecosystem actors is weak. Earlier research by (Kusmoldaeva & Khudaybergenova, 2017) similarly stresses that the innovation system is heavily state-driven, while market-based mechanisms and private R&D investment remain underdeveloped.

Taken together, these studies indicate that while the institutional context of R&D in Kazakhstan has been examined from various angles, the literature predominantly focuses on descriptive assessments of innovation capacity, structural barriers, and policy frameworks. What remains less explored is how these institutional characteristics translate into measurable macroeconomic outcomes. In particular, despite the recognized importance of R&D for innovation and growth, few studies investigate the quantitative relationship between R&D expenditures, capital formation, and economic growth using econometric approaches.

At the empirical level, identifying the causal impact of R&D expenditures on investment and economic growth is challenging due to several sources of endogeneity. First, reverse causality is likely,

so faster economic growth and higher investment capacity may themselves lead to increased R&D spending. Second, omitted variables (institutional quality, human capital or macroeconomic stability) may simultaneously affect R&D intensity and growth outcomes, biasing simple estimations. Third, R&D investments often exhibit delayed effects implying dynamic adjustment processes rather than instantaneous impacts.

To address these issues, the empirical literature has employed a range of time-series and panel econometric strategies. Multivariate time-series approaches, such as Vector Error Correction Models (VECM) and Structural VAR (SVAR), are commonly employed to model feedback effects and long-run equilibrium relationships among R&D, investment, and output (Ercan Merve, 2025). Cross-country and panel studies frequently rely on instrumental variable techniques to address simultaneity and omitted variable bias. More recently, Autoregressive Distributed Lag (ARDL) models have gained prominence, particularly in studies focusing on single-country analyses or small samples, as they allow for mixed orders of integration, explicitly model short- and long-run dynamics, and partially alleviate endogeneity by incorporating lag structures (Xuan, 2025; Simut Ramona et al., 2003).

Despite these methodological advances, relatively few studies apply such econometric frameworks to resource-rich, transition economies like Kazakhstan, where the structure of R&D financing is heavily state-driven and private-sector innovation remains limited. This raises an additional identification concern. The effectiveness of R&D expenditures may depend not only on their volume but also on institutional complementarities and the investment climate. Consequently, the estimated impact of R&D on growth may differ substantially from that observed in advanced economies.

Against this background, the present study contributes to the literature by empirically examining the dynamic relationship between R&D expenditures, capital investment, and economic growth in Kazakhstan within an endogenous growth perspective. By employing a time-series framework that distinguishes between short- and long-run effects, the analysis explicitly accounts for feedback mechanisms and mitigates endogeneity concerns inherent in the R&D-growth nexus. This approach allows for a more nuanced assessment of whether R&D acts primarily as a direct engine of growth, an indirect driver through capital accumulation, or both.

The present study proposes a two-level empirical analysis assessing the relationship between R&D expenditures, capital investment and economic growth in Kazakhstan. Accordingly, the following hypotheses are formulated:

H1: There is a relationship between R&D investment and investment in fixed capital;

H2: R&D investment has a positive effect on Kazakhstan's economic growth.

Methodology

The study employed the following variables: economic growth (real GDP volume index by production method, % compared to the previous year), investment in fixed assets (in comparable prices of 2000, billion tenge) and R&D expenditures (in comparable prices of 2000, billion tenge). Control variable – share of the working-age population (as a percentage of the total population). The study used annual data from the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan for the period 2000–2024.

Figure 1 shows the dynamics of the indicators used to build the econometric model, according to the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan.

Figure 1 presents annual data for Kazakhstan over the period 2000–2024, including economic growth, investment in fixed assets, R&D expenditures, and the share of the working-age population. Economic growth exhibits pronounced cyclical fluctuations, ranging from rapid expansion in the early 2000s to a contraction in 2020, reflecting major external and domestic shocks. Investment in fixed assets, measured in constant 2000 prices, shows a long-term upward trend with notable volatility, particularly during periods of economic instability. R&D expenditures, also expressed in constant prices, increase gradually over the sample period but remain relatively modest in scale, indicating limited research intensity despite recent acceleration after 2022. The share of the working-age population follows a declining trajectory after the mid-2010s, suggesting emerging demographic constraints. Overall, the table highlights substantial variation across macroeconomic and innovation-related indicators, providing a suitable basis for analyzing the dynamic relationship between R&D activity, investment behavior, and economic growth in Kazakhstan.

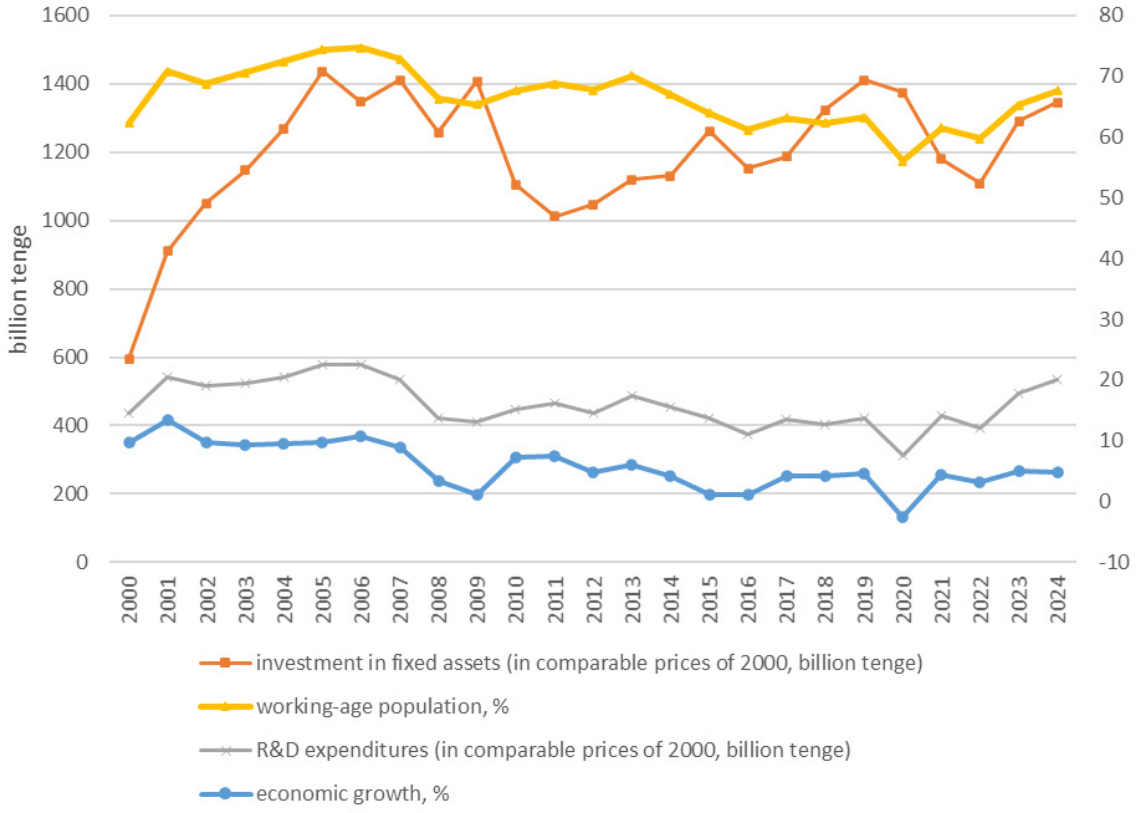

Figure 1 – Economic growth, R&D expenditures and capital investment in Kazakhstan
Note – compiled by the authors

In our study, the assessment of the relationship between variables was carried out using the construction of a VAR model, OLS, ADF test, and Granger causality test, implemented with Python in the Google Colab environment. The VAR system is estimated equation-by-equation using OLS, which is standard under the assumption of identical regressors across equations

The selection of the VAR model is based on the dynamic nature of the relationship between R&D expenditures, capital investment, and economic growth. VAR is suitable when variables may influence each other over time and when the objective is to capture short-run interactions without imposing restrictive structural assumptions.

Before estimating the model, we performed unit-root testing using the Augmented Dickey–Fuller (ADF) test. The results showed that some variables are non-stationary in levels but become stationary after first differencing. Since all transformed series are stationary and no cointegration relationship was detected, the use of a Vector Error Correction Model (VECM) is not justified. Likewise, the ARDL approach is typically applied when the goal is to estimate long-run cointegration relationships between I(0) and I(1) variables, which is not the aim of the present study.

Given the absence of cointegration and the study's focus on short-term dynamic effects, the VAR model represents the most appropriate methodological choice. The optimal lag length was selected using standard information criteria (AIC, BIC, FPE, HQIC), which consistently indicated the need to include several lags. This provides a statistically grounded basis for examining how changes in R&D expenditures propagate through investment and growth channels.

At the first stage of the study, the relationship between investment in fixed capital and R&D expenditures was assessed. These indicators may influence each other with a certain time lag. Therefore, the time lag effect was incorporated into the model specification.

At the second stage of the study, the relationship between R&D expenditures and economic growth was examined.

Results and discussion

The use of the VAR (Vector Autoregression) model requires that the time series be stationary, that is, their statistical properties do not change over time. Stationarity testing of the time series was conducted using the Augmented Dickey-Fuller (ADF) test. To transform the non-stationary time series into stationary ones, differencing was applied. Stationarity was achieved after the first differencing.

Since the time series exhibit a mixed order of integration, the VAR model was estimated in first differences to ensure stationarity of all variables. This approach avoids spurious regression and satisfies the statistical requirements of the VAR framework. While differencing eliminates potential long-run equilibrium relationships, it enables a consistent examination of short-run dynamic interactions between changes in R&D expenditures, investment and economic growth. Thus, in our case, the use of VAR in first differences focuses on the short-run effects of changes in R&D, investment, and economic growth.

The results of the stationarity test are presented in Table 1.

Table 1 – Results of the time series stationarity test

	ADF Statistic	p-value	Critical values		
			1%	5%	10%
Δ Investments in fixed assets	-4.086078	0.001021	-4.012034	-3.104184	-2.690987
Δ R&D expenditures	-4.299762	0.000445	-3.752928	-2.998500	-2.638967
Δ Economic growth	-6.381253	2.219486e-08	-3.752928	-2.9985	-2.638967
Δ Share of the working-age population (first differentiation)	-5.468752	2.425335e-06	-3.752928	-2.9985	-2.638967
Note – Calculated by the authors					

The ADF statistics for the analyzed data were below the critical value at the 1% significance level, indicating stationarity of the time series. The p-value confirmed that the null hypothesis of the presence of a unit root was rejected.

After data transformation and stationarity testing, it was necessary to determine the optimal number of lags to include in the model. The lag selection was performed using the AIC, BIC, FPE, and HQIC criteria based on the construction of a Vector Autoregression (VAR) model. These criteria helped select the optimal number of lags (Table 2).

The table shows that the minimum is reached at lag 4 (AIC = -0.01249). This means that to capture the dynamics of changes in the data, it is necessary to account for 4 periods back. Since differencing removes the trend, the selected lags reflect the period over which past changes in the variables influence current changes. In other words, changes in R&D expenditures, investments, and economic growth from 4 years ago have an impact on the current changes in the respective variable.

From an economic perspective, the effects of investment in fixed capital and R&D expenditures are expected to materialize within a relatively short horizon. For annual data, a lag length of 1 to 4 years captures the medium-term adjustment process related to investment planning, implementation, and innovation diffusion, while longer lags are difficult to interpret economically.

At the first stage, the causal relationship between R&D expenditures and investment in fixed assets was analyzed. The modeling results are presented in the tables 3-5.

The model results indicate that changes in fixed capital investment are primarily driven by their own past changes, particularly with a three-period lag. In contrast, changes in R&D expenditures do not have a statistically significant impact on the current changes in fixed capital investment.

Table 2 – AIC, BIC, FPE and HQIC values for determining the optimal number of lags (* – optimal lag)

Lags	AIC	BIC	FPE	HQIC
Lag 0	2.369	2.519	10.69	2.399
Lag 1	2.447	3.044	11.74	2.563
Lag 2	2.621	3.666	15.08	2.825
Lag 3	1.018	2.512	3.722	1.310
Lag 4	-0.01249*	1.929*	2.094*	0.3665*
Note – Calculated by the authors				

Table 3 – Characteristics of the VAR model

Model:	VAR	Log Likelihood	-148.229
Method:	OLS	AIC	10.9471
Date:	Tue, 08, Jul, 2025	BIC	11.8433
Time:	12:58:29	HQIC:	11.1221
No. of Equations:	2.00000	FPE:	65245.7
Nobs:	20.0000	Det(Omega_mle):	31032.5
		Correlation	0.668420
Note – Calculated by the authors based on the VAR model			

Table 4 – Results of the VAR model for investments in fixed capital

	coef	std err	t-stat	prob
const	-1.304465	32.905869	-0.040	0.968
L1. Δ Investment	-0.096889	0.384460	-0.252	0.801
L1. Δ R&D	-6.750701	31.461402	-0.215	0.830
L2. Δ Investment	0.219680	0.388023	0.566	0.571
L2. Δ R&D	-34.186676	34.842102	-0.981	0.326
L3. Δ Investment	-0.774445	0.395484	-1.958	0.050
L3. Δ R&D	50.744009	32.559880	1.558	0.119
L4. Δ Investment	0.033502	0.426858	0.078	0.937
L4. Δ R&D	28.168025	35.165001	0.801	0.423
Note – Calculated by the authors based on the VAR model				

Table 5 – Results of the VAR model for R&D expenditures

	coef	std err	t-stat	prob
const	0.122628	0.416293	0.295	0.768
L1. Δ Investment	-0.004466	0.004864	-0.918	0.358
L1. Δ R&D	0.239315	0.398019	0.601	0.548
L2. Δ Investment	0.002183	0.004909	0.445	0.657
L2. Δ R&D	-0.437388	0.440788	-0.992	0.321
L3. Δ Investment	-0.012475	0.005003	-2.493	0.013
L3. Δ R&D	0.629078	0.411916	1.527	0.127
L4. Δ Investment	0.004250	0.005400	0.787	0.431
L4. Δ R&D	-0.005823	0.444873	-0.013	0.990
Note – Calculated by the authors based on the VAR model				

The VAR model results for R&D investment indicate that past changes in fixed capital investment at lag 3 have a statistically significant negative effect on current changes in R&D expenditures (p = 0.013). Other lags do not show statistically significant effects.

The correlation between the residuals of the two equations is 0.668, suggesting a moderate positive relationship between the unexplained components of the two models. Overall, the results point to a one-way, lagged effect of changes in fixed capital investment on changes in R&D expenditures, while no reverse effect is observed.

Subsequently, the causal relationship between changes in R&D expenditures and changes in fixed capital investment was examined using Granger causality tests, which assess the predictive influence of one variable's past changes on another. The results of the Granger tests are presented in Tables 6–7.

Table 6 – Granger test values (the impact of R&D expenditures on fixed capital investment)

Lags	F	p	chi2	p	df
Lag 1	0.1557	0.6973	0.1791	0.6721	1
Lag 2	0.0123	0.9877	0.0319	0.9842	2
Lag 3	0.5588	0.6509	2.5145	0.4727	3
Lag 4	1.0690	0.4172	7.7747	0.1002	4
Note – Calculated by the authors					

The Granger causality test, applied to the first-differenced (stationary) series, revealed no statistically significant causal relationship from changes in R&D expenditures to changes in fixed capital investment for any of the lags considered (from 1 to 4). In all cases, the p-values for the main statistical indicators (the F-test, the chi-square test, and the likelihood ratio test) were substantially above the 0.05 significance level. This indicates that there is no evidence to support hypothesis H1, which posits a relationship between R&D investment and fixed capital investment. Past changes in R&D expenditures do not significantly influence current changes in fixed capital investment.

Table 7 – Granger test values (the impact of fixed capital investment on R&D expenditures)

Lags	F	p	chi2	p	df
Lag 1	0.1789	0.6769	0.2057	0.6502	1
Lag 2	0.4249	0.6606	1.0998	0.5770	2
Lag 3	1.3049	0.3119	5.8721	0.1180	3
Lag 4	1.9412	0.1736	14.1180	0.0069	4
Note – Calculated by the authors					

The Granger causality test results generally do not support a robust causal relationship. At lag 4, a weak or unstable causal relationship from changes in fixed capital investment to changes in R&D spending may be suspected. However, this result requires further verification using more comprehensive data.

At the second stage of the study, the relationship between R&D expenditures and economic growth was assessed. The modeling results are presented in Tables 8-10.

The model results, based on differenced data, indicate that changes in economic growth with a two-period lag have a positive and statistically significant effect on changes in R&D investment (p = 0.008). Changes in the share of the working-age population with a three-period lag exert a negative effect on changes in R&D investment (p = 0.016). Overall, the results suggest that R&D investment responds to the dynamics of economic growth and is sensitive to shifts in labor market conditions rather than to their levels.

Table 8 – Characteristics of VAR model

Model:	VAR	Log Likelihood	-46.0114
Method:	OLS	AIC	-0.0124867
Date:	Wed, 09, Jul, 2025	BIC	1.92919
Time:	05:39:50	HQIC:	0.366549
No. of Equations:	3.00000	FPE:	2.09448
Nobs:	20.0000	Det(Omega_mle):	0.466256
Note – Calculated by the authors based on the VAR model			

Table 9 – Results of the VAR model for R&D expenditures

	coef	std err	t-stat	prob
const	0.217606	0.411099	0.529	0.597
L1. Δ R&D	-0.011579	0.326445	-0.035	0.972
L1. Δ GDP_Growth	0.123087	0.196586	0.626	0.531
L1. Δ Workforce	-0.787971	1.045943	-0.753	0.451
L2. Δ R&D	0.573420	0.457643	1.253	0.210
L2. Δ GDP_Growth	0.456533	0.172796	2.642	0.008
L2. Δ Workforce	1.457245	0.810066	1.799	0.072
L3. Δ R&D	-0.399682	0.371714	-1.075	0.282
L3. Δ GDP_Growth	0.006057	0.188193	0.032	0.974
L3. Δ Workforce	-1.608152	0.665970	-2.415	0.016
L4. Δ R&D	0.037462	0.366472	0.102	0.919
L4. Δ GDP_Growth	-0.014242	0.256039	-0.056	0.956
L4. Δ Workforce	0.148190	0.663125	0.223	0.823
Note – Calculated by the authors based on the VAR model				

Table 10 – Results of the VAR model for economic growth

	coef	std err	t-stat	prob
const	-1.254261	0.783918	-1.600	0.110
L1. Δ R&D	1.595670	0.622493	2.563	0.010
L1. Δ GDP_Growth	-0.545376	0.374868	-1.455	0.146
L1. Δ Workforce	2.130796	1.994495	1.068	0.285
L2. Δ R&D	0.922851	0.872673	1.057	0.290
L2. Δ GDP_Growth	-0.742389	0.329502	-2.253	0.024
L2. Δ Workforce	-1.110866	1.544704	-0.719	0.472
L3. Δ R&D	-0.936341	0.708816	-1.321	0.187
L3. Δ GDP_Growth	-1.200942	0.358863	-3.347	0.001
L3. Δ Workforce	-1.098891	1.269929	-0.865	0.387
L4. Δ R&D	0.063895	0.698821	0.091	0.927
L4. Δ GDP_Growth	-0.317771	0.488237	-0.651	0.515
L4. Δ Workforce	-1.244589	1.264505	-0.984	0.325
Note – Calculated by the authors based on the VAR model				

The model, estimated using differenced data, confirms that changes in R&D investment with a one-period lag have a positive and statistically significant effect on changes in economic growth ($p = 0.010$). In addition, an error-correction–type dynamic is observed: changes in GDP growth in the two- and three-period lags negatively affect current changes in economic growth. In this specification, changes in the share of the working-age population do not have a statistically significant impact on changes in economic growth.

Next, the causal relationship between R&D investment and economic growth rates was analyzed based on the concept of Granger causality. The results of the Granger causality test are presented in Tables 11–12.

Table 11 – Granger test values (the impact of R&D expenditures on economic growth)

Lags	F	p	chi2	p	df
Lag 1	0.1471	0.7054	0.1691	0.6809	1
Lag 2	0.0779	0.9254	0.2017	0.9041	2
Lag 3	2.2315	0.1297	10.0418	0.0182	3
Lag 4	2.2889	0.1251	16.6466	0.0023	4
Note – Calculated by the authors					

The results of the Granger causality test did not reveal a statistically significant causal relationship from changes in R&D expenditures to changes in economic growth for any of the considered lag lengths (from 1 to 4 lags). The p-values of the F-test were well above the 0.05 significance level. Alternative tests (chi-squared test and likelihood ratio test) for lags 3 and 4 show lower p-values ($p < 0.05$). However, F-test results are generally preferred for small samples, and in this case, they do not support causality.

Table 12 – Granger test values (the impact of economic growth on R&D expenditures)

Lags	F	p	chi2	p	df
Lag 1	0.1341	0.7181	0.1542	0.6945	1
Lag 2	5.1056	0.0183	13.2144	0.0014	2
Lag 3	3.7717	0.0357	16.9728	0.0007	3
Lag 4	3.0454	0.0645	22.1483	0.0002	4
Note – Calculated by the authors					

The results of the Granger causality test, conducted on differenced series, indicate a stable causal relationship at lags 2 and 3. Specifically, past changes in GDP growth rates statistically significantly improve the forecast of changes in R&D investment. This provides evidence of one-way Granger causality running from changes in economic growth to changes in R&D investment.

Although the VAR model based on differenced data identifies a statistically significant positive effect of changes in R&D investment with a one-period lag on changes in economic growth, the Granger causality result does not support the existence of causality from changes in R&D expenditures to changes in economic growth. This discrepancy may arise because the Granger test evaluates the joint predictive power of all included lags of a variable, whereas the VAR framework assesses the statistical significance of individual lagged coefficients while controlling for other variables in the system. In addition, the small sample size may reduce the statistical power of the Granger tests.

Based on these results, the study's hypotheses can be summarized as follows.

Hypothesis H1 regarding the relationship between R&D investment and investment in fixed capital is partially confirmed. According to the VAR model in first differences, changes in fixed

capital investment are mainly explained by their own lagged changes, particularly at lag 3, while no statistically significant effect of changes in R&D expenditures on fixed capital investment is detected. In contrast, in the equation for changes in R&D investment, a statistically significant negative effect of changes in fixed capital investment at lag 3 ($p = 0.013$) is observed, which may indicate a delayed substitution effect between the two types of investment. The Granger causality test does not confirm causality from changes in R&D expenditures to changes in fixed capital investment for any of the considered lags. In the reverse direction (changes in fixed capital – changes in R&D investment), causality is also not detected for lags 1-3; however, at lag 4, the results are mixed: the chi-squared test ($p = 0.069$) and LR test ($p = 0.0304$) suggest a possible link, while the F-test ($p = 0.1736$) does not support it.

Hypothesis H2, regarding the effect of R&D investment on Kazakhstan's economic growth, is also partially confirmed. The VAR model reveals a positive and statistically significant impact of changes in R&D investment with a one-period lag on changes in economic growth, as well as a reverse effect in which changes in GDP growth at lag 2 positively affect changes in R&D investment. However, the Granger causality test does not confirm causality from changes in R&D expenditures to changes in GDP growth according to the F-test at any lag. At the same time, alternative tests (the chi-squared and LR tests) at lags 3 and 4 yield lower p-values, indicating a potentially weak relationship. In contrast, Granger causality from changes in GDP growth rates to changes in R&D investment is robustly confirmed at lags 2 and 3 by all tests, pointing to a predominantly one-way dynamic relationship between these variables.

Conclusion

This study provides a comprehensive empirical analysis of the dynamic interactions between R&D expenditures, investment in fixed capital, and economic growth in Kazakhstan over the period 2000–2024. Using a VAR framework estimated in first differences, combined with stationarity testing and Granger causality analysis, the study focuses on short-term dynamics and predictive relationships among changes in these variables. This approach allows for a more precise interpretation of innovation-driven growth processes in a developing economy by emphasizing adjustments and fluctuations rather than long-run levels.

The results indicate that changes in fixed capital investment are primarily driven by their own past changes, particularly at a three-period lag, while changes in R&D expenditures do not exert a statistically significant direct influence on changes in capital investment. At the same time, a lagged negative effect of changes in fixed capital investment on changes in R&D expenditures is identified, suggesting a delayed substitution effect between these two forms of investment. Granger causality tests largely confirm the absence of a strong predictive relationship between the two, with only weak and lag-specific indications that warrant further investigation.

With respect to economic growth, the VAR results show that changes in R&D investment with a one-period lag have a positive and statistically significant effect on changes in GDP growth, underscoring the role of innovation in shaping short-term growth dynamics. In addition, changes in economic growth positively influence subsequent changes in R&D expenditures, indicating that innovation activity is responsive to improvements in macroeconomic conditions. Although Granger causality tests do not support causality running from changes in R&D expenditures to changes in economic growth, they consistently confirm one-way causality from changes in GDP growth to changes in R&D investment, highlighting economic performance as a key driver of innovation dynamics.

Overall, the findings partially confirm the proposed hypotheses. Hypothesis H1, which posits a relationship between R&D investment and fixed capital investment, receives limited support, with evidence pointing to a lagged negative effect from changes in fixed capital investment to changes in R&D expenditures. Hypothesis H2, concerning the positive impact of R&D investment on economic growth, is also partially confirmed: while the VAR model identifies a significant short-term effect of changes in R&D investment on growth dynamics, Granger causality results emphasize the predictive role of economic growth for R&D activity rather than the reverse. These results underscore the complexity and lag-dependent nature of interactions between innovation, investment, and growth in Kazakhstan.

This study contributes to the literature by providing empirical evidence on the short-term dynamics of R&D, investment, and economic growth in an emerging economy context using differenced data. From a policy perspective, the findings suggest that

increases in R&D investment alone may not immediately translate into sustained economic growth, and that a stable and supportive macroeconomic environment is crucial for stimulating innovation activity and fostering long-term development.

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БУХГАЛТЕРЛІК ЕСЕПТЕГІ КӨПӨЛШЕМДІ ЖАСАНДЫ НЕЙРОНДЫ ЖЕЛІЛЕР

Жасанды нейрондық желілер бизнес-процестерге автоматтандыру және деректерді интеграциялау мүмкіндіктері арқылы айтарлықтай ықпал етеді. Алайда автоматтандырылған рәсімдерді шектеусіз қолдану бухгалтерлік есеп саласында айқын көрінетін тәуекелдермен байланысты. Көпөлшемді бухгалтерлік есеп жүйелеріне сараптамалық жүйелер, нейрондық желілер, генетикалық алгоритмдер және зияткерлік агенттер әсер етеді.

Зерттеу әдіснамасы сандық және сапалық тәсілдерді үйлестіретін аралас әдіске негізделді. Бұл зерттеуде бухгалтерлік есеп пен аудит саласының мамандары арасында сауалнама жүргізіліп, жасанды нейрондық желілердің қосымшаларын (бұл мамандардың нейрондық желілерді қаншалықты танып-біліп, сеніммен қабылдап, тәжірибеде қолданатынын көрсететін өлшем) қабылдау деңгейі мен олардың бухгалтерлік есепке болжамды көпөлшемді ықпалы анықталды. Нәтижелер нейрондық желілердің дәстүрлі бухгалтерлік үдерістерді түрлендіру, болжамдық мүмкіндіктерді арттыру және күрделі бизнес ортада басқарушылық шешімдерді қолдау әлеуетін көрсетеді. Қосымшаларды қабылдау деңгейі мен формалды нәтижелер арасындағы өзара байланысты талдау үшін корреляциялық және регрессиялық талдауды қамтитын статистикалық әдістер қолданылды.

Зерттеу нәтижелері генетикалық алгоритмдерді пайдалану жасанды нейрондық желілердің ең маңызды әрі тиімді қосымшаларының бірі болып табылатынын және есептік ақпарат сапасын арттыруға ықпал ететінін көрсетті. Ал сараптамалық жүйелердің, нейрондық желілердің және зияткерлік агенттердің есептік деректер сапасына әсері статистикалық тұрғыдан маңызды емес болып шықты. Генетикалық алгоритмдердің оң әсері Астанадағы кәсіби және технологиялық ортаның әлі күрделі жасанды интеллект технологияларын (сараптамалық жүйелер, нейрондық желілер, зияткерлік агенттер) тиімді қолдануға жеткілікті деңгейде жетілмегендігімен, бірақ практикалық талдау құралдарын дамытуға қолайлы жағдай жасағандығымен түсіндірілуі мүмкін.

Зерттеу қорытындысында бірқатар ұсынымдар тұжырымдалды, олардың ең маңыздылары бухгалтерлер мен практиктердің жасанды нейрондық желілер технологияларын қабылдауын кеңейту және оларды тереңірек түсіну қажеттілігіне қатысты.

Түйін сөздер: жасанды нейрондық желілер, сараптамалық жүйелер, нейрондық желілер, генетикалық алгоритмдер, зияткерлік агенттер.

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The multidimensional artificial neural networks of accounting

The artificial neural networks exert a significant influence on business processes through their capacity for automation and data integration. However, the unrestricted application of automated procedures entails risks that are particularly evident in the field of accounting. Multidimensional accounting systems are affected by expert systems, neural networks, genetic algorithms, and intelligent agents.

The research methodology was based on a mixed approach, combining quantitative and qualitative methods. In this study, a survey was conducted among professionals in the fields of accounting and auditing to assess the level of adoption of artificial neural network applications (an indicator of how well these professionals understand, trust, and apply neural networks in practice) and to determine their projected multidimensional impact on accounting. The results reveal the potential of neural networks to transform traditional accounting processes, enhance predictive capabilities, and support managerial decision-making in complex business environments. A range of statistical methods, including correlation and regression analysis, was employed to examine the relationship between the adoption of neural network applications and formal outcomes.

The findings revealed that the use of genetic algorithms is among the most significant and effective

quality. In contrast, expert systems, neural networks, and intelligent agents demonstrated no statistically significant effect on the quality of accounting data. The positive impact of genetic algorithms may be attributed to the professional and technological environment in Astana, which has not yet reached the maturity required for the effective implementation of more complex artificial intelligence technologies, but fosters the development of practical analytical tools.

The study concludes with a set of recommendations, the most important of which emphasize the need to deepen understanding and expand the adoption of artificial neural network technologies in accounting and auditing practice.

Keywords: artificial neural networks, analytical systems, neural networks, genetic algorithms, intelligent agents.

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Многомерные искусственные нейронные сети бухгалтерского учета

Искусственные нейронные сети оказывают существенное влияние на бизнес-процессы благодаря возможностям автоматизации и интеграции данных. Однако неограниченное применение автоматизированных процедур сопряжено с рисками, которые в наибольшей степени проявляются в сфере бухгалтерского учета. Многомерные системы бухгалтерского учета находятся под воздействием экспертных систем, нейронных сетей, генетических алгоритмов и интеллектуальных агентов.

Методология исследования основана на смешанном подходе, сочетающем количественные и качественные методы. В данном исследовании был проведён опрос среди специалистов в области бухгалтерского учёта и аудита с целью оценки уровня принятия приложений искусственных нейронных сетей (показателя того, насколько хорошо эти специалисты понимают, доверяют и применяют нейронные сети на практике) и определения их предполагаемого многоаспектного влияния на бухгалтерский учёт. Результаты демонстрируют потенциал нейронных сетей в трансформации традиционных бухгалтерских процессов, повышении прогностических возможностей и поддержке управленческих решений в условиях сложной бизнес среды. Для анализа взаимосвязи между уровнем принятия технологий и формальными результатами применялись статистические методы, включая корреляционный и регрессионный анализ.

Результаты исследования показали, что использование генетических алгоритмов является одним из наиболее значимых и эффективных приложений искусственных нейронных сетей, способствующих повышению качества учетной информации. В то же время влияние экспертных систем, нейронных сетей и интеллектуальных агентов на качество учетных данных не выявило статистической значимости. Положительный эффект генетических алгоритмов может быть обусловлен профессиональной и технологической средой в г. Астане, но пока не достигла зрелости, чтобы внедрять самые сложные технологии искусственного интеллекта, необходимого для широкого внедрения более сложных технологий искусственного интеллекта, но способствует развитию практических инструментов анализа.

Исследование завершается формулировкой ряда рекомендаций, ключевыми из которых являются углубление понимания и расширение практики применения технологий искусственных нейронных сетей в бухгалтерском учете и аудите.

Ключевые слова: искусственные нейронные сети, аналитические системы, нейронные сети, генетические алгоритмы, интеллектуальные агенты.

Кіріспе

Жаңа дәуірде, бухгалтерлік есептің көп өлшемді жасанды нейрондық желілері – бұл әртүрлі секторларда қолданылатын технология. Осындай жаңа технологиялар нейронды желіні дамытатын инновациялар болып саналады. Фирмалар бухгалтерлік есептегі жасанды нейронды желілермен тәжірибе жасап жатыр, бірақ ол әлі нақты тапсырмалар үшін қолданылмады. Бүгінгі күні, цифрлық транзиттік экономикада жасанды нейрондық желімен жұмыс істейтін роботтар белгілі бір фирмаларға пайдалы болуы мүмкін, бірақ бұл олардың жұмыс жасайтын саласына байланысты. Айталық, зауытта әртүрлі өнім түрлерін жасайтын компания адамдарға қарағанда арзанырақ және ұзағырақ жұмыс істей алатын жасанды нейрондық желіге бағдарламаланған роботты таңдай алады (Akinadewo, 2021).

Бухгалтерлік есепте жасанды нейронды желілер енгізу үрдісі қаржылық мәліметтерді заңдылықтар мен ауытқуларды анықтау үшін машиналық оқыту алгоритмдерін пайдалануды қамтиды. Айталық, жасанды нейронды желілер негізіндегі белгіленген жүйелер нормалардан ауытқитын қаржылық транзакцияларды талдап, алаяқтықты анықтай алады. Бұдан басқа, бухгалтерлік есептегі жасанды нейронды желілер, салықтық есептер және қаржылық есептілікті жасақтау барысындағы міндеттерді автоматтандыруға мүмкіндік береді. Ол тиімділікті арттырып қана қоймай, көбінесе қолмен есептеу процестерімен байланысты адам қателіктерінің қаупін де азайтады (Tontiset, 2022).

Бухгалтерлік есеп практикасы өз клиенттерінің ақшасымен жұмыс істеуді көздейді, онда бухгалтерлер этикалық нормаларды сақтауы және жауапкершілікте болуы тиіс. Сондықтан да этикалық және моральдық мәселелер бухгалтерлік есепті зерделеудің ағымдағы бағдарламаларында маңызды аспект болып саналады және осындай болып қалуға тиіс (De Souza et al.,2020).

Бухгалтерлер үшін жасанды нейрондық желілер олардың бухгалтерлік есеп жүргізу әдістеріне қалай әсер етеді және ЖИ олардың жұмысын өз мойнына ала ала ма деген сұрақ қалып отыр.

Осы зерттеудің мақсаты – жасанды нейрондық желінің дамуы бухгалтерлік есеп практикасына қалай әсер етуі мүмкін екенін көрсету және Бухгалтерлік есептің тиімділігін арттырудағы жасанды нейронды желінің рөлін анықтау. Зерттеу міндеттері:

1) Жасанды нейронды желіні пайдалану бухгалтерлер қалыптастырған қаржылық есептіліктің сапасын жақсарту;

2) Жасанды нейронды желіні қолдану бухгалтерлердің консультативтік рөлін арттыру;

3) Жасына байланысты бухгалтерлік есепте жасанды нейронды желіні дайындауға және пайдалануға қатысты айырмашылықты анықтау;

4) Әртүрлі жыныс өкілдері арасында бухгалтерлік есепте жасанды нейронды желіні әзірлеуге және пайдалануға негіз ұсынылады.

Осы үрдістер мен салдарды жан-жақты түсіну бухгалтерлік мамандар мен ұйымдар үшін жасанды нейронды желіні пайдалануды оңтайландыруға, сонымен қатар, бухгалтерлік фирмаларға жасанды нейронды желіні қолданылатынын анықтауға және бухгалтерлер жұмысына жасанды нейрондық желіге әсерін анықтауға көмектеседі.

Әдебиеттерге шолу

Зерттеуде есеп пен есептіліктің тиімділігі бухгалтерлік ақпаратты және шешімдер қабылдау процесінде әртүрлі пайдаланушылар үшін пайдалы ұсынымдарды жасаудан тұрады. Бухгалтерлік ақпарат компания туралы дұрыс түсінік беруі тиіс, ал деректер пайдаланушылар үшін өзекті болуы тиіс (Akinadewo, 2021).

Зерттеушілер арасында жасанды нейронды желіні енгізуде құралдарды пайдалануда да, міндеттерді қолдануда да шектеулі болып қалуда. Олардың көпшілігі ашық жасанды нейронды желілер ChatGPT-мен таныс, бірақ басқа ЖИ генерациялық құралдарымен таныс емес (Tontiset, 2022).

Қаржылық есептілікті дайындау кезінде туындауы мүмкін ықтимал адами көзқарастар туралы зерттеулер жүргізді. Адамдардың табиғатында кейде бейсаналық немесе байқаусызда шешім қабылдау мүмкіндігі бар. Мұндай шешімдер орын алған кезде белгілі бір бухгалтерлік қызметке әсер етуі мүмкін. Біржақтылықтың мысалы ретінде бухгалтерлердің клиент туралы ешқандай деректері немесе байланысы жоқ пікірі бар екенін келтіруге болады. Біржақтылықтың бірнеше түрлері бар және бухгалтерлік қызметте бұл жағымсыздықтарды анықтау қиын. Қаржылық есептілікті оларды әртүрлі мақсаттарда пайдаланатын әртүрлі пайдаланушылар пайдаланады. Аталған мәлімдемелер жоғары сапалы және пайдаланушылар үшін қатесіз болуы керек (De Souza et al., 2020).

Кейбір классикалық бухгалтерлік есеп мәселелерін жасанды интеллект арқылы шешуге болады. Екі зерттеу де бухгалтерлік есепте жасанды интеллектті қолдануға және жасанды интеллектті пайдаланудан туындайтын көптеген мүмкіндіктерге бағытталған. Бухгалтерлік есеп деректерге қатты тәуелді, ал ол деректерді түрлендіру көп уақытты және еңбекті қажет ететін қолмен енгізуді қажет етеді. Жасанды интеллектті қолданудың мысалы – деректерді алуды автоматтандыратын бағдарлама, онда адами қателіктерді және деректерді алуға қажетті уақытты азайтады. Жасанды интеллект бұл тапсырмаларға қажетті уақытты қысқартады және адами қателіктерді азайту арқылы деректердің сапасын оңтайландырады (Yi et al., 2023)

Бухгалтерлер уақытты қажет ететін белгілі бір жалықтыратын міндеттерге тап болады. Сол міндеттердің көпшілігі қаржылық есептерді немесе кеңестерді жасау үшін деректерді түрлен-

діруге немесе талдауға қатысты (Hashem, 2021). Жасанды интеллект белгілі бір жалықтыратын міндеттерді тезірек орындау үшін пайдаланылуы мүмкін, ол шығындарды азайтады және басқа міндеттерге жұмсалатын уақытты арттырады (Kommunuri, 2022).

Қазақстан Республикасының Президенті Қасым-Жомарт Тоқаев білім мен инновацияға негізделген экономиканы қалыптастырудың стратегиялық маңызын атап өтті. Бұл бағытта адам капиталының сапасын арттыру, цифрлық технологияларды енгізу және жасанды интеллектті дамыту негізгі басымдықтар ретінде қарастырылуда. Қазақстанның Еуразиядағы ірі цифрлық хабқа айналуы елдің геосаяси рөлін күшейтіп, халықаралық бәсекеге қабілеттілігін арттыруға мүмкіндік береді (Тоқаев, 2025).

Жаңа технологияларды енгізу, көбінесе нарықтық бәсекеге қабілеттілікті қолдау үшін стратегиялық қажеттілік ретінде қарастырылады (Kumar, 2020).

Фирмалардың бәсекелестік артықшылықтары тұрақты емес, уақытша және қысқа мерзімді болып келеді (Luan et al., 2020).

Жасанды нейронды желілер саласындағы инновацияларды енгізу барысында салалық құрылымдарды өзгерте алады, бәсекелестік ережелерін қайта ойластыра алады, бәсекелестерден асып түсу үшін жаңа әдістерді қолдана алады және сайып келгенде бәсекелестік ортаны өзгерте алады (Nguyen et al., 2022).

Зерттеушілер өз ұсыныстары мен қызметтерін жақсартуға жасанды нейронды желілер жаңа технологияларын тиімді пайдаланатын компаниялар бәсекелестікке басымдық танытуы (Zhang et al., 2023).

«Жасанды нейрондық желілер» ұғымына жан-жақты түсінік берілді, оларды зерделеу негізінде бухгалтерлік есепте оның артықшылықтарын бөліп көрсеттік. Сондай-ақ, ұғымдарды жинақтай отырып, жасанды интеллектіні анықтау тереңдетілді.

Әдіснама

Зерттеу бухгалтерлік есептің жасанды нейрондық желілеріндегі көпөлшемділікті талдауға бағытталды. Мұнда сипаттамалық және аналитикалық тәсілдер қолданылды. Сипаттамалық әдіс нейрондық желілердің құрылымдық ерекшеліктерін жүйелі түрде сипаттауға мүмкіндік берсе, аналитикалық әдіс олардың тиімділігін бағалауға және көпөлшемділікке байланысты артықшылықтарын айқындауға жағдай жасады. Әдістерді үйлестіріп қолдану зерттеу нәтижелерінің сенімділігін арттырып, бухгалтерлік есепте жасанды нейрондық желілердің практикалық құндылығын нақтылауға мүмкіндік береді (Жолаева, 2023). Тақырыпты жан-жақты түсінуді қамтамасыз ету үшін сандық және сапалық әдістерді біріктіретін аралас әдіс-тәсіл арқылы жүзеге асырылды. Сандық деректер бухгалтерлік есеп және аудит мамандарына арналған құрылымдық сауалнама жүргізіліп жинақталды. Сандық нәтижелерді толықтыру және тереңдету үшін таңдалған қатысушылармен ашық жауаптар мен сұхбаттар арқылы сапалы ақпарат алынды.

Сауалнамадағы мәліметтерді жинаудың негізгі құралы, екі бөлімнен тұрды:

1) Демографиялық ақпарат (айталық, жасы, білімі, тәжірибесі, лауазымы);

2) Бухгалтерлік есептің көп өлшемді жасанды нейрондық желілер өлшемдерінің бухгалтерлік ақпаратқа әсерін өлшейтін есептер.

Жауаптар үшін 5 балдық Лайкерт шкаласы қолданылды:

1) мүлдем келіспеймін;

2) келіспеушілік;

3) бейтараптылық;

4) келісемін;

5) өте қатты келісемін.

Сауалнаманы сарапшылар Альфа Кронбахты пайдалана отырып, сенімділікті қамтамасыз етуге барлық өлшемдер үшін сенімділіктің қолайлы коэффициенттерімен қарастырылды, онымен қоса, сенімділікті тексеру үшін пилоттық зерттеу жүргізілді. Деректер SPSS көмегімен талданып келесі әдістер қолданылды (Cronbach, 1951):

- Сипаттамалық статистика;
- Сенімділікті талдау;
- Корреляциялық талдау;
- Регрессиялық талдау. Барлық гипотезалар $\alpha \leq 0{,}05$ маңыздылық деңгейінде тексеріп жүргізді.

Пирсонның корреляция коэффициенті жасанды интеллект қосымшаларының өлшемдері арасындағы байланысты зерттеу үшін пайдаланылды. Осындай статистикалық әдіс, өлшемдердің әрбір жұбы арасындағы сызықтық қатынастың беріктігі мен бағытын анықтауға көмектеседі. Корреляциялық талдау нәтижелері 1-кестеде келтірілген.

1-кесте – Корреляция коэффициенті

	Өлшемі	**Корреляциялық коэффициенті**	**Маңыздылық деңгейі**
1	Сараптама жүйесі	0,826**	0,00
2	Нейрондық желілері	0,899**	
3	Генетикалық алгоритмдер	0,881**	
4	Зияткерлік агенттер	0,837**	
Корреляция «($p \leq 0,01$) мәнділік деңгейінде статистикалық маңызды» болып табылады деген түжырым екі айнымалылар арасында шынайы байланыс бар деп болжай отырып, байқалатын корреляцияның кездейсоқ болуының өте төмен ықтималдығы (1% ≤) бар екенін білдіреді			
Ескерту: авторлармен (Cronbach, 1951) негізінде өңделді			

Алдыңғы кестеде тәуелсіз айнымалының барлық өлшемдері (жасанды нейронды желілер қосымшалары) бір-бірімен оң және айтарлықтай корреляцияланғандығы көрсетілген. Мұндай корреляциялар 0,01 деңгейінде статистикалық мәні бар болып саналады, мұнда, сонымен қатар, күшті ішкі жүйелілікті және өзара тәуелділікті көрсетеді.

Әртүрлі ақпараттан жинақталған деректерді талдаудың әдістерін пайдалана отырып бағаланды. Зерттеу деректерді сипаттамалық талдауды, қалыпты тестіні, валидтілікті талдауды, сенімділік тестін талдауды қамтиды. Сауалнама элементтерінің ішкі сәйкестігін бағалау үшін Кронбах Альфа пайдаланылды. Зерттеу айнымалыларының сенімділікті талдау – Кронбах Альфа сынақ (тест) нәтижелері, 2-кестеде бейнеленген.

Мұндағы, Кронбах Альфаға қатысты «параграфтар» термині тесттегі немесе масштабтағы элементтердің (сұрақтардың) санын білдіреді және ол санның көбеюі әдетте альфа мәнін арттырады.

2-кесте – Сенімділік коэффициенттері

Альфа сенімділік дәрежесі	**Параграфтар саны**	**Сауалнама тақырыптары**
0,672	4	Сараптама жүйесі
0,792	3	Нейрондық желілер
0,831	5	Генетикалық алгоритм
0,786	3	Интелектуалды агенттер
0,913	15	Жасанды нейронды желі қосымшасының жалпы саны
0,705	7	Жарамдылығы
0,741	5	Адал таза өкілдігі
0,746	4	Тексеру мүмкіндігі
0,874	2	Түсініктілігі
0,787	5	Салыстырмалығы
0,604	4	Мерзімі
0,931	27	Көпөлшемді жасанды нейрондық желідегі бухгалтерлік есептің жалпы сапасы
0,944	42	Жалпы сауалнама
Ескерту: авторлармен (Cronbach, 1951) негізінде өңделді		

2-кестедегі мәліметте, сенімділік пен дәйектіліктің өте жоғары деңгей болуы, яғни мәліметтерді жинақтау барысында сенімділік коэффициенті 0,944 болғанын көрсетті. Сауалнамадағы ақпарат зерттеу үшін сенімді және тиімді болды.

Нәтижелер мен талқылау

Жасанды нейронды желінің бухгалтерлік есепте енгізілуін бағалау үшін арифметикалық құралдар, стандартты ауытқулар және респонденттердің жауаптарының пайызы есептеліп, нәтижесі 3-кестеде келтірілген.

Кестеде жасанды нейронды желіні қолдану деңгейі көрсетілген, ол зерттеу үлгісі бойынша жоғары болды (арифметикалық орташа мәні 4,04, стандартты ауытқуы 0,636). Жасанды нейронды желілер қосымшаларының барлық өлшемдері әртүрлі деңгейде қол жетімді. Сараптамалық жүйелер бірінші орынға шықты (орташасы 4,4, стандартты ауытқуы 0,59). Екінші орынға генетикалық алгоритмдер (орташасы 4,07, стандартты ауытқуы 0,67). Үшінші орынды нейрондық желілер иеленді (орташасы 3,9, стандартты ауытқуы 0,81). Соңғысы интеллектуалды агенттер (орташа 3,9, стандартты ауытқу 0,89) болып келді.

Бухгалтерлік есептегі көпөлшемді жасанды нейрондық желілерде тәуелді айнымалының өлшемдерін сипаттамалық талдауын 4-кестеде көрсетілген.

3-кесте – Жасанды нейронды желінің арифметикалық орташа және стандартты ауытқуы

№	Өлшемі	Орташасы	Стандартты ауытқуы	Қол жетімділік деңгейі	Ранг
1	Сараптама жүйесі	4,4	0,59	өте жоғары	1
2	Нейрондық желілер	3,4	0,81	жоғары	3
3	Генетикалық алгоритм	4,1	0,67	жоғары	2
4	Интелектуалды агенттер	3,9	0,89	жоғары	4
Орташа		4,04	0,636	Жоғары	
Ескерту: авторлармен (Cronbach, 1951) негізінде өңделді					

4-кесте – Бухгалтерлік есептің көпөлшемді жасанды нейрондық желілер орташа мәні мен ауытқу сипаттамасы

№	Өлшемі	Орташасы	Стандартты ауытқуы	Қол жетімділік деңгейі	Ранг
1	Жарамдылығы	4,6	0,44	өте жоғары	2
2	Адал таза өкілдігі	4,4	0,56		3
3	Тексеру мүмкіндігі	4,3	0,56		6
4	Түсініктілігі	4,3	0,70		5
5	Салыстырмалығы	4,4	0,52		4
6	Мерзімі	4,6	0,49		1
Орташа		4,4	0,45		
Ескерту: авторлармен (Cronbach, 1951) негізінде өңделді					

Кестеде бухгалтерлік ақпараттың сапасы өте жоғары, орташа есептік мәні 4,4 және стандартты ауытқуы 0,45 болғандығы көрсетілген. Бухгалтерлік ақпарат сапасының өлшемдері әртүрлі орташа мәнін алды. Бірінші орынды уақыт өлшемінің орташа мәні 4,6 және стандартты ауытқуы 0,49 болатын иеленді. Екінші орынға жарамдылық өлшемі шықты, орташа мәні 4,51 және стандартты ауытқуы 0,44. Үшінші орында орташа есеппен 4,4 және стандартты ауытқуы 0,56 адал таза өкілдігі болды. Салыстыру өлшемі төртінші орынға орташа мәні 4,4 және стандартты ауытқуы 0,52. бесінші орында түсініктілік, орташа мәні 4,3 және стандартты ауытқуы 0,70.

Ақырында, алтыншы орынға тексеру мүмкіндік өлшемі болды, орташасы 4,3 және стандартты ауытқуы 0,56 болды.

Зерттеу гипотезалары бірнеше статистикалық әдістерді пайдалана отырып тексерілді, оның ішінде, қарапайым сызықтық регрессиялық талдау және сызықтық регрессиялық талдау. Сондай-ақ тәуелсіз үлгілердің t-тесті қатысушылардың жасанды нейронды желілердің бухгалтерлік есептегі көпөлшемділігін, сапасын зерттеу үшін пайдаланылды.

Негізгі гипотезада былай делінген: «Жасанды нейронды желілер қосымшаларын пайдаланудың маңыздылығы ($\alpha \leq 0,05$) деңгейінде бухгалтерлік есепке статистикалық тұрғыдан маңызды әсері жоқ».

Мұны тексеру үшін қарапайым сызықтық регрессиялық талдау жүргізілді. Регрессия нәтижелері ұсынылған және көпөлшемді жасанды нейронды желілер қосымшалары мен бухгалтерлік есеп арасында түсіндірілетін дисперсия дәрежесі 5-кестеде көрсетілген.

5-кесте – Сызықтық регрессиялық тесттің қарапайым нәтижелері (бухгалтерлік есептің көпөлшемді жасанды нейрондық желілер)

R корреляциялық коэффициенті	R^2 Детерминация коэффициенті	F – test	F маңыздылық деңгейі	Регрессияда (β) коэффициенті	T – test	T – маңыздылық деңгейі Ескерту авторлар тарапынан жинақталып, өңделді
0,567	0,322	25, 280	0,0	0,402	5,029	0,0
Ескерту: авторлармен (Cronbach, 1951) негізінде өңделді						

Кесте 5 мәліметтеріне сүйенсек, бухгалтерлік есептің көпөлшемді жасанды нейрондық желілерге R^2 детерминация коэффициенті 0,32-ден бастап статистикалық маңызды әсерін көрсетеді. Ал, F – 25,28 мәні мұны 0,05 деңгей мәнінде растайды. Бухгалтерлік есептің көпөлшемді жасанды нейрондық желілерге нәтижесі айтарлықтай оң әсер ететінін көрсетеді.

Яғни:

- Генетикалық алгоритмдер бухгалтерлік есепте жоғары тиімділік көрсетті;
- Сараптамалық жүйелер мен дәстүрлі нейрондық желілердің әсері шектеулі;
- Инфрақұрылымдық дайындық пен кадрлық әлеует толық әлеуетті іске асыруға жеткіліксіз;
- Жасанды нейрондық желілерді стратегиялық енгізу ұйымдардың тиімділігін арттырады;
- Қызметкерлерді оқыту және инфрақұрылымды дамыту – басты шарт.

Нәтижесі алдыңғы зерттеулермен, әсіресе бухгалтерлік есептің көпөлшемді жасанды нейрондық желілер тәжірибеде генетикалық алгоритмдердің тиімділігі туралы келісіледі (Page et al., 2021). Мұндай өлшем өзінің икемділігінің, талдамалық мүмкіндіктерінің және бухгалтерлік есептің нақты проблемаларына бейімделуінің арқасында басқалардан асып түсті (Zholayeva, 2025). Сараптамалық жүйелердің, нейрондық желілер мен зияткерлік агенттердің шектеулі әсері бухгалтерлік салада және инфрақұрылымдық шектеулермен байланысты болуы мүмкін. Осындай технологиялар озық жүйелерді, білікті қызметкерлерді және жетілген сандық экожүйені – жергілікті контексте әлі де жеткілікті дамымауы мүмкін элементтерді талап етеді (Жолаева, 2020).

Технологиялық дайындығы жоқ орталар жасанды нейронды желілер технологияларының барлық әлеуетін іске асырмауы мүмкін екенін атайды, ол айқындалған, зерттелген нәтижелермен растайды жіне де жасанды нейронды желілерді бухгалтерлік есеп практикасына стратегиялық енгізу қажеттігін атап көрсетеді (Hasan et al., 2023).

Қорытынды

Қорытындылай келе, зерттеуде бухгалтерлік есеп саласында жасанды нейрондық желілердің ықпалын далалық тәсіл арқылы бағалауға бағытталды. Нәтижелер көрсеткендей, нейрондық желілердің генетикалық алгоритмдері айтарлықтай оң әсерін тигізіп, практикалық бейімделгіштігімен ерекшеленді. Нәтижесінде:

- Генетикалық алгоритмдер бухгалтерлердің кәсіби қажеттіліктеріне сәйкес келіп, нақты пайдалы нәтижелер берді;

- Сараптамалық жүйелер, дәстүрлі нейрондық желілер және зияткерлік агенттер статистикалық тұрғыдан маңызды әсер көрсеткен жоқ;

- Астанадағы *Digital Bridge* алаңында жасанды интеллектті енгізу барысында инфрақұрылымдық күрделілік байқалды, бұл озық нейрондық желілерді тиімді пайдалануға шектеу қоюы мүмкін;

- Практикалық және бейімделетін құралдар бухгалтерлердің қабілеттерімен үйлесіп, нақты қолданбалы құндылыққа ие болды.

Алынған нәтижелер, жасанды нейрондық желілерді бухгалтерлік есепте қолдану олардың маңыздылығын дәлелдейді. Бұл технологияларды кеңінен енгізу үшін кәсіби дағдыларды жетілдіру, инфрақұрылымды дамыту және қызметкерлерді оқыту қажет. Сонымен қатар, жасанды нейронды желіге қатысты шығармашылық ізденісті жалғастыру, жаңа шешімдерді тәжірибеге енгізу елдің цифрлық даму стратегиясына сәйкес келеді.

Алғыс, мүдделер қақтығысы

Авторлар зерттеудің жүзеге асуына үлес қосқан барлық ұйымдар мен тұлғаларға, соның ішінде Зоя Нұртлеуқызы Ажибаева – Аудитор, «K&C Аудит Консалтинг» ЖШС және «Diamond consulting» (Даймонд консалтинг) ЖШС шынайы алғыс білдіреді. Авторлар осы мақалаға қатысты ешқандай қаржылық немесе жеке мүдделер қақтығысы жоқ екенін мәлімдейді.

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ELECTRONIC LEADERSHIP AND EFFECTIVENESS OF ORGANISATION DURING COVID-19 PANDEMIC IN SOUTH-WEST, NIGERIA

In a digitalised environment, achieving greater success require a technological driven leader who influence behaviour using advance information technology to ensure organisational effectiveness especially during COVID-19 Pandemic. However, this study investigated electronic leadership and organisational effectiveness during COVID-19 Pandemic, in selected Universities in South-west Nigeria, specifically, the study aims at analysing the role of electronic leadership on organisational effectiveness. Data collection was through structured questionnaire the research utilized simple random sampling techniques to select the study's respondent. Taro Yamane sample size formular was used to detemine the sampling size of seven hundred and thirteen (713) from the total population of one thousand eight hundred and forty-five (1,845). Descriptive and inferential statistic was the statistical tools that was adopted for the study. Bio-data of the respondents were analsed using descriptive statistics while the hypothesis was analysed using inferential statistics. Essentially, this study hypothesis was tested at 0.05 alpha level utilizing linear regression. The outcome of the study depict that electronic leadership significantly influenced orgnisational effectiveness ($R^2 = 0.038$, $\beta = 0.195$, $F_{(1,632)} = 24.977$, $p < 0.05$). The study concluded that electronic leadership significantly influenced organisational effectiveness. It was recommended that selected Universities should prioritize training their academic staff on the use of digital tools, virtual team management and remote management skills for improved organisational effectiveness and effective performance for future crisis.

Keywords: Electronic Leadership, organisational Effectiveness, COVID-19 pandemic.

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Нигерияның Оңтүстік-Батысында COVID-19 пандемиясы кезіндегі ұйымдастырушылық өнімділікті жақсартудағы электрондық басқарудың рөлін талдау

Цифрландырылған әлемде үлкен табысқа жету үшін, әсіресе COVID-19 пандемиясы кезінде ұйымдастырушылық тиімділікті қамтамасыз ету үшін озық ақпараттық технологияларды пайдалану арқылы мінез-құлыққа әсер ететін технологияға бағытталған көшбасшы қажет. Бұл зерттеуде Нигерияның оңтүстік-батысындағы университеттерде COVID-19 пандемиясы кезіндегі электрондық көшбасшылық пен ұйымдастырушылық өнімділік қарастырылады, яғни зерттеу электрондық көшбасшылықтың ұйымдық тиімділіктегі рөлін талдауға бағытталған. Деректер құрылымдалған сауалнама арқылы жиналды; респонденттерді таңдау үшін қарапайым кездейсоқ іріктеу қолданылды. Таро Яманенің іріктеу өлшемі формуласы іріктеу өлшемін анықтау үшін пайдаланылды, ол жалпы 1845 халықтың 713-ін құрады. Зерттеу үшін статистикалық құралдар ретінде сипаттамалық және қорытынды статистика пайдаланылды. Респонденттердің өмірбаяндық деректері сипаттамалық статистиканы қолдану арқылы талданды, ал гипотеза қорытынды статистиканы қолдану арқылы тексерілді. Зерттеу гипотезасы сызықтық регрессияны қолдану арқылы $\alpha = 0,05$ маңыздылық деңгейінде тексерілді. Зерттеу нәтижелері электрондық көшбасшылықтың ұйымдық өнімділікке айтарлықтай әсер еткенін көрсетеді ($R2 = 0,038$, $\beta = 0,195$, $F(1632) = 24,977$, $p < 0,05$). Зерттеуде электрондық көшбасшылықтың ұйымдық өнімділікке айтарлықтай әсер еткені туралы қорытынды жасалынды. Жеке университеттерге ұйымдық тиімділікті арттыру және болашақ дағдарыстарда тиімділікті арттыру үшін оқытушылар

дарды, виртуалды командалық басқаруды және қашықтықтан басқару дағдыларын пайдалануға үйретуге басымдық беру ұсынылды.

Түйін сөздер: цифрлық технологиялар, электрондық көшбасшылық, ұйымдастырушылық тиімділік, COVID-19 пандемиясы.

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Анализ роли электронного управления в повышении эффективности организаций в условиях пандемии COVID-19 на юго-западе Нигерии

В условиях цифровизации для достижения большего успеха необходим лидер, ориентированный на технологии, который влияет на поведение, используя передовые информационные технологии для обеспечения эффективности организации, особенно во время пандемии COVID-19. В данном исследовании изучалось электронное лидерство и эффективность организации во время пандемии COVID-19 в отдельных университетах на юго-западе Нигерии. В частности, исследование направлено на анализ роли электронного лидерства в эффективности организации. Сбор данных осуществлялся с помощью структурированной анкеты; для отбора респондентов использовалась простая случайная выборка. Для определения размера выборки использовалась формула размера выборки Таро Ямане, которая составила 713 человек из общей численности населения в 1845 человек. В качестве статистических инструментов исследования использовались описательная и инференциальная статистика. Биографические данные респондентов анализировались с помощью описательной статистики, а гипотеза проверялась с помощью инференциальной статистики. Гипотеза исследования проверялась на уровне значимости $\alpha = 0,05$ с использованием линейной регрессии. Результаты исследования показывают, что электронное лидерство оказало значительное влияние на эффективность организации ($R2 = 0,038$, $\beta = 0,195$, $F(1,632) = 24,977$, $p < 0,05$). Исследование пришло к выводу, что электронное лидерство оказало значительное влияние на эффективность организации. Было рекомендовано, чтобы отдельные университеты уделяли приоритетное внимание обучению своего преподавательского состава использованию цифровых инструментов, управлению виртуальными командами и навыкам удаленного управления для повышения эффективности организации и повышения результативности в условиях будущих кризисов.

Ключевые слова: цифровые технологии, электронное лидерство, организационная эффективность, пандемия COVID-19.

Introduction

The advent and transmission of COVID-19 has resulted in quick growth for numerous employees who work from home, with little time and resources to prepare this change (Maheshwari, et al 2024). COVID-19 also affected companies and individuals worldwide, posing new business challenges for organisations, such as working from home (Caligiuri, et al., 2020). Numerous studies have indicated that leadership has a greater impact on organisational effectiveness since the epidemic spread (Bailey and Breslin, 2021; Contreras, 2021). According to Atalan, (2020) global economic and social situations have been impacted by the COVID-19 Pandemic since 2019. Government across the globe promptly implemented measures to suppress the transmission rate by introducing measures like social distancing, reducing physical contact by implementing lockdowns and limiting community activities (Bonal. & Gonzalez, 2020). Consequently, the strain on economic conditions had a widespread effect in every region, coupled with conditions that were worse than before (Nyoma & Gede, 2023).

Meanwhile, organisation can only survive in a well-structured and crises free environment, but it is important to note that COVID-19 obstructed businesses and hindered organisations to be effective and efficient especially their decision-making process on account of the restriction (Oginni, Akpor-Robaro & Oghenetega, 2020). That notwithstanding, organisational effectiveness is the extent to which organisation has recorded a milestone achievement overtime. According to Mikelsone & Leila, (2016) organisational effectiveness can be characterized as multidimensional, and it has been realised that organisational effectiveness extends beyond the traditional predictors for success. However, numerous

variables have been identified to be an influencing factor of organisational effectiveness especially during COVID-19 but for the purpose of this study electronic leadership will be examined. Electronic leadership connotes the ability for an individual to use modern information technology to add value to an organization. (Avalio et al. 2000) initially introduced this notion, describing electronic leadership as a socially beneficial process mediated by AIT (advanced information technology) that results in a change in attitudes, feelings, thinking, behavior, and/or performance with people, groups, and/or organizations. They further claimed that electronic leadership may occur at any level of an organization, encompassing both one-to-one and one-to-many interactions via electronic platforms. This leadership style came to reality during COVID-19 where all businesses and institutions were short as result of the pandemic. Moreso, in the literature today, electronic leadership has been identified as e-leadership, electronic leadership and virtual leadership (Sunarsi et al, 2020: Restu and Wibowo, 2022: Nuha and Lim, 2022).

According to Ojo et al., (2024) electronic leadership is the ability to lead organisation successfully through digital transformation. Electronic leadership means leading by using advanced information technology to support the existing organisational structure. Carreño (2014) views electronic leadership as an influencing process mediated by AIT that leads to changes in results. Furthermore, it is a new leadership framework in which the head achieves goals of leadership through digital collaboration with teams spread across space and time, with the electronic intermediary supported by computers serving as the primary medium for interacting with leader(s) and followers. The new perspective brings new possibilities, challenges, and procedures (Carreño, 2014; Bush, 2020). Summarily, the reality of this lockdown and limitations on community and organisations activities affected the effectiveness and efficiency of all universities in Nigeria, at the same time, it led to total lockdown and switch to virtual leaning especially in Southwest, Nigeria.

Statement of the Problem

COVID-19 opened the eyes of many organisations to new style of work. Despite the fact that the pandemic threatens life and businesses the threatening resulted to new business model which is normal such as working from home, hybrid work and flexible work arrangement. These work arrangements may not be easily practiced without technological driven individual. The ability for this individual to navigate and influence behaviour using technological tools to connect employees far and near and ensure goals are met is refers to electronic leadership. According to ElSawy et al., (2016) electronic leadership is a new forms of communicating and organising, but this is far different from physical or traditional leadership such as transactional, democratic, autocratic etc. reason been that it is not limited with space and time and emphasis on the use of digital asset and technologies. Despites it again, many organisations still find it difficult to practice it during the pandemic; this affected the effectiveness and efficiency of many organisation. Poor knowledge of technology, negative attitude toward technology and poor perception of technology may be the reason for not adopting electronic leadership (Ojo & Odebode, 2022).

However, it is important know that study of this nature is scanty, for instance, Ojo et al., (2024) examined the role of electronic leadership style on employees work engagement, Elyousfi and Amitabh (2021) analysed the effect of virtual leadership with collaboration on remote collaborative effectiveness in a public organization, Noor and Suhair (2022) investigated the role of electronic leadership in the effectiveness of organisation management. It is based on this the study investigated electronic leadership and organisational effectiveness during COVID-19 Pandemic in South-west Nigeria.

Research Question

To what extent will electronic leadership influence organisational effectiveness during COVID-19 in selected universities in Southwest, Nigeria?

Research Objective

The objective of the study is to investigate electronic leadership and organisational effectiveness during COVID-19 in selected universities in Southwest, Nigeria.

Research Hypothesis

Electronic leadership will not significantly influence organisational effectiveness during COVID-19 in selected Universities Southwest, Nigeria.

Literature review

Concept of Electronic Leadership

Electronic leadership is the effective utilization and integration of electronic and conventional means of disseminating information. According to Odebode et al., (2024) electronic leadership is the style of leadership that operates in multiple dimensions using technological tools. It comprises being aware of current information communication

technology, strategically adopting new information communication technology for oneself and the company, and demonstrating technical competency in the ICTs selected (Wart et al 2016). As a result, effective e-leadership does not necessarily imply using more ICTs; rather, it entails using ICTs when they are beneficial for various reasons, using the most appropriate and effective ICTs available in relation to the value of various resources, using physically present communication channels when appropriate, and using ICTs effectively, such as when we would distinguish a good face-to-face speaker from a poor one on a variety of grounds. Competent e-leaders use a range of information and communication technologies in an array of environments, but they also incorporate them with in-person techniques, identify the most effective ones for the right uses, and are proficient in their usage (Wart et al., 2016).

Researchers such as Rudito and Sinaga (2017) and Oberer and Erkollar (2018) have diverse perspectives on the issue of electronic leadership. Some researchers define electronic leadership as giving direction and instructions over the Internet (Holtmann, 2011). Also, dgital leadership was described as the ability of a leader to use cutting-edge information technology to influence people's and groups' attitudes, feelings, ideas, behaviours, and performance. According to Caulat (2010), virtual leadership is the phenomena of one individual purposefully influencing other members of an organization in a setting where most interactions take place over the phone and through computers.

Concept of Organizational Effectiveness

Organizational effectiveness has been referred to as one component of organizational performance as it is the degree to which a particular organization is accomplishing its planned goals and objectives, or, to put it succinctly, goal achievement (Lee, 2003). Lewin (2000) expounded on the notion of organizational effectiveness, stating that it is a term that is nearly universally employed by academics and is among the most extensively studied topics since the inception of organizational theory. Despite considerable consensus, there is still a great deal of variation in how this idea is operationalised. The method of achieving goals without wasting organizational resources is known as organizational effectiveness. Organizational effectiveness, corresponding to management scholars, has been described as setting objectives, allocating resources, and assessing if the objectives were accomplished.

According to Yankey et al. (2003), organisational effectiveness is established by how well it performed during the process and how successfully it accomplished its stated goals. Additionally, Malik et al. (2011) revealed that organizational effectiveness is a condensed notion that is nearly impossible to quantify. The organization adopts proxy measures that may be used to indicate efficiency in place of using its own metrics to assess performance. However, it is important to note that effectiveness of staff of universities depend on the approach of leadership introduced during crisis. Electronic leadership has been proven effective and efficient especially during crisis (Noor and Suhair, 2022). Electronic leadership enhances organisational effectiveness by enabling faster communication, greater flexibility and improved collaboration. Sunarsi et al., (2020) noted that organisational effectiveness is a modern context increasingly depend on leader's ability to integrate electronic tools with sound leadership behaviours to drive performance and long-term success.

Theoretical review

The underpinning theory for this study was Adaptive Structuration Theory (AST) which was initially proposed by Giddens (1984), but its most influential development came from DeSanctis and Poole (1994). The theory emerged from Giddens' Structuration Theory, which focuses on the interplay between individual actions and social structures. DeSanctis and Poole adapted Giddens' ideas to explain how information technology is used in organizations and how it shapes and is shaped by organizational structures. AST primarily focuses on understanding how individuals and groups use, interpret, and adapt technological structures, emphasizing that technology and organizational structures are co-constructed through social practices. The theory suggests that technology both influences and is influence by social action, emphasizing human agency in shaping technological outcomes. AST is grounded in several key assumptions, one of which is the concept of human agency. It assumes that individuals within an organization are not passive recipients of technological systems, but rather active agents who interpret and adapt technology to fit their needs (DeSanctis & Poole, 1994). Additionally, AST assumes that structures whether technological or social are neither fixed nor deterministic. Instead, they are seen as dynamic and subject to change through the continuous interaction between human actors and technology. It also assumes that technology is not inherently good or bad; its impact on organizations depends on how it is used. Lastly,

AST proposes that both social structures (such as organizational norms) and technological systems (such as software or hardware) must be understood in their interdependent relationship to explain organizational behaviour and change. The adoption of ICT for teaching, research and administration remains a challenge, applying AST it offers a theoretical view to understand how electric leadership influence the effectiveness of organisation. This connection underscores that effective electronic leadership in Nigerian universities must be adaptive and context-sensitive, guiding the iterative shaping of technology and organisational structure.

Empirical review

Electronic leadership and Organizational Effectiveness

Nuha and Lim (2022) carried out a research on Effectiveness, electronic leadership styles and Skills in E-Business. This study examined effectiveness of e-leadership and skills in e-business and how it influenced performance of employees. Aualitative techniques accompany with secondary means of data collection was employed. Also, open ended questionnaire was created to collect data from the respondent which serves as primary means of data collection. The result of the study revealed that coaching in electronic leadership is the most effective style to increase effectiveness. The study therefore concluded that training, skills, experience are encouraged for effective practices of team to ensure organisational goals are met. Bandana et al., (2018) investigated leadership role and effectiveness which was carried out on food processing company in India. The aim of the study was to examine the relationship between various leadership styles and organisational effectiveness in india food processing companies. Primary source of data collection was employed using structured questionnaire. the sample size consists of two hundred and twenty-seven (227) was used for the study. Study's outcome showed that employees leadership style and supervisor had a positive impact on organisational effectiveness in an Indian processing food industry. The study concluded that strong relationship exists between leadership style and effectiveness of organisation.

The influence of electronic leadership style, service of organisation effectiveness in Indonesian school was carried out by Sunarsi et al., (2020). The study adopted qualitative research method using smart PLS version 3.0 as a processing tools. Online questionnaire was used to collect data using snowballing sampling techniques. The result of the study shows electronic leadership, organisational effectiveness and quality service significantly impacted the performance of teachers in Indonesian schools. Conclusion of the study stated that electronic leadership, effectiveness of organisation and quality service influenced the performance of teachers in Indonesia significantly. The study concluded that e-leadership, organizational commitment and service quality significantly influence school performance. Leidner (2017) examine effectiveness of leadership in global digital team. Purpose of the study was to identify factors related to effective team leadership in digital team environment. The use of secondary means of data collection was adopted for the study. Effective team leaders were able to handle paradox and contradiction by balancing different leadership responsibilities, according to the study's findings. It was concluded that detailed and prompt communication should be embraced. The work of Oginni, Ayantunji, Lanre-Babalola, and Balogun (2022) on employee silence and industrial conflict in unionized organisations using Lagos State as the unit of analysis corroborated this, however, drew the attention of leaders to the silence from employees to avoid hoarding of information that may be inimical to the overall survival of the organisation.

Noor and Suhair (2022) investigated the effect of digital leadership in the effectiveness of managing organisation. The study adopted the descriptive exploratory approach, 160 respondents were sample, the study adopted questionnaire, personal interview to collect data from the respondents. The result revealed a strong statistical influence of electronic leadership on effectiveness of organizational management. It was concluded that digital insight came in with the highest score among the dimensions of the study for all variables.

Elyousfi and Amitabh (2021) examined how team dynamics and electronic leadership affected the success of virtual teams at a public company. The convenient sample and snow bow sample were used for the purpose of this research. The study population stood at two hundred and twenty-two (224). According to the study's findings, electronic leadership significantly impacted the quality of the job. It was concluded that electronic leadership significantly influenced work engagement. Ojo et al., (2024) investigated the influence of digital leadership on engagement of employees in Uniosun. Structured questionnaire was the major means of collecting data from the respondents, 117 respondents participated in the study, collected data was analysed by

using descriptive statistics and inferential statistics. The statistical tool that was used was T-test which was used to run the analysis. It was therefore concluded that employees work engagement will increase when trust of a leader and effective communication of leader were adopted in the organization since the study recorded positive influence of digital leadership on engagement of employees.

Odebode et al., (2024) investigated influence of digital leadership on organizational effectiveness among staff of private university in Ogun State, Nigeria. The aim of the study was to examine how electronic style of leadership influenced the effectiveness of organization during COVID-19 pandemic. The research design adopted by the study was ex post-facto research design. Data was collected using structured questionnaire. Simple random sampling technics was used to select respondents. The study utilised descriptive and inferential statistics to analyse the data collected. The findings revealed that electronic leadership significantly influenced the effectiveness of organisation during COVID-19.

Methodology

Ex-Post Facto research design was considered appropriate for the study. The study area consists of three (3) selected Universities in South-west Nigeria namely, University of Lagos Akoka, Lagos State, Osun State University, Osogbo and Covenant University, Ota. The target population comprises of academic staff. The justification for chosen these universities was base on the fact that academic activities were carried out virtually. Majorly online during COVID-19. The population stood at one thousand eight hundred and forty-five (1,845). This figure was gotten from administrative department of the selected universities, simple random sample techniques and stratified sample techniques was adopted to select respondents, the entire sample size of the study was seven hundred and thirteen (713) using Taro Yamane sample size formular. The methods of data collection were structured questionnaire which was divided into three parts namely: the first part focused on the socio-demographic characteristics of the respondent, the second section of the questionnaire entails information on electronic leadership developed by (Elyousfi et. al., 2021) this scale has five likert rating scale from Strongly Disagree (SD) to Strongly agree (SA) with reliability coefficient of 0.78. The third section of the questionnaire comprises of information on organisational effectiveness developed by Trierweiller, (2012) the scale consisted of five-point rating scale with Cronbach ‘s alpha of 0.91 as reported by the author of the scale. A pilot study was conducted on the two scales to make sure the instrument consistently measures the variables it meant to measure. Both descriptive and inferential statistics were adopted to analyse the data collected. Descriptive was used to analysed the respondent information while inferential statistics was adopted to analysed the stated hypothesis, specifically, linear regression was used to analysed the hypothesis at 0.05 significant levels.

Results and discussion

Hypothesis Testing

Electronic leadership will not significantly influence organisational effectiveness in selected Universities South-west, Nigeria.

Table 1 – A Summary Table Showing the F ratio of the Predictive Influence of Electronic Leadership on Organisational Effectiveness

ANOVAa						
Model	Sum of Squares	df	Mean Square	F	Sig.	
1	Regression	13982.169	1	13982.169	168.368	.000b
Residual	52484.727	632	83.045			
Total	66466.896	633				
a. Dependent Variable: ORGANISATIONAL EFFECTIVENESS						
b. Predictors: (Constant), ELECTRONIC LEADERSHIP						

Source: Source: Author ‘s Field Survey (2024)

Table 1 above revealed a significant prediction of organisational effectiveness by the electronic leadership variable. The F-statistic of F(1, 632) = 168.368, with a significant value which is less than 0.05, signifies that the entire regression model demonstrates a high level of statistical significance in terms of its goodness of fit. This is supported by the fact that the calculated F-statistic (Fcal) surpasses the critical F-value (Ftab). This result therefore, suggests that electronic leadership significantly explains variance in organisational effectiveness. This showed that with the introduction of electronic leadership during COVID-19 the effectiveness of staff in selected universities increases.

This study evaluated electronic leadership and organisational effectiveness during COVID-19 Pandemic in selected University Southwest, Nigeria. The first hypothesis stated that electronic leadership will not significantly influence organisational effectiveness during COVID-19 in selected Universities Southwest, Nigeria. However, the results showed that electronic leadership will significantly influence organisational effectiveness in selected Universities South-west, Nigeria. The findings concur to the outcome of the research of Maheshwari, et al, (2024), who affirmed that electronic leadership style was positively significant to employee work outcomes in higher education sector during COVID-19 and beyond in Vietnam. Also, the findings of Odebode et al., 2024 concur with this study.

Conclusion and recommendations

This study has examined the importance of electronic leadership on organizational effectiveness during the COVID-19 pandemic. The pandemic acted as a catalyst for organisations to rapidly shift to digital platforms, remote work, and virtual leadership, providing a unique context to explore how electronic leadership affects employee outcomes in a crisis scenario. The critical role played by electronic leaders especially, during uncertainty like the COVID-19 Pandemic in shaping organisational effectiveness as revealed by the study. Therefore, the study recommended that management of the selected Universities should prioritise training their academic staff on using electronic equipment, virtual team management and remote management skills for improved organisational effectiveness. Also, the management of the selected universities should equip their staff with technological tools so as to be effective and efficient during and post crisis.

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FEATURES OF THE IMPLEMENTATION OF ESG PRINCIPLES IN THE CORPORATE GOVERNANCE SYSTEM OF CENTRAL ASIAN COUNTRIES

The article examines the specific features of implementing ESG principles into the corporate governance systems of Central Asian countries. The relevance of the topic is determined by the need to adapt the national economies of the region to global sustainable development requirements and to increase the transparency of corporate reporting. The aim of the study is to identify institutional differences, barriers, and factors affecting the effectiveness of ESG transformation in the corporate sector of Central Asia.

The methodological basis of the study includes systemic, comparative-analytical, and institutional approaches, as well as content analysis of regulatory and legal acts, corporate reports, and statistical data from international organizations for the period 2019-2025.

The results showed that Kazakhstan has formed an institutionalized ESG model based on a developed sustainable finance infrastructure, Uzbekistan is implementing a state-centric model, while Kyrgyzstan, Tajikistan, and Turkmenistan are at the stage of institutional formation of the ESG agenda. The key barriers identified include a lack of ESG expertise, a weak regulatory framework, limited financial resources, and low business engagement.

The scientific value of the study lies in the development of a comparative model of ESG maturity for the region, while the practical significance lies in formulating directions for improving corporate governance and sustainable financing.

Keywords: ESG, corporate governance, sustainable development, Central Asia, sustainable finance.

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Орталық Азия елдерінің корпоративтік басқару жүйесіне ESG қағидаттарын енгізу ерекшеліктері

Мақала Орталық Азия елдерінің корпоративтік басқару жүйесіне ESG қағидаттарын енгізудің ерекшеліктерін зерттеуге арналған. Тақырыптың өзектілігі аймақ елдерінің ұлттық экономикаларын тұрақты дамудың жаһандық талаптарына бейімдеу және корпоративтік есептіліктің ашықтығын арттыру қажеттілігімен айқындалады. Зерттеудің мақсаты – Орталық Азияның корпоративтік секторындағы ESG-трансформацияның тиімділігіне әсер ететін институционалдық айырмашылықтарды, кедергілерді және факторларды анықтау.

Зерттеудің әдіснамалық негізі жүйелік, салыстырмалы-талдамалық және институционалдық тәсілдерді, сондай-ақ 2019-2025 жылдар аралығындағы халықаралық ұйымдардың нормативтік-құқықтық актілеріне, корпоративтік есептеріне және статистикалық деректеріне контент-талдау жүргізуді қамтиды.

Нәтижелер көрсеткендей, Қазақстан тұрақты қаржыландырудың дамыған инфрақұрылымына сүйенетін институционалданған ESG моделін қалыптастырды, Өзбекстан мемлекеттік-орталық моделін жүзеге асыруда, ал Қырғызстан, Тәжікстан және Түрікменстан ESG күн тәртібінің институционалдық қалыптасу сатысында тұр. ESG сараптамасының жетіспеушілігі, нормативтік базаның әлсіздігі, қаржылық ресурстардың шектеулігі және бизнестің төмен деңгейдегі қатысуы сияқты негізгі кедергілер де анықталды.

Зерттеудің ғылыми құндылығы аймақ үшін ESG жетілуінің салыстырмалы моделін әзірлеуде, ал практикалық маңыздылығы – корпоративтік басқару мен тұрақты қаржыландыруды жетілдіру бағыттарын тұжырымдауда көрініс табады.

Түйін сөздер: ESG, корпоративтік басқару, тұрақты даму, Орталық Азия, тұрақты қаржыландыру.

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Особенности внедрения принципов ESG в систему корпоративного управления стран Центральной Азии

Статья посвящена исследованию особенностей внедрения принципов ESG в систему корпоративного управления стран Центральной Азии. Актуальность темы обусловлена необходимостью адаптации национальных экономик региона к глобальным требованиям устойчивого развития и повышению прозрачности корпоративной отчётности. Цель исследования – выявить институциональные различия, барьеры и факторы, влияющие на эффективность ESG-трансформации в корпоративном секторе Центральной Азии.

Методологическая основа исследования включает системный, сравнительно-аналитический и институциональный подходы, а также контент-анализ нормативно-правовых актов, корпоративных отчётов и статистических данных международных организаций за 2019–2025 гг.

Результаты показали, что Казахстан сформировал институционализированную модель ESG, опирающуюся на развитую инфраструктуру устойчивого финансирования, Узбекистан реализует государственно-центричную модель, а Кыргызстан, Таджикистан и Туркменистан находятся на стадии институционального становления ESG-повестки. Выявленные ключевые барьеры – недостаток ESG-экспертизы, слабая нормативная база, ограниченные финансовые ресурсы и низкая вовлечённость бизнеса.

Научная ценность исследования заключается в разработке сравнительной модели ESG-зрелости для региона, а практическая значимость – в формулировке направлений совершенствования корпоративного управления и устойчивого финансирования.

Ключевые слова: ESG, корпоративное управление, устойчивое развитие, Центральная Азия, устойчивое финансирование.

Introduction

In the context of the global transformation of economic and managerial systems, the principles of sustainable development (Environmental, Social and Governance – ESG) are becoming an integral element of strategic planning and corporate governance. In recent years, the formation of ESG-oriented models has acquired particular significance for countries with emerging market economies, including the states of Central Asia. The region is characterized by a high dependence on resource-based industries, a significant share of carbon-intensive production, and limited access to sustainable development financial resources, which determines the need for a comprehensive implementation of ESG principles in corporate and public practice.

The choice of the research topic is due to the fact that, despite the growing interest in issues of sustainable development and corporate responsibility in the scientific and analytical literature, there is still insufficient elaboration of the comparative aspects of ESG implementation in Central Asian countries. Existing studies generally focus on individual elements of environmental or social policy, while the integration of ESG principles into corporate governance systems is considered only fragmentarily. Thus, a problematic situation arises, consisting in the absence of a comprehensive analysis of the factors, mechanisms, and peculiarities of implementing the ESG agenda in a regional context.

The relevance of the study is further reinforced by the fact that, amid increasing climate risks and international investors' demands for transparency in corporate reporting, the countries of Central Asia are compelled to adapt their corporate governance systems to the new principles of sustainability. On the one hand, Kazakhstan, as the most developed economy in the region, has demonstrated significant progress – the introduction of a national carbon trading system, the development of a "green" bond market, and the adoption of a strategy for achieving carbon neutrality by 2060 (Spankulova et al., 2025). On the other hand, Uzbekistan, Kyrgyzstan, Tajikistan, and Turkmenistan are only beginning to form the institutional foundations of ESG policy, facing barriers such as a lack of data, weak business motivation, and limited access to green financing (AIFC&GIP, 2024; Kabilovna & Nasriddinovna, 2024; Ismailakhunova et.al., 2025). These differences make the Central Asian region a unique platform for analyzing how corporate governance can contribute to the transition toward a sustainable development model.

The theoretical foundation of the study is formed by the works of domestic and foreign authors devoted to the problems of sustainable development,

corporate social responsibility, and institutional regulation of ESG practices. In particular, the studies of international organizations (UNDP, 2021) reflect general approaches to assessing ESG integration; however, the regional specifics of Central Asia remain insufficiently explored. The present study aims to fill this gap.

The purpose of the research is to identify the features of implementing ESG principles in the corporate governance systems of Central Asian countries, to determine institutional differences, key barriers, and factors influencing the effectiveness of ESG transformation.

To achieve this goal, the following objectives are set:

1. To analyze international and national approaches to the formation of ESG policies.

2. To conduct a comparative analysis of the degree of ESG principles implementation in the five countries of Central Asia.

3. To identify key factors determining differences in the level of ESG maturity of corporate governance.

4. To determine the role of government regulation, financial institutions, and business in promoting ESG initiatives.

5. To formulate directions for improving ESG practices in order to enhance the competitiveness and attractiveness of investment in the region.

The object of the research is the corporate governance systems of the Central Asian countries.

The subject of the research is the mechanisms, instruments, and specific features of implementing ESG principles within these systems.

The methodological basis is founded on systemic and comparative approaches, content analysis of regulatory and strategic documents, as well as the synthesis of analytical reports and statistical indicators.

The research hypothesis assumes that the effectiveness of ESG principles implementation in corporate governance directly depends on the level of institutional maturity of national economies, the development of sustainable financing instruments, and the interaction between the state and business within the ESG agenda.

The scientific novelty of the study lies in identifying the regional characteristics of ESG transformation in the corporate sector of Central Asia and in proposing a conceptual model for integrating ESG principles into corporate governance, considering the specifics of the region's socio-economic development.

The practical significance of the research is that the obtained results can be used in the development of national ESG strategies, corporate sustainability codes, as well as for educational and analytical purposes is assessing the maturity of ESG practices in developing economies.

Literature review

In recent years, the principles of ESG (Environmental, Social, and Governance) have taken a central place in the global sustainable development agenda, becoming the foundation of a new model of corporate governance and investment policy. Contemporary research demonstrates that the integration of ESG factors into company strategies contributes to the creation of long-term value, reduces investment risks, and increases business resilience to external shocks (Tariq, 2024). ESG transformation is viewed not only as an instrument of environmental and social responsibility but also as a factor that enhances the effectiveness of corporate governance and business transparency.

In academic literature, ESG is interpreted as a combination of ethical, economic, and managerial factors that influence enterprise development strategy. The shift from a profit-centric approach to a comprehensive consideration of environmental, social, and governance criteria is viewed as a necessary condition for sustainable growth (Luo et al., 2024). ESG is commonly conceptualized through three fundamental dimensions: environmental – related to emission reduction and resource efficiency, social – encompassing equality, human capital development, and labor rights, governance – linked to transparency and accountability in managerial decisions (Li et al., 2021).

Studies by foreign authors emphasize that the successful integration of ESG principles requires institutional support from the state, adaption of corporate governance mechanisms to ownership structures, and the implementation of reporting standards aligned with international systems such as GRI, SASB, and IFRS S1/S2 (Dinh & Calabro, 2018; Mahmood et al, 2018). It is also noted that board-level oversight and the integration of ESG indicators into strategic planning and risk management processes have become essential components of effective corporate governance (Rashid, 2018).

Empirical research confirms the relationship between ESG and increased innovation potential, transparency, and financial performance. Evidence shows that a high level of ESG disclosure contrib-

utes to improvements in both social and economic indicators of companies (Alsayegh et al., 2020). Similarly, research demonstrates that the integration of ESG principles into corporate practice enhances investor confidence and reduces the risk of corporate conflicts, particularly in developing market countries (Rasool et al., 2025).

International experience demonstrates that the implementation of ESG principles in corporate governance can be achieved through clearly structured regulatory mechanisms and standardized requirements for non-financial disclosure. For example, in the European Union, the regulatory framework includes the Corporate Sustainability Reporting Directive (CSRD), which obliges companies to treat sustainability as an integral part of corporate reporting (Miller, 2025). Companies falling under CSRD are required to disclose a wide range of ESG indicators – from greenhouse gas emissions and resource use to risk management, social policies, and corporate governance mechanisms – in accordance with the European Sustainability Reporting Standards (ESRS). These standards aim to ensure comparability, reliability, and materiality of ESG information, thereby strengthening the accountability of boards of directors and senior management for sustainable development (Leal Filho et al., 2025).

Japan represents another illustrative example of institutionalizing ESG disclosure within the corporate governance system. In 2022, the Sustainability Standards Board of Japan (SSBJ) was established and mandated to develop national sustainability reporting standards aligned with the international approach of the International Sustainability Standards Board (ISSB) (SSBJ, 2025).

In 2025, the SSBJ published the first national sustainability disclosure standards. The new package includes a general-purpose standard and two thematic standards – «General Disclosures» and «Climate-related Disclosures». These standards were designed to be functionally aligned with IFRS S1 and IFRS S2, ensuring the comparability of Japanese reporting with international practice.

An important milestone in the development of Japan's ESG regulatory system was achieved earlier, in 2023, when the Financial Services Agency (FSA) introduced a mandatory requirement for all public companies to include a sustainability-related section in their annual securities reports. These disclosures must correspond to the four key components recommended by the Task Force on Climate-related Financial Disclosures (TCFD): governance, strategy, risk management, metrics and targets (EY, 2023).

This set of reforms reflects Japan's transition from a hybrid «comply or explain» model to a more stringent and institutionalized system of ESG disclosure regulation. The creation of national SSBJ standards and the mandatory TCFD-aligned disclosures increase the transparency of corporate reporting, strengthen investor confidence, and establish conditions for long-term sustainable corporate governance (Schumacher et al., 2020).

Another example is the Korea Exchange (KRX) in South Korea, which in 2021 published ESG Disclosure Guidelines aimed at encouraging listed companies to provide ESG information. In recent years, the government and regulatory authorities have also taken steps toward a transition from voluntary to mandatory disclosure: key documents such as the K-ESG Guideline and the national K-Taxonomy have been developed, and the process of introducing mandatory ESG reporting and sustainable finance has begun (Matanle et al., 2025). South Korea's legislative measures are aimed at increasing transparency, reducing ESG-related greenwashing risks, and aligning corporate governance standards with international practice (IFRS Foundation, 2023).

A comparative analysis of these models shows that the EU's approach is oriented toward strict institutionalization – mandatory reporting, unified disclosure standards, double materiality of ESG risks, and board-level responsibility. In contrast, Asian models (Japan, South Korea) combine voluntary and mandatory measures, flexible regulation, market incentives, and a gradual expansion of coverage, making them more adaptable for companies in emerging economies.

The international experience demonstrates various institutional models of ESG integration, which form an important benchmark for assessing the maturity and development trajectory of ESG systems in Central Asia.

In the countries of Central Asia, the transition towards ESG principles is gradually moving beyond declarative statements and becoming an integral part of strategic management. Over the past five years, interest in sustainable development has significantly increased among government institutions, the financial sector, and corporate businesses (Devi et al., 2024). The growing importance of ESG is also linked to its role as a key indicator of corporate sustainability and investment attractiveness (Duque-Gristales & Aguilera-Caracuel, 2021). This trend is driven not only by the global emphasis on environmental and social responsibility but also by the growing dependence of national economies on

foreign investments, where ESG serves as a key criterion for assessing corporate sustainability and risk.

The region, however, is characterized by pronounced institutional heterogeneity. Kazakhstan acts as a leader, forming the regulatory, financial, and infrastructural foundation for the development of ESG practices (Kuanova et al., 2023). On Uzbekistan and Kyrgyzstan, the implementation process is carried out mainly through the adaptation of national strategies to the Sustainable Development Goals, with the support of international organizations (Cui et al., 2025). Tajikistan and Turkmenistan are at the initial stage of ESG agenda formation, where environmental and social policy issues are being integrated into broader economic modernization programs. Thus, the Central Asian countries demonstrate varying levels of ESG maturity, determined by a combination of internal reforms and external institutional pressure.

In the context of Central Asia, ESG initiatives acquire particular importance due to the region's structural challenges – climate vulnerability, resource dependence, and institutional heterogeneity. The Central Asian countries demonstrate varying levels of ESG system maturity: Kazakhstan and Uzbekistan are forming institutional platforms, Kyrgyzstan and Tajikistan are developing basic regulatory mechanisms, while Turkmenistan adheres mainly to declarative approaches.

Kazakhstan demonstrates the most significant progress in the region in promoting ESG principles. National companies are transitioning to a sustainable management model that combines economic and socio-environmental priorities. The country has established a "green" bond market, developed a carbon trading system, and adopted a strategy to achieve carbon neutrality by 2060 (Zinetullina et al., 2025). Despite this progress, research shows that key barriers remain insufficient ESG literacy, limited resources, and fragmented regulation, which require further strengthening of the institutional framework and wider involvement of small and medium-sized enterprises (SMEs) (Kuur et al., 2024). At the same time, the disclosure of ESG information in Kazakhstan's financial market remains largely voluntary and unsystematic, which reduces data reliability and hinders the formation of unified and transparent reporting (Azretbergenova et al., 2023).

In Uzbekistan, there is an observable shift from declarative ESG policies to their institutionalization (Shaislamova & Kudratova, 2024). Government programs stimulate the development of sustainable practices, partnerships are being established with international financial institutions, and specialized sustainability departments are being formed within the corporate sector. In Kyrgyzstan and Tajikistan, the ESG agenda is at an early stage of development, with the main focus on renewable energy, social protection, and climate change adaption (Komendantova et al., 2022). Turkmenistan is taking its first steps, focusing on energy efficiency and environmental modernization; however, institutional, and regulatory support remains limited.

The existing literature confirms the growing interest in ESG principles as an instrument of sustainable development but also highlights the need for further research aimed at a comprehensive comparison of national models for implementing ESG principles within the corporate governance systems of Central Asian countries. The present study fills this gap by focusing on institutional features, barriers, and mechanisms for adapting ESG practices in the regional context.

Methodology

The methodological basis of the study is founded on an interdisciplinary approach that combines theoretical, comparative-analytical, institutional, and empirical methods. The research was conducted in several stages, which ensured the systematic nature of the analysis and the reliability of the obtained results.

At the first stage, a theoretical and methodological analysis of the ESG concept was carried out in the context of sustainable development and corporate governance. Using the method of historicism, the evolution of the concepts of "sustainable development" and "ESG agenda" in global practice was traced. Content analysis of scientific publications and analytical materials made it possible to identify key approaches to assessing the effectiveness of ESG policies, as well as to reveal gaps in existing research related to the institutional characteristics of the Central Asia region.

At the second stage, empirical data were collected and systematized, including official national strategies, regulatory and legal documents, corporate ESG reports of leading companies from Kazakhstan, Uzbekistan, Kyrgyzstan, Tajikistan, and Turkmenistan, as well as analytical reviews by international organizations (UNDP, 2023, EDB) for the period 2019-2025. The collected materials were classified into three categories: environmental, social, and governance components of corporate management.

At the third stage, comparative-analytical and institutional methods were applied, allowing for the identification of the features of state regulation of ESG practices, the degree of business and financial institution involvement, and the differences in the level of institutionalization of ESG systems across the countries of the region. Content analysis of strategic and corporate documents made it possible to determine the priority directions of ESG integration and the key barriers to their development.

At the fourth stage, methods of statistical generalization and structural analysis were applied. There methods ensured the systematization of quantitative indicators such as the volume of investments in "green" projects, the share of companies publishing non-financial reports, indicators of carbon intensity, and the scale of development of sustainable financing instruments. The obtained data made it possible to identify trends in the formation of ESG institutions and to assess the dynamics of their development in a regional context.

The final stage included synthetic and interpretative analysis aimed at forming a comprehensive understanding of the influence of ESG principles on the corporate governance system and developing recommendations for their further implementation. The application of a systemic approach made it possible to consider ESG as interrelated components of a unified model of sustainable corporate development that ensures the integration of environmental, social, and governance factors into corporate strategy.

The methodological framework of the study is based on a combination of qualitative and quantitative methods that ensure the scientific validity and reproducibility of the results. The application of a multi-stage analysis made it possible to objectively assess the current state of the ESG agenda in the countries of Central Asia and to formulate the conclusions.

Results and discussion

Kazakhstan holds a leading position in Central Asia in the implementation of ESG principles and the development of sustainable finance infrastructure. The advancement of ESG is being carried out through legislative reforms, institutional mechanisms, and the active involvement of the financial sector. A key role is played by the Astana International Financial Centre (AIFC) and its Green Finance Centre (GFC), which account for approximately 80% of the regional green finance market. Between 2020 and 2024, the volume of sustainable financing in Kazakhstan reached UDS 1.389 billion, with the majority of bond issuances undergoing international verification. The Green Climate Fund (GCF) also contributes significantly to the development of green initiatives, supporting three projects with a total value of USD 173 million (AIFC&GIP, 2024).

Kazakhstan has also become the first country in the Commonwealth of Independent States (CIS) to implement a national carbon trading system, covering nearly half of all CO_2 emissions. The system includes 135 companies operating 212 facilities, making it one of the most advanced in the region (AIFC, 2025). Within the framework of the Strategy for Achieving Carbon Neutrality by 2060, investments totaling USD 610 billion are planned, reflecting the transition toward a low-carbon and innovation-driven economy (Zhakiyev et al., 2023). Kazakhstan demonstrates a strategic shift from a carbon-intensive model to an innovation-oriented and environmentally sustainable economy, making it a key actor in regional climate policy.

According to PwC (2024), Kazakhstan shoes the highest level of managerial engagement in ESG among Eurasian countries: in 69% of companies, ESG implementation is overseen by top management, in 52% by boards of directors, and one-third of companies already have specialized departments and committees. More than half of the companies have adopted ESG strategies, a quarter of which include specific KPIs. This indicates a transition from declarative measures to the systemic integration of ESG into corporate governance.

The combination of institutional support, financial sector engagement, and international partnerships forms a model in which Kazakhstan serves as a regional hub of ESG leadership, combining economic growth with climate responsibility.

In contrast to Kazakhstan, where the implementation of ESG principles is driven primarily by the private sector and financial institutions, in Uzbekistan sustainable financing is developing mainly within the framework of a state-centered model. The government acts as the main driver of ESG integration, employing tools of strategic planning, regulatory frameworks, and the issuance of sovereign bonds.

Uzbekistan issued bonds linked to the Sustainable Development Goals (SDGs), raising USD 235 million in 2021 for social and infrastructure projects (Jumaniyazov et al., 2025). In 2023, the country also mobilized around USD 337 million through debut

"green" bonds denominated in the national currency with the support of UNDP. In 2024, the Ministry of Finance issued two tranches of sovereign SDG bonds worth EUR 600 million and EUR 500 million, marking the transition to a regular practice of sustainable borrowing (Yudina, 2025). The increased investor interest reflects growing confidence in Uzbekistan's ESG instruments, despite the persisting country risk.

At the corporate level, a gradual formation of the private segment of sustainable finance is being observed. The institutional framework is also actively evolving. Uzbekistan became the second country in the region, after Kazakhstan, to develop its own taxonomy, thereby strengthening its position in shaping the regional green capital market.

According to PwC (2024), 46% of companies in the country demonstrate an understanding of ESG principles, although half of respondents assess their economic impact as moderate. Responsibility for ESG lies mainly with boards of directors and top management, while specialized structures remain underdeveloped – reflecting a transitional stage of corporate practice from declarative acknowledgment to institutionalization.

Although financial performance remains a business priority, growing attention is being paid to social issues such as working conditions, education, and employee safety, while the environmental component is being integrated more slowly. However, the expansion of government programs and international cooperation is creating favorable conditions for ESG-driven innovations.

Uzbekistan's model combines state leadership with the gradual involvement of the private sector, transforming ESG instruments into a foundation for economic modernization and strengthening investment resilience.

In the countries of Central Asia, where state institutions play a dominant role in regulating economic processes, the formation of the ESG agenda is progressing unevenly. Kyrgyzstan, Tajikistan, and Turkmenistan demonstrate an initial stage of institutionalizing sustainable development, with key attention focused on climate policy, energy transition, and the creation of elements of regulatory infrastructure. Unlike Kazakhstan and Uzbekistan, where sustainable finance has already acquired corporate and investment forms, is these countries ESG functions primarily as an instrument of governmental and donor-driven climate policy (Skolkovo, 2022).

In Kyrgyzstan, since 2023, the regulatory and institutional framework for sustainable finance has been under development. The National Bank approved the Roadmap for Sustainable Finance and the Implementation of ESG Principles, which provides for the integration of ESG risks into banking supervision, adaption to international reporting standards IFRS S1-S2 and ISSB, as well as strengthening the resilience of the financial sector. An important step was the adoption of the ESG Guide by the Kyrgyz Stock Exchange (KSE), compliance with which has become mandatory for public companies under the "comply or explain" principle. This decision promotes transparency and improves the quality of non-financial reporting, aligning the corporate sector with international GRI and SASB standards (Ismailakhunova et.al, 2025).

However, as noted by the European Bank for Reconstruction and Development, corporate governance maturity remains low: the number of independent board committees is limited, and non-financial reporting is often formal in nature. At the same time, the launch of the first sustainable finance instruments on the KSE and the preparation for the issuance of green bonds create the foundation for the development of the local ESG capital market. In the climate sphere, Kyrgyzstan has committed to reducing greenhouse gas emissions by 15.97% by 2030, which gives the ESG agenda a strategic orientation and links it to the country's national commitments under the Paris Agreement (Davtyan & Khachikyan, 2024).

In Tajikistan, the environmental component of ESG holds a dominant position due to the structure of the country's energy balance, in which more than 90% of electricity is generated by hydroelectric power plants (Kosowska & Kosowski, 2022). This dependence on hydropower resources simultaneously reduces the carbon footprint and increases climate risks associated with seasonality and glacial melting. According to the updated Nationally Determined Contribution (NDC), the country has committed to reducing greenhouse gas emissions by 30-40% unconditionally, and up to 50% with international support, by 2030. These goals are supported by plans to modernize major hydroelectric stations, improve energy efficiency, and develop sustainable agriculture. The National Bank of Tajikistan, together with international partners, is implementing initiatives for the introduction of sustainable finance principles; however, the absence of unified standards for non-financial reporting and the low level of corporate sector transparency limit the potential for attracting green investments. The main prospects are associated with the integration of ESG

criteria into large hydropower megaprojects, which could enhance their compliance with international environmental and social standards.

Turkmenistan remains one of the most closed economies in the region, where ESG integration faces significant institutional barriers. The country's economy continues to rely on hydrocarbon exports, which account for more than 90% of foreign currency revenues, creating a contradiction between economic priorities and environmental commitments (Iwaszczuk et al., 2021). In its updated Nationally Determined Contribution, Turkmenistan announced its intention to reduce greenhouse gas emissions by 20% by 2030 (Penjiyev, 2024). The country lacks both a national ESG strategy and stock market, which restricts the development of corporate reporting and transparency. Despite these limitations, the government has initiated several modernization efforts in the fuel and energy sector, with a particular focus on energy efficiency and the gradual adoption of renewable energy technologies. In cooperation with UNDP and the Global Environment Facility, Turkmenistan has launched a number of projects aimed at promoting energy-efficient practices and introducing solar energy solutions in selected sectors, signaling the country's cautions steps toward diversifying its energy mix and strengthening environmental management (UNDP, 2021; UNDP, 2023).

Common features for Kyrgyzstan, Tajikistan, and Turkmenistan include the fragmented nature of the regulatory framework, low engagement of the private sector, limited competencies in non-financial reporting, and dependence on international institutions. ESG development occurs mainly in the form of individual climate and energy initiatives, while corporate institutionalization remains at an early stage. At the same time, the formation of national taxonomies, the growing activity of central banks, and the involvement of international partners create the preconditions for a transition from project-based initiatives to a systemic model of ESG governance. These processes reflect the gradual integration of the countries into the regional architecture of sustainable development in Central Asia, where ESG is becoming an instrument for institutional modernization and enhancing investment attractiveness.

Despite the emergence of several progressive initiatives, the countries remain at an early stage of ESG transformation. The lag is determined by a combination of structural factors – limited institutional capacity, dependence on external financing, underdeveloped financial markets, and insufficient transparency of the corporate sector. In the context pf weak economic diversification and dominant state regulation, the ESG agenda is perceived more as an external requirement than as an internal managerial necessity, which slows down the formation of sustainable corporate practices.

Summarizing the analysis across the five countries of the region, it is possible to identify both common and specific features in the formation of ESG systems. Their comparative characteristics are presents in Table 1.

Table 1 – Comparative analysis of ESG maturity in Central Asia countries

Indicator	Kazakhstan	Uzbekistan	Kyrgyzstan	Tajikistan	Turkmenistan
Level of ESG maturity	High	Medium	Low	Low	Low
Type of ESG model	Institutionalized, market-oriented	State-centered, transitional	Emerging, regulated	Climate-centered, project-based	Declarative, resource-based
Corporate implementation	Broad implementation of ESG strategies and reporting under GRI and SASB standards	Expansion of ESG practices in the public and banking sectors	Initial stage, pilot projects and formal reports	Fragmentary implementation in energy and agriculture	ESG components limited to environmental initiatives of state-owned companies
Main ESG focus	Sustainable finance, decarbonization, corporate governance	Green and SDG binds, development of climate finance	Financial sector, climate adaption, green bonds	Renewable energy, water resource management	Energy efficiency, reduction of methane emissions
Note – complied by the authors based on the source (Skolkovo, 2022; AIFC&GIP, 2024)					

A comparison of the Central Asian countries makes it possible to distinguish three conditional levels of ESG practice maturity. Kazakhstan is forming a sustainable model with institutional support and active corporate participation; Uzbekistan is in the process of consolidating its regulatory and market framework; while Kyrgyzstan, Tajikistan, and Turkmenistan remain at the initial stage of implementation, relying mainly on external initiatives. This hierarchy is illustrated in Figure 1.

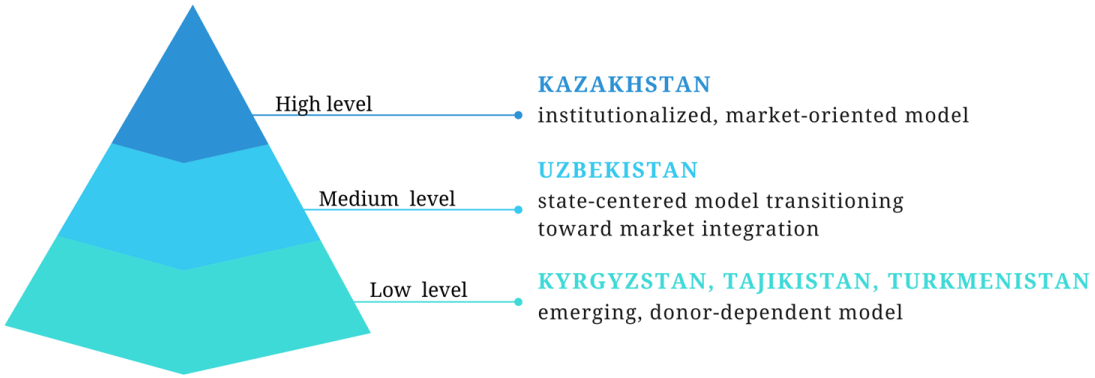

Figure 1 – Pyramid of ESG maturity levels in Central Asian countries
Note – complied by the authors

High level – Kazakhstan. The country has established an institutionalized ESG system that includes legally defined standards of sustainable finance, a functioning infrastructure through the AIFC, and active participation of the corporate sector. Kazakhstan demonstrates integration of ESG principles into corporate governance, strategic planning, and investment processes.

Medium level – Uzbekistan. This level is characterized by a transition toward a comprehensive ESG management model, where the state plays a key role in forming regulatory frameworks and stimulating the sustainable capital market through the issuance of sovereign and corporate bonds. The corporate sector is gradually becoming involved in the process of institutionalization.

Low level – Kyrgyzstan, Tajikistan, and Turkmenistan. In these countries, the ESG agenda remains fragmented, and the implementation of sustainable development principles depends mainly on international financial institutions and donor programs. Corporate practice is at an early stage, and the institutional framework is still in the process of formation.

To develop recommendations for improving the effectiveness of ESG integration in the Central Asian countries, key institutional barriers and corresponding measures to overcome them were identified (Table 2).

Table 2 – Key barriers to ESG implementation and recommended development directions in Central Asian countries

Country	Key barriers to ESG implementation	Recommended measures and development directions
Kazakhstan	– Lack of qualified ESG specialists – High cost of auditing non-financial reporting – Fragmentation of data-disclosure standards – Uneven ESG implementation among regional companies	– Introduction of a national certification system for ESG experts – Development of the domestic “green” bond market – Harmonization of reporting standards with GRI and IFRS S1/S2 – Support of regional ESG projects through grant mechanisms

Continuation of the table

Country	Key barriers to ESG implementation	Recommended measures and development directions
Uzbekistan	– Limited institutional coordination between ministries – Insufficient depth of corporate reporting – Weak participation of SMEs in ESG initiatives – Low liquidity of the sustainable-finance market	– Creation of a unified ESD-regulation center – Mandatory implementation of non-financial reporting for state-owned companies by 2026 – Competence-building programs for SMEs – Stimulation of the issuance of corporate ESG instruments
Kyrgyzstan	– Lack of unified statistical data and sustainability indicators – Weak regulatory framework – Dependence on donor financing – Limited resources of regulators and supervisory authorities	– Development of a green taxonomy and ESG methodological recommendations – Expansion access to ESG financing through development banks – Creation of ESG education centers – Institutional strengthening of regulators
Tajikistan	– Limited institutional capacity – Insufficient private-sector involvement – Lack of corporate reporting and systematic monitoring – Insufficient verification of ESG indicator data	– Integration of ESG principles into state energy and climate programs – Attracting the private sector through tax incentives – Creation of a national ESG register of companies – Support for independent auditing and monitoring
Turkmenistan	– Closed corporate sector – Lack of ESG regulation – High concentration of the economy in the hydrocarbon sector – Low transparency and data availability	– Development of a national ESG strategy – Expanding participation in international climate initiatives – Increasing transparency of state-owned companies in the energy sector – Creating an independent center for ESG statistics and monitoring
Note – complied by the authors		

The analysis revealed common institutional and human resource barriers for all countries in the region, with their nature and depth depending on the level of ESG maturity. Kazakhstan and Uzbekistan are focused on improving regulation and corporate instruments, while Kyrgyzstan, Tajikistan, and Turkmenistan are in the process of developing basic regulatory, educational, and analytical mechanisms. The implementation of the proposed measures will make it possible to build a phased model of ESG integration in Central Asia, considering national characteristics and sustainable development priorities.

Conclusion

The conducted study aimed to identify the specific features of ESG principle implementation in the corporate governance systems of Central Asian countries, as well as to analyze institutional differences, barriers, and factors determining the effectiveness of ESG transformation. To achieve this goal, systemic, comparative-analytical, institutional, and empirical methods were applied, ensuring the comprehensiveness of the analysis and the reliability of the conclusions. The methodological framework of the study was based on a combination of qualitative and quantitative tools, including content analysis of regulatory acts, corporate reports, and statistical data from international organizations for the period 2019-2025.

The results of the research confirmed the hypothesis that the effectiveness of ESG principle implementation in corporate governance directly depends on the level of institutional maturity of national economics, the development of sustainable financing mechanisms, and the degree of interaction between the state and business. The analysis showed that different models of ESG integration have been formed in the Central Asian countries, reflecting their economic and institutional characteristics.

Kazakhstan acts as the regional leader, having established a developed infrastructure of sustainable finance and a regulatory framework that includes carbon trading, a green bond market, and a strategy for achieving carbon neutrality by 2060. Uzbekistan implements a state-centered model in which the key role belongs to government institutions and international partners actively developing the market for ESG instruments. Kyrgyzstan, Tajikistan, and Turkmenistan are at the stage of ESG agenda formation,

where institutionalization processes remain fragmented and depend largely on international support.

The comparative analysis made it possible to identify three levels of ESG maturity:

- High level (Kazakhstan) – institutionalized, market-oriented model;
- Medium level (Uzbekistan) – state-centered model transitioning toward market integration;
- Low level (Kyrgyzstan, Tajikistan, and Turkmenistan) – emerging, donor-dependent model.

The study also identified a system of institutional and structural barriers characteristic of the region. For countries with a higher level of ESG maturity (Kazakhstan and Uzbekistan), the main challenges remain the need to standardize non-financial reporting, develop ESG expertise, and engage regional companies. For countries with a lower level of maturity (Kyrgyzstan, Tajikistan, and Turkmenistan), the key issues include limited institutional resources, a weak regulatory framework, dependence on donor programs, and low business involvement. Despite these differences, common challenges for all countries include a shortage of qualified personnel, insufficient ESG data, and the need to consolidate regulatory frameworks.

In this regard, the strategic directions for development are:

- Forming a unified approach to national ESG standards and harmonizing them with international systems (GRI, IFRS S1/S2);
- Developing human capital by training ESG specialists and creating national centers of excellence;
- Encouraging the corporate sector to adopt voluntary and then mandatory non-financial reporting;
- Developing a regional platform for cooperation and exchange of best practices in sustainable finance;
- Strengthening the role of financial institutions in promoting ESG instruments and climate investments.

Thus, the conducted study made it possible to summarize the features and levels of ESG institutionalization in the Central Asian countries, identify the patterns of their development, and outline the key directions for improving corporate governance in the context of sustainability. The obtained results contribute to the development of scientific knowledge about ESG transformation processes in emerging economies and can be used in the formulation of national ESG strategies, corporate sustainability codes, and educational programs.

Prospects for further research are associated with an in-depth analysis of the influence of ESG factors on companies' innovation activity, financial stability, and the investment attractiveness of the region, as well as with the development of integrated ESD maturity indices for monitoring the dynamics of corporate transformations. In the long term, the implementation of the proposed measures will make it possible to build an effective ESG management model that combines economic efficiency, environmental responsibility, and social justice, ensuring the transition of Central Asian countries toward a sustainable and competitive economy of the future.

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FIRM INTERNATIONALIZATION STRATEGY IN THE CONTEXT OF DIGITIZATION: MANAGERIAL INSIGHTS BASED ON AI INVESTMENT

Rapid digitalization has changed how firms organize production, manage information, and operate across national borders, raising growing interest in how digital technology shapes international expansion. While existing studies have discussed the role of digital transformation in firm performance, empirical evidence on how specific digital investments relate to firm internationalization remains limited, particularly in emerging-market contexts.

Using panel data from Chinese A-share listed companies between 2015 and 2024, this study examines the relationship between artificial intelligence (AI) investment and firm internationalization. A fixed-effects regression model is employed to account for unobserved firm heterogeneity, and a series of robustness checks are conducted to ensure the stability of the results. Firm internationalization is measured by overseas income, while AI investment captures firms' engagement in digital transformation.

The empirical results show that firms with higher levels of AI investment tend to generate greater overseas income, indicating a positive association between digital investment and internationalization. This relationship remains stable across alternative model specifications and sample adjustments. In addition, firm size and profitability are positively related to internationalization, suggesting that resource availability and financial capacity support overseas expansion. By contrast, firms experiencing rapid growth in the domestic market are less active internationally, reflecting potential trade-offs in strategic focus.

Overall, the findings provide firm-level empirical evidence on how digital investment relates to internationalization outcomes. The results also suggest that digital transformation is more likely to support international expansion when it is aligned with firms' resources, technological capabilities, and organizational structures, rather than treated as an isolated technological initiative.

Keywords: digital transformation, international management, artificial intelligence, internationalization strategy, Chinese firms.

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Цифрландыру жағдайындағы кәсіпорындардың интернационалдану стратегиясы: инвестициялар негізінде жасанды интеллектке басқарушылық қорытындылар

Жеделдетілген цифрландыру өндірісті ұйымдастыру, ақпаратты басқару және компаниялардың қызметін ұлттық шекарадан тыс жүзеге асыру тәсілдерін өзгертті, бұл цифрлық технологиялардың бизнестің халықаралық кеңеюіне қалай әсер ететініне қызығушылықты арттырды. Дегенмен қолданыстағы зерттеулер цифрлық трансформацияның компаниялардың тиімділігіне әсерін кеңінен талқылайды, нақты цифрлық инвестициялардың фирмаларды интернационалдандырумен қалай байланысты екендігі туралы эмпирикалық дәлелдер шектеулі болып қалады, әсіресе дамушы нарықтар жағдайында.

Бұл зерттеуде 2015-2024 жылдар аралығындағы А-акциялар нарығында тізімделген қытайлық компаниялардың панельдік деректері негізінде жасанды интеллектке (AI) инвестициялар мен компаниялардың интернационалдандыру деңгейі арасындағы байланыс талданады. Бақыланбайтын фирмалық гетерогенділікті есепке алу үшін тұрақты әсерлері бар регрессия моделі қолданылады, сондай-ақ алынған нәтижелердің сенімділігін растау үшін бірқатар тұрақтылық тексерулері жүргізіледі. Компаниялардың интернационалдандыру деңгейі шетелдік кірістер көлемімен өлшенеді, ал AI инвестициялары компаниялардың цифрлық трансформация процестеріне қатысу дәрежесін көрсетеді.

Эмпирикалық нәтижелер жасанды интеллектке инвестиция деңгейі жоғары компаниялар шетелдік кірістердің жоғары көлемін алуға бейім екенін көрсетеді, бұл цифрлық инвестициялар мен интернационалдандыру арасындағы оң байланысты көрсетеді. Бұл байланыс модельдердің

балама сипаттамаларын пайдалану және үлгіні түзету кезінде сақталады. Сонымен қатар, компанияның мөлшері мен оның кірістілік деңгейі интернационалдандырумен оң байланысты, бұл халықаралық экспансияны қолдаудағы ресурстармен қамтамасыз ету мен қаржылық мүмкіндіктердің рөлін көрсетеді. Сонымен қатар, ішкі нарықта жылдам өсуді көрсететін компаниялар халықаралық нарықтарда аз белсенділік танытады, бұл стратегиялық басымдықтарда ықтимал компаға келуді (trade-off) көрсетеді.

Жалпы алғанда, зерттеу нәтижелері цифрлық инвестициялардың компанияларды интернационалдандыру нәтижелерімен қалай байланысты екендігі туралы фирмалық эмпирикалық дәлелдер береді. Нәтижелер сонымен қатар цифрлық трансформация оқшауланған технологиялық бастама ретінде қарастырылмай, компанияның ресурстарымен, оның технологиялық мүмкіндіктерімен және ұйымдық құрылымымен келісілген жағдайларда халықаралық экспансияға көбірек ықпал ететінін көрсетеді.

Түйін сөздер: цифрлық трансформация, халықаралық менеджмент, жасанды интеллект, интернационалдандыру стратегиясы, Қытай кәсіпорындары.

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Стратегия интернационализации предприятий в условиях цифровизации: управленческие выводы на основе инвестиций в искусственный интеллект

Ускоренная цифровизация изменила способы организации производства, управления информацией и осуществления деятельности компаний за пределами национальных границ, что усилило интерес к тому, как цифровые технологии влияют на международную экспансию бизнеса. Несмотря на то, что в существующих исследованиях широко обсуждается влияние цифровой трансформации на эффективность деятельности компаний, эмпирические доказательства того, каким образом конкретные цифровые инвестиции связаны с интернационализацией фирм, остаются ограниченными, особенно в контексте развивающихся рынков.

В данном исследовании на основе панельных данных китайских компаний, котирующихся на рынке А-акций, за период 2015–2024 гг. анализируется взаимосвязь между инвестициями в искусственный интеллект (AI) и уровнем интернационализации компаний. Для учета ненаблюдаемой фирменной гетерогенности используется модель регрессии с фиксированными эффектами, а также проводится серия проверок на устойчивость для подтверждения надежности полученных результатов. Уровень интернационализации компаний измеряется объемом зарубежных доходов, в то время как инвестиции в AI отражают степень вовлеченности компаний в процессы цифровой трансформации.

Эмпирические результаты показывают, что компании с более высоким уровнем инвестиций в искусственный интеллект, как правило, получают более высокий объем зарубежных доходов, что свидетельствует о положительной связи между цифровыми инвестициями и интернационализацией. Данная взаимосвязь сохраняется при использовании альтернативных спецификаций моделей и корректировке выборки. Кроме того, размер компании и уровень ее прибыльности положительно связаны с интернационализацией, что указывает на роль ресурсной обеспеченности и финансовых возможностей в поддержке международной экспансии. В то же время компании, демонстрирующие быстрый рост на внутреннем рынке, проявляют меньшую активность на международных рынках, что отражает возможный компромисс (trade-off) в стратегических приоритетах.

В целом результаты исследования предоставляют фирменно-ориентированные эмпирические доказательства того, каким образом цифровые инвестиции связаны с результатами интернационализации компаний. Полученные выводы также свидетельствуют о том, что цифровая трансформация с большей вероятностью способствует международной экспансии в тех случаях, когда она согласована с ресурсами компании, ее технологическими возможностями и организационной структурой, а не рассматривается как изолированная технологическая инициатива.

Ключевые слова: цифровая трансформация, международный менеджмент, искусственный интеллект, стратегия интернационализации, китайские компании.

Introduction

The expansion of the digital economy has gradually altered firms' production processes, organizational structures, and competitive strategies. (Plekhanov et al., 2023). With the continuous development of the digital economy, digital transformation increasingly shapes how firms reorganize internal processes, reduce coordination frictions, and support cross-departmental decision-making (Vial, 2019). Existing studies have examined the economic consequences of digital transformation, focusing primarily on firm performance and innovation outcomes.

Existing research has mainly focused on traditional determinants of internationalization such as firm size, ownership structure, institutional distance and market conditions. Recent research has begun to focus on the importance of digitization, but systematic firm-level empirical evidence on how specific digitization investments translate into international market outcomes remains fragmented, particularly in the context of emerging economies.

This limitation is particularly evident in the study of Chinese firms. Over the past decade, China has developed into one of the world's major digital economies, and many firms have increased their AI investment, data analytics, and digital platforms. At the same time, Chinese firms expanding into international markets face institutional differences, competitive pressures, and uncertainty related to changes in the global economic environment. Under these conditions, it remains unclear whether digital transformation helps firms improve their internationalization outcomes, particularly in emerging economies.

This study examines the relationship between digital transformation and firm internationalization. Specifically, it focuses on whether firm-level investment in AI is associated with internationalization outcomes, measured by overseas income. AI investment is used as an observable indicator of digital transformation, as it more directly reflects firms' engagement with digital technologies than composite indices or qualitative descriptions.

The research object of this study consists of Chinese A-share listed companies during the period 2015-2024. These firms operate in a rapidly digitizing environment and disclose standardized financial information, which allows for firm-level panel analysis. Using this sample, the study examines whether AI investment is related to firms' international expansion and provides empirical evidence relevant to internationalization strategies in the digital era.

Literature review

The impact of digital transformation on firm internationalization: Prior studies document that digital technologies influence firms' operations in industries such as energy, mining, and manufacturing, albeit through different mechanisms. (Ionascu et al., 2005) emphasize the importance of institutional distance (including normative, regulatory and cognitive dimensions) in shaping international business strategies. As firms expand globally through digital means, they navigate through different regulatory environments and normative expectations. This broader understanding of institutional factors becomes increasingly important. In terms of industry-specific impacts, (Dragičević et al., 2019) emphasize that digital transformation in the mining industry involves a fundamental reassessment of strategy, value streams and operating models. In particular, it has a significant impact on customers, partners and employees. As well, (Balashova et al., 2019) discuss how digital technologies enable new ways of communicating with consumers and transform the energy industry by developing advanced digital platforms to maintain competitive advantage. (Gutman et al., 2019) further explore the role of digital transformation in improving operational efficiency and strategic management. They propose simulation models to assess the combined impact of internal and external environmental factors on business value. This kind of models is useful for firms operating internationally as they help to understand complex interactions and support strategic decision making in a rapidly digitizing environment. Furthermore, (Tuan et al., 2021) showed that digital transformation streamlines business processes such as cash accounting and document digitization, which improves operational efficiency and decision-making. This is in line with the general trend of digitizing core business activities to support international operations. As stated by Ochara (2016) who illustrated how social firms can utilize online platforms to expand market reach and increase sales, exemplifying digital transformation at the firm level. (Murahovscaia, 2021) conducted a study on the development of logistics infrastructure, an important component of international business operations. He noted that digital technologies help to optimize operational activities and people management at regional and global levels. This emphasized the importance of digital infrastructure in supporting seamless international supply chains and logistics. The study by (Chintalapati et al., 2021), exemplified how digital

technologies are reshaping marketing strategies for more targeted and efficient participation in international markets. They categorize marketing activities into digital, content, experiential, operational, and research themes, highlighting the multifaceted impact of digital transformation on firms' global competitiveness. In the international business environment, digital transformation is a catalyst for strategic alignment, operational efficiency and market expansion. It entails adapting to institutional differences, industry-specific changes and infrastructure developments, ultimately shaping the future trajectory of global business operations.

The role of artificial intelligence in internationalization: Integrating AI into business operations is increasingly seen as a key factor in improving competitiveness and supporting internationalization efforts. (Sharp, 2018) highlighted that disruptive technologies such as AI are fundamentally transforming the workplace by introducing advanced analysis, algorithms and robotics, challenging traditional human roles and driving organizational change. This technological change is seen as a catalyst for organizations to maintain a competitive edge in a fast-moving global environment. To support this view, (Strusani et al., 2019) present the potential of AI to augment human intelligence and revolutionize access to products and services, especially in emerging markets. They argued that private sector solutions utilizing AI are essential for the promotion of innovative business models, more efficient service delivery and increased competitiveness in local markets, thus facilitating international expansion. In terms of national strategies, (Fatima et al., 2020) analyzed how countries can use AI to modernize the public sector and improve industry competitiveness. Their content analysis of strategic plans shows a focus on responsible data and algorithm management, governance and capacity development. This is critical to creating an environment that is conducive to both business development and international engagement. Furthermore, the role of AI in specific industries highlights its importance in business competitiveness. (Indriasari et al., 2019) explored AI and big data analytics in the Indonesian banking industry, demonstrating how digital innovation can improve customer experience and operational efficiency. This is a key factor in maintaining a competitive edge in the international market.Artificial intelligence-driven customer relationship management can improve sustainable business performance by strengthening relationship capital and organizational coordination (Wang et al., 2020; Rehman & Anwar, 2019). (Roy, 2021) examined the use of AI in workforce management in India, noting that AI tools are transforming the HR function and have the potential to reshape the global labor market. (Baothman, 2021) further noted the disruptive impact of AI on legal contracts. He believed that firms need to develop tailored AI strategies to optimize legal processes and contractual efficiencies, which are critical for international business operations. Finally, (Trad, 2021) explored educational and conceptual frameworks to support AI-driven business transformation. The study pointed to models that integrate AI with business architecture and educational systems. These frameworks are critical for fostering innovation, ensuring responsible AI deployment, and maintaining firm agility in a competitive global environment. These studies paint a picture of AI as more than just a technological tool; it emerges as a strategic enabler that helps firms innovate, plan, adapt to specific industries, and build the capabilities necessary to compete beyond domestic borders. As a result, the integration of AI is positioned as a key driver for businesses to thrive in the global economy.

Firm internationalization management strategy: Strategic corporate management in the context of internationalization covers a multifaceted approach. These include innovation, functional coordination, human resources, risk management, branding, project maturity and knowledge sharing. A foundational framework is provided by (Miller, 1992), who suggested that risk management is at the core of an effective international management strategy. Firms must develop a comprehensive approach to the multifaceted risks inherent in global operations. (Gerybadze et al., 2010) emphasized the importance of technology strategy and innovation management in global business research centers. They suggested that innovation practices are critical to sustaining international growth. More specifically, technological innovation and disclosure practices significantly influence the ability of firms to expand globallyIn an increasingly globalized marketplace, firms must strategically coordinate multiple functional areas to sustain competitiveness. The integration of technological, financial, and operational functions enhances firms' ability to adapt to international market demands (Gerybadze et al., 2010; Vial, 2019). (Chen et al., 2015) found that flexible HRM can enhance innovation performance by improving organizational learning capabilities. This suggests that adaptive HR practices can help to enhance firms' innovation and international competitiveness. At the same time,

the role of internal capabilities in supporting global strategies is emphasized. Risk management is another key element which is influenced by organizational culture and leadership. (Yilmaz et al., 2017) explored how firm risk management fits with strategic management and organizational culture. They pointed out that effective ERM practices can cope with the uncertainty of international markets. Rehman and Anwar (2019) noted that formal risk management mediates between business strategy and SME performance. This suggests that strategic risk practices are critical for achieving superior international market outcomes. Brand management has become a powerful tool in the internationalization strategy of SMEs (Couto et al., 2017) . They discussed the importance of brand creation and management to enhance international competitiveness. They pointed out that a good brand facilitates a strong foothold in overseas markets. This is complemented by (Xu et al., 2020). They proposed a "five-ification" management strategy for energy firms, focusing on standardization, platform operation and industrialization. These are aimed at building international influence and competitiveness. (Schelini et al., 2017) analyzed how project management capabilities can be a competitive advantage for Brazilian firms' international expansion from a Resource-Based View (RBV). Their findings suggest that mature project management practices can facilitate the implementation of strategic internationalization plans by optimizing resource utilization and project execution. (Chatterjee et al., 2021) examined the role of firm social networks (ESNs) in facilitating cross-border knowledge transfer. They emphasized the importance of effective knowledge management among subsidiaries for the implementation of international strategies and the promotion of innovation. In short, firm internationalization management strategies are comprehensive. These elements are interrelated and are essential for firms to enhance their global competitiveness and sustain growth in international markets.

Existing studies mainly examine the effects of digitalization on firm performance, innovation, and organizational capabilities. Other studies focus on firms' internationalization paths and influencing factors from a macro-level perspective. However, fewer studies explore how digitalization supports firm internationalization in practice, especially from the perspective of management strategy. In particular, the interaction between digital strategy and internationalization strategy at the firm level has not been sufficiently examined.

To address this gap, this study uses firm-level panel data to examine the relationship between AI investment and firm internationalization from a management perspective. By focusing on AI investment, the study provides empirical evidence on how digital transformation is associated with firms' international expansion.

Overall, although prior research suggests that digital transformation is related to internationalization, existing findings are not fully consistent and are often limited to specific contexts. Therefore, further empirical analysis based on Chinese firms is needed. Based on the above discussion, the following hypothesis is proposed:

H1: Digital transformation, measured by AI investment, promotes firm internationalization.

Methodology

Sample selection and data processing: This paper takes Chinese A-share listed companies from 2015 to 2024 in the CSMAR database as its research subjects. It explores the impact of corporate digital transformation on their internationalization development levels and provides management recommendations. Based on the original sample, the following sample selection criteria were applied: excluding samples from the financial, insurance, and securities industries; excluding samples subject to special treatment; and excluding bankrupt samples. Ultimately, 37883 observations are obtained, covering 3790 listed companies.

The study examines the relationship between firms' AI investment (representing the level of digitization) on the degree of internationalization (measured by overseas income) by constructing a fixed-effects panel regression model and introducing the variables of firm size, profitability, leverage level, capital structure, cash ratio, Tobin's Q, board size, and proportion of independent directors as control factors.

In order to comprehensively assess the impact of digital transformation on firm internationalization, this paper constructs the following fixed effects panel regression model:

$$\ln(\text{Income}_{i,t}) = \alpha + \beta \ln(\text{AI}_{i,t}) + \\ + \gamma^{\text{T}}\text{X}_{i,t} + \mu_i + \lambda_t + \varepsilon_{i,t} \quad (1)$$

Where:

$\text{Income}_{i,t}$: logarithm of overseas income, representing the internationalization level of firm i at year t, measured by the log of overseas income

ln $AI_{i,t}$: logarithm of AI investment of firm *i* in year *t*, representing the level of digital transformation.

$X_{i,t}$: vector of control variables, including firm size (Ln_Size), leverage (LEV), return on equity (ROE), cash ratio, growth rate, Tobin's Q, board size, and board independence.

μ_i: firm fixed effects.

λ_t: time fixed effects

$\varepsilon_{i,t}$: error term.

To determine whether the fixed effects (FE) model or the random effects (RE) model is more appropriate, this study conducted Hausman tests on Model: $\chi^2(9) = 458.92$, $p < 0.01$, so we select the fixed effects model.

Table 2 shows the descriptive statistics of the main variables in this paper. All variables were winsorized to reduce the interference of extreme values in the analysis.

Table 1 – Variable definitions and measurement

Variable Name	Symbol	Measurement
Overseas income	Ln_income	Natural logarithm of main business income from overseas, reflecting the degree of internationalization of the firm
AI Investment	Ln_AI	Natural logarithm of firm digital transformation scores based on annual report keyword word frequencies. This variable reflects the intensity of a firm's investment in digital technology.
Firm Size	Ln_Size	Total asset size of the firm during the reporting period, used to account for firm scale effects.
Profitability	ROE	Return on equity, calculated as net profit divided by shareholders' equity. This measures a firm's financial efficiency and ability to return on investment.
Leverage	LEV	Debt-to-asset ratio, calculated as total liabilities divided by total assets. This indicates the financial risk and capital structure of the firm.
Cash Ratio	CashRatio	Cash and cash equivalents divided by current liabilities. This measures a firm's liquidity and ability to meet short-term obligations.
Growth Rate	GrowthRate	Annual growth rate of operating income, capturing the expansion speed of the firm.
Tobin's Q	TobinQ	Ratio of market value of the firm to the replacement cost of its assets. Reflects market expectations and firm valuation.
Board Size	BoardSize	Total number of board members in the firm.
Board Independence	BoardIndep	Proportion of independent directors in the board, expressed as a percentage.
Note – completed by the authors		

Table 2 – Descriptive statistics

Variable	Number	Mean	Std. Dev.	Min	P50	Max
Ln_income	20157	19.2184	2.2773	12.3755	19.4675	24.2152
Ln_AI	24051	15.6593	1.9119	10.4346	15.7007	20.2969
Ln_Size	27935	21.9989	1.3171	18.8495	21.8734	25.9707
LEV	27910	0.3916	0.1980	0.0559	0.3777	0.9164
ROE	27803	0.0541	0.1561	-0.9087	0.0708	0.3616
CashRatio	23235	0.9361	1.3939	0.0193	0.4467	8.5933
GrowthRate	17524	0.2383	0.5887	-0.6297	0.1037	3.6728
TobinQ	17035	2.0639	1.2632	0.8667	1.6518	8.2042
BoardSize	17140	8.1354	1.4762	5.0000	9.0000	12.000
BoardIndep	17140	37.9908	5.3500	33.33	36.36	57.140
Note – completed by the authors based on the CSMAR data						

Table 2 presents the descriptive statistics for key variables. Overall, the means, medians, and standard deviations of all variables fall within reasonable ranges. The sample firms exhibit notable variation in their levels of digital transformation and international market involvement.

As shown in Table 2, the mean value of internationalization level (Ln_income) is 19.2184, the median is 19.4675, the standard deviation is 2.2773, the minimum value is 12.3755, and the maximum value is 24.2152. This explains that the overseas income of the sample firms varies significantly, with some firms exhibiting a high degree of internationalization, but the overall distribution remains relatively concentrated.

The mean value of the digitization level (Ln_AI) is 15.6593, with a median of 15.7007, a standard deviation of 1.9119, and maximum and minimum values of 20.2969 and 10.4346, respectively. It is clear that there are significant differences among firms in their investment in artificial intelligence. This indicates that a small number of firms have invested far beyond the average level in digital transformation, potentially gaining a first-mover advantage.

Regarding control variables, firm scale reveals significant disparities in distribution. The mean value of LEV is 0.3916 with a standard deviation of 0.1980, primarily distributed between 0.056 and 0.916, indicating that most firms maintain a moderate debt-to-equity ratio. The mean value of ROE is only 0.0541, yet the minimum value reaches -0.9087 and the maximum value is 0.3616, suggesting that some firms are operating at a loss.

Other variables such as Cash Ratio, Growth Rate, and Tobin's Q exhibit greater volatility. It is evident that the sample firms show remarkable levels of variation in liquidity, growth potential, and market valuation. The mean value for BoardSize is 8.1354 with a standard deviation of 1.4762. Most corporate boards comprise between 5 and 12 members, indicating minimal variation. The mean proportion of BoardIndep is 37.99 %, with a maximum of 57.14 %. This suggests that most sample firms meet regulatory requirements, with a reasonable distribution of independent director ratios. Descriptive statistics reveal significant variations among firms in both internationalization levels and digital investment, providing robust data support for subsequent empirical analysis.

Overall, the paper employs a fixed-effects model to control for firm-level variation and conduct our analysis step-by-step through descriptive statistics, correlation analysis, and benchmark regression. And we further conduct multiple robustness tests. Considering that digital investments may exhibit a lagged effect on firm internationalization, we regress the core explanatory variable Ln_AI on its lagged value Ln_AI(-1). If the lagged variable remains significant, it indicates that the promotional effect of digital transformation on firm internationalization is persistent. Also we exclude observations from the COVID-19 pandemic period of 2021-2022 to verify whether the conclusions hold outside of exceptional years. Empirical results indicate that the core findings from these robustness tests align with those of the benchmark regression. This enhances the reliability of our causal inference.

Results and discussion

Firstly, we conducted correlation tests between the variables, with the results shown in Table 3.

Table 3 – Variable correlation analysis

	Ln_income	Ln_AI	Ln_Size	LEV	ROE	CashRatio	Growth-Rate	TobinQ	BoardSize	Board-Indep
Ln_income	1									
Ln_AI	0.40***	1								
Ln_Size	0.56***	0.63***	1							
LEV	0.30***	0.36***	0.52***	1						
ROE	0.13***	0.00	0.06***	-0.25***	1					
CashRatio	-0.16***	-0.19***	-0.25***	-0.58***	0.10***	1				
Growth-Rate	-0.16***	0.02**	-0.01	0.06***	-0.02**	-0.03***	1			
TobinQ	-0.14***	-0.10***	-0.22***	-0.22***	0.12***	0.14***	-0.01	1		

Continuation of the table

	Ln_income	Ln_AI	Ln_Size	LEV	ROE	CashRatio	Growth-Rate	TobinQ	BoardSize	Board-Indep
BoardSize	0.12***	0.17***	0.25***	0.12***	0.01	-0.07***	0.04***	-0.04***	1	
Board-Indep	0.02**	0.04***	0.03***	0.03***	-0.02*	-0.01	-0.02**	-0.01	-0.58***	1

Note – * p < 0.1, ** p < 0.05, *** p < 0.01.
Completed by the authors

Table 3 presents the correlations among key variables. Overall, both the signs and significance levels of the correlation coefficients align with expectations. The correlations between the vast majority of variables fall within a reasonable range.

First of all, regarding core variables, digitization level (Ln_AI) exhibits a significant positive correlation with internationalization level (Ln_income) (correlation coefficient approximately 0.40, p<0.01). We observe that firms with higher digital investment demonstrate higher levels of overseas income, providing preliminary evidence to validate the hypothesis that "digitalization promotes internationalization" in subsequent regression analysis.

Secondly, the correlation coefficient between firm size and internationalization level (Ln_income) is relatively high (approximately 0.56, p<0.01), which indicates that larger firms possess greater advantages in the internationalization process. Simultaneously, a strong positive correlation also exists between Ln_Size and Ln_AI (approximately 0.63, p<0.01), reflecting that larger firms tend to increase their digital investment.

Regarding financial variables, LEV exhibits a significant positive correlation with Ln_income (0.30, p<0.01). This suggests that moderate debt levels may support a firm's internationalization activities. ROE shows a significant positive correlation with internationalization level (0.13, p<0.01), indicating that firms with stronger profitability are more likely to achieve international expansion. However, it is noteworthy that the correlation coefficient between LEV and ROE is negative (-0.25, p<0.01), consistent with the logic that high debt ratios may suppress profitability.

Among liquidity and growth indicators, the cash ratio exhibits a negative correlation with internationalization level (-0.16, p<0.01). This suggests that firms holding substantial cash reserves do not necessarily pursue aggressive overseas market expansion. Growth rate is negatively correlated with internationalization level (-0.16, p<0.01). This reveals that high-growth firms may focus more on domestic market expansion rather than overseas markets.

In the relationship between market valuation and governance structure, Tobin's Q exhibits a negative correlation with Ln_income (-0.14, p<0.01). We observe that highly valued firms do not necessarily exhibit greater internationalization. Board size exhibits a significant positive correlation with internationalization level (0.12, p<0.01), reflecting that larger boards may facilitate resource allocation and overseas market decision-making. The correlation between the proportion of independent directors and internationalization level is weaker (0.02, p<0.05), yet still indicates a certain positive effect.

In summary, the correlation analysis results provide preliminary support for the notion that digital investment promotes firm internationalization. Simultaneously, it reveals the potential influence of firm size, financial structure, and governance factors on internationalization levels. This establishes a data foundation for subsequent regression analysis and robustness testing.

Table 4 presents the benchmark regression results of digital investment (Ln_AI) on firm internationalization level (Ln_income). To verify the mechanism through which digital transformation influences internationalization, the study constructed separate regression models for the core explanatory variable and the control variable.

In the regression model containing only core explanatory variables, the regression coefficient for digital investment is 0.1327 and is statistically significant at the 1 % level. This indicates that enhancing an firm's digitization level can significantly promote its internationalization development. Digital transformation enables firms to accelerate their entry into overseas markets and boost international income by enhancing information processing capabilities, reducing cross-border transaction costs, and optimizing resource allocation.

Table 4 – Benchmark regression results

Variables	(1) Ln_income	(2) Ln_income
Ln_AI	0.1327*** (0.0138)	0.0334*** (0.0125)
Ln_Size		0.9292*** (0.0534)
LEV		0.0847 (0.1903)
ROE		0.4439*** (0.1150)
CashRatio		-0.0122 (0.0126)
GrowthRate		-0.1014*** (0.0301)
TobinQ		0.0083 (0.0127)
BoardSize		-0.0006 (0.0170)
BoardIndep		-0.0050 (0.0039)
_cons	17.1414*** (0.2176)	-1.7912 (1.1842)
Year_FE	Yes	Yes
Firm_FE	Yes	Yes
N	18029	11767
Adj. R2	0.8813	0.9053
F	92.5749	50.1709
Note – Robust standard errors in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01. Completed by the authors.		

Furthermore, after incorporating other control variables, the regression coefficient for digital investment was 0.0334 and remained statistically significant at the 1 % level. This indicates that regardless of corporate characteristics and governance factors, the role of digital transformation in promoting internationalization remains robust.

From the results of controlling variables, firm scale exhibits a significant positive relationship with internationalization levels. Large firms possess more resources and channels for cross-border operations, making it easier for them to achieve international expansion. ROE also significantly remained positive, indicating that firms with higher profitability possess greater capacity to bear the capital and risk costs associated with internationalization. In contrast, operating income growth rate showed a negative correlation with internationalization level, suggesting that firms in the rapid expansion phase of the domestic market tend to focus on consolidating their domestic presence rather than immediately expanding into overseas markets. Other variables such as capital structure, cash ratio, Tobin's Q ratio, board size, and proportion of independent directors did not exhibit significant effects.

To further validate the reliability of the benchmark regression results, this study conducted robustness tests. Specifically, on one hand, considering that digital investments may have a lagged effect on firm internationalization, the AI investment variable was regressed after being lagged by one period. On the other hand, samples from the pandemic years of 2021-2022 were excluded to avoid interference from these exceptional years on the results. The results are presented in Table 5.

Table 5 – Robustness test: lagged variable and excluding pandemic years

Variables	(1) **One-period Lag of AI Investment**	(2) **Excluding 2021- 2022**
Ln_AI (-1)	0.0307** (0.0142)	
Ln_AI		0.0308** (0.0140)
Ln_Size	0.9276*** (0.0576)	0.9115*** (0.0576)
LEV	0.0428 (0.1896)	0.1093 (0.2125)

Continuation of the table

Variables	(1) **One-period Lag of AI Investment**	(2) **Excluding 2021- 2022**
ROE	0.4694*** (0.1065)	0.2726** (0.1285)
CashRatio	0.0043 (0.0148)	-0.0062 (0.0149)
GrowthRate	-0.0830*** (0.0320)	-0.0987*** (0.0356)
TobinQ	0.0072 (0.0120)	0.0175 (0.0151)
BoardSize	0.0058 (0.0167)	-0.0104 (0.0187)
BoardIndep	-0.0068* (0.0037)	-0.0059 (0.0044)
_cons	-1.6655 (1.2770)	-1.2737 (1.2704)
Year FE	Yes	Yes
Firm FE	Yes	Yes
Observations	10,113	8,528
Adj. R^2	0.9121	0.8980
F-statistic	41.4163	39.6951

Note- Robust standard errors in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01
Completed by the authors

In Model (1), after lagging the AI investment variable by one period, its regression coefficient is 0.0307 and is statistically significant at the 5 % level. The result shows that AI investment not only effectively promotes firm internationalization in the current period but also continues to exert a positive effect in the following year. The impact is persistent.

In Model (2), the study excluded observations from the pandemic period of 2021-2022. The regression coefficient for AI investment (Ln_AI) is 0.0308, which remains statistically significant at the 5 % level. This demonstrates that our findings are not confounded by the sample from the exceptional pandemic years, and the positive effect of AI investment on firm internationalization remains robust.

Additionally, the results for control variables in both sets of models are largely consistent: firm size consistently exerts a significant positive effect on internationalization levels (0.9276*** and 0.9115***).

ROE remained positive and significant in both robustness tests (0.4694*** and 0.2726**). In contrast, the growth rate exhibited a significant negative effect in both tests (-0.0830*** and -0.0987***), suggesting that faster-growing firms are not necessarily more inclined toward international expansion, possibly constrained by resource allocation or external environments.

Overall, the robustness test results align with the benchmark regression. This further confirms that the promotional effect of AI investment on firm internationalization is robust and reliable.

Conclusion

This study addresses the research question by examining whether digital transformation, reflected by firm-level AI investment, promotes firm internationalization. The empirical findings reveal the following results:

Empirical results indicate that digital transformation significantly enhances a firm's level of internationalization. Whether in regression models incorporating only core variables or after controlling for firm size, profitability, capital structure, liquidity, and corporate governance, the impact of digital investment (Ln_AI) on internationalization level (Ln_income) consistently remains significantly positive. This suggests that firms' continuous investment in digital technologies, such as AI, can effectively enhance their multinational operation capability and competitiveness in the global market.

According to the analysis of controlling variables, firm scale and profitability exert a significant positive influence on internationalization development. Larger total assets correlate with higher levels of overseas income, reflecting that resource base, organizational capabilities, and risk tolerance serve as crucial safeguards for advancing internationalization strategies. Large firms and those with stronger profitability are more likely to achieve successful international expansion. Meanwhile, the growth rate of operating income shows a significant negative correlation with the level of internationalization. This may reflect that during China's rapid domestic

market growth phase, some firms tend to concentrate resources on the local market rather than actively expanding into international markets.

Additional robustness tests further support the above conclusions. Whether incorporating AI with a one-period lag or excluding samples from the 2021-2022 pandemic period, regression results consistently indicate that digital transformation exerts a significant positive effect on internationalization levels. This demonstrates that the findings of this study are not coincidental but exhibit strong robustness and reliability.

Theoretically, this study contributes by providing large-sample, firm-level evidence that clarifies AI investment as a concrete channel through which digital transformation is associated with firms' internationalization outcomes.

Management Insights

Based on these findings, this paper makes the following strategic recommendations for business managers: Firms should incorporate digital transformation into the core of their long-term strategy, especially by continuing to invest in AI, data analytics, smart manufacturing, and cross-border e-commerce platforms. Digital transformation can improve international market responsiveness and operational efficiency. It is not only a cost tool, but also a new engine for global competition.

Firms should formulate their internationalization paths in phases and match their resources and capabilities. Large firms can accelerate overseas market mergers and acquisitions, brand export and global industry chain integration; while SMEs can prioritize "asset-light going overseas" through digital technology, such as cross-border e-commerce, SaaS services or online content to enter the international market and reduce risks.

Firms should make reasonable use of leveraged financing while maintaining financial soundness. firms should formulate strategies to support the construction of AI infrastructure, data platforms and the expansion of internationalization teams, so as to form a new growth model with the synergy of "digital + global".

In the process of promoting digital transformation, firms should simultaneously build an internationalized management talent team and IT capability system. In particular, strengthening the cultivation of IT collaboration ability, language and cultural integration ability of overseas teams is the key to improving internationalization performance.

Limitations and outlook

Although this paper draws a series of robust conclusions, certain limitations remain. The measurement of AI investment primarily relies on financial data and has yet to fully encompass firms' digital practices at the application level. Future research could incorporate more non-financial indicators. At the same time, the relationship between digital transformation and internationalization may exhibit heterogeneity across different industries and firms with varying ownership structures, warranting further research through groups. Finally, this paper examines only the Chinese sample. As the global geopolitical and trade landscape evolves, further research is needed on how digitization can help firms navigate external changes.

Briefly, firms should leverage digitization as their foundation and AI as their core driver to address information asymmetry and operational efficiency challenges in international expansion. In this way, they can gain sustainable competitive advantages in the global marketplace.

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FINANCIAL ANALYSIS OF EDUCATIONAL INSTITUTIONS LISTED ON THE US STOCK MARKET

This paper examines the financial indicators of educational organizations whose shares are traded on the US stock market. The study aims to analyze private educational companies focused on online learning and technological educational services. The study's main objective is to analyze these organizations' key financial indicators and determine their investment attractiveness and sustainability. The methodological basis includes observation, classification, statistical analysis, and comparative analysis of market indicators. The study examines capitalization, beta coefficient, dividend yield, profitability, and liquidity indicators of 43 educational companies listed on the NYSE, NASDAQ, and AMEX. The data was collected from financial platforms and then classified and analyzed by key financial metrics.

The results show that most companies are classified as Nano-cap, indicating high volatility and investment risks. More than 80% of the companies do not pay dividends. The share of loss-making companies has decreased over the past 5 years, but there remains a significant spread in profitability indicators. Financial stability varies: there is both high return on equity in some companies and low liquidity in others, which increases the risk of insolvency.

The value of the study lies in the comprehensive analysis of educational organizations in the context of the stock market, which has not previously received sufficient coverage in the scientific literature. The results obtained may be useful for investors in assessing the risks and investment opportunities in this sector.

Keywords: Educational organizations, stock market, indicators.

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АҚШ қор нарығында тіркелген білім беру ұйымдарының қаржылық талдауы

Мақалада АҚШ қор нарығында акциялары сатылатын білім беру ұйымдарының қаржылық көрсеткіштері зерттелді. Зерттеу онлайн оқытуға және технологиялық білім беру қызметтеріне бағытталған жеке білім беру компанияларын талдауға бағытталған. Зерттеудің негізгі мақсаты – осы ұйымдардың негізгі қаржылық көрсеткіштерін талдау, олардың инвестициялық тартымдылығын және тұрақтылығын анықтау. Әдістемелік негіз ретінде нарықтық көрсеткіштерді бақылау, жіктеу, статистикалық талдау және салыстырмалы талдауды қамтиды. Зерттеу NYSE, NASDAQ және AMEX биржаларында тіркелген 43 білім беру компаниясының капиталдандыру, бета, дивиденд табыстылығы, жалпы табыстылық және өтімділік коэффициенттерін зерттейді. Деректер қаржылық платформалардан жиналды, содан кейін негізгі қаржылық көрсеткіштер бойынша жіктеледі және талданды.

Талдау нәтижелері ретінде ұйымдардың көпшілігінің жоғары құбылмалылық пен инвестициялық тәуекелдері анықталып, ұйымдардың Nano-cap санатына жататынын көрсетеді. Соннымен қатар, зерттеу барысында компаниялардың 80%-дан астамы дивидендтер төлемейтіні анықталды. Соңғы 5 жылда рентабельді емес компаниялардың үлесі азайды, бірақ табыстылық көрсеткіштері бойынша айтарлықтай дисперсия сақталуда. Қаржылық тұрақтылық әртүрлі сипатқа ие. Кейбір компаниялар үшін меншікті капиталдың жоғары табыстылығы сипатталса, ал басқалары үшін төмен өтімділігі және төлем қабілетсіздігі қаупі анықталды.

Зерттеудің құндылығы ретінде ғылыми әдебиеттерде білім беру ұйымдарының қор нарығындағы қызметі жеткілікті түрде қамтылмағанын атап өтуге болады. Мақалада анықталған

лер инвесторлар үшін осы сектордағы тәуекелдер мен инвестициялық мүмкіндіктерді бағалау үшін пайдалы болуы мүмкін.

Түйін сөздер: білім беру ұйымдары, қор нарығы, көрсеткіштер.

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Финансовый анализ образовательных компаний, котирующихся на фондовом рынке США

В настоящем исследовании рассматриваются финансовые показатели образовательных организаций, акции которых обращаются на фондовом рынке США. Исследование направлено на анализ частных образовательных компаний, ориентированных на онлайн-обучение и технологические образовательные услуги. Основной целью исследования является изучение ключевых финансовых показателей данных организаций, определение их инвестиционной привлекательности и устойчивости. Методологическая база включает наблюдение, классификацию, статистический анализ и сравнительный анализ рыночных индикаторов. В исследовании рассматривается капитализация, бета-коэффициент, дивидендная доходность, показатели рентабельности и ликвидности 43 образовательных компаний, котирующихся на NYSE, NASDAQ и AMEX. Данные были собраны с финансовых платформ, затем классифицированы и проанализированы по ключевым финансовым метрикам.

Результаты показывают, что большая часть организаций относится к категории Nano-cap, что указывает на высокую волатильность и инвестиционные риски. Более 80% компаний не выплачивают дивиденды. Доля убыточных компаний за последние пять лет снизилась, однако сохраняется значительный разброс в показателях доходности. Финансовая устойчивость также варьируется: у ряда компаний наблюдается высокая рентабельность капитала, тогда как у других – низкая ликвидность, что увеличивает риски неплатежеспособности.

Ценность исследования заключается в комплексном анализе образовательных организаций в контексте фондового рынка, что ранее не получало достаточного освещения в научной литературе. Полученные результаты могут быть полезны инвесторам для оценки рисков и инвестиционных возможностей в данном секторе.

Ключевые слова: образовательные организации, рынок акций, индикаторы.

Introduction

Most traditional universities do not have shares in stock markets. These universities are usually private non-profit organizations that are funded through donations, government funding, and tuition fees, rather than through public investment. Regarding the organizational and legal form, universities are created in the form of JSC, and various types of partnerships, and, depending on the specifics of regulation, they can also be created in other forms. At the same time, according to JSC, higher education organizations are classified as non-profit JSC.

Publicly traded educational institutions primarily focus on online education and private educational services, as opposed to traditional universities. Among educational organizations, some institutions provide online learning, massive online courses (e.g., COURSERA, Udemy), various educational technologies (e.g., Chegg), and advanced training.

Despite the increase of organizations, and commercialization of educational services, the issue of financial stability and financial attractiveness of educational organizations for investors has not been disclosed. First of all, attractiveness from investors is observed in the stock market. It is interesting what economic and financial characteristics are observed in educational organizations. How stable are these organizations, and how attractive are shares for investors? In this study, we studied and analyzed the activities of educational organizations whose shares are traded on US stock exchanges.

The purpose of our study is to study the activities of educational institutions using the example of the American market based on the analysis of key financial indicators. The objectives of the research are to study the works of scientists in the field of the attractiveness of shares of educational organizations, analyze educational institutions by criteria, analyze financial indicators and indicators, and conduct a comparative analysis of the attractiveness of shares within the industry.

The objects of the study are educational institutions whose shares are traded on US stock exchang-

es. The subject of the study is a system of indicators and indicators of educational organizations on the stock market. The following research methods were chosen: observation, classification, comparison, and statistical analysis.

Our hypothesis is based on determining the attractiveness of shares of educational organizations for investors.

H0: There are no major differences between the stocks of educational organizations.

H1: Shares of educational organizations are less attractive.

Additionally, we examined the relationship between the size of a company and its financial performance. Thus, H2: There is a statistically significant relationship between the financial performance of educational organizations and their market capitalization.

The value of the study is that academic works lack articles devoted to the analysis of the financial activities of educational institutions in the stock market, the sustainability of organizations, and the attractiveness of shares of these organizations.

Literature review

In conducting the literature review, the first direction was to identify whether there was a difference between stocks depending on the sector and what metrics were used to determine the attractiveness of stocks.

The authors (Niu et al., 2023) investigated the relationship between stock market sector returns and investor sentiment. Empirical evidence shows that in stable market conditions, investor sentiment is most strongly related to stock returns in the industrial, consumer discretionary, healthcare, utilities, real estate, and financial sectors. During crisis periods, there is a significant positive relationship between investor sentiment and stock returns in all sectors. In the short term, there is a bidirectional causality between investor sentiment and stock returns in all sectors. However, in the medium and long term, stock returns in most sectors are predicted by investor sentiment, while investor sentiment does not always affect stock returns in all sectors, which is different from the dynamics observed in developed markets.

There are comparative analysis studies between market sectors. Thus, the study (Coronello et al., 2008) examines methods for identifying economic sectors based on the analysis of time series of returns of stocks traded on the New York Stock Exchange (NYSE). The study was conducted based on data from the platform finance.yahoo.com.

Educational organizations in the United States that provide primary, secondary, higher, and post-secondary education are generally not public companies whose shares are traded on the stock exchange. Therefore, when conducting a literature review, it was intended to determine what studies exist on the shares of companies in the Consumer defense sector and the Training and Education industry.

Digdowiseiso, K. (2023) conducted a study to examine the impact of fundamentals on the stock returns of consumer defense companies. The study was conducted based on companies listed on the Indonesia Stock Exchange from 2016 to 2018. The fundamental indicators used were liquidity ratios, asset turnover, debt-to-equity ratio (DER), price-to-book value (PBV), net profit margin (NPM), return on assets (ROA), and earnings per share. The results showed that defensive companies are less susceptible to market fluctuations, and their financial strength is not always reflected in liquidity and debt ratios. The study confirms that investors in defensive stocks focus more on profitability ratios (such as ROA) than on liquidity ratios and capital structure. The main conclusion of the study is that return on assets (ROA) is the key indicator for evaluating the stock returns in the defensive sector, while other financial ratios have little impact.

Researchers (Ole-Meiludie et al., 2014) conducted a study to examine the performance of defensive sectors in the stock market during economic crises and recessions, with a particular focus on their resilience on the Johannesburg Stock Exchange (JSE). The main objective of this study was to determine whether defensive sectors retain their non-cyclical nature during market crises by comparing their performance during the crisis (2007–2009) and recession (1996–1999). The results showed that defensive sectors generally retain their resilience and low sensitivity to market fluctuations during crises. A comparative analysis was conducted between sectors during the study. Defensive sectors showed reduced volatility, making them less risky investments during crisis periods. The greatest resilience was seen in the consumer, healthcare, and consumer services sectors. During crises, investors more often switched to defensive assets, reducing investments in cyclical sectors. The study confirms that defensive sectors remain a reliable choice for investors in conditions of economic instability.

There are studies on comparative analysis between Cyclical and Defensive Sectors. The author (Asinas, 2018) examines the behavior of beta coefficients (β) for cyclical and defensive sectors of the stock market. The article examines differences in volatility and sensitivity of stocks for Cyclical and Defensive Sectors. The author found that in the Cyclical Sector, companies often have beta coefficients greater than 1, which indicates higher risks and profitability potential. In contrast, stocks of Defensive Sector companies usually have beta coefficients below 1, which reflects lower volatility and more stable income.

Another study (Md Qamar Azam et al., 2022) determines the impact of the pandemic on investor behavior in Cyclical and Defensive Sectors. The focus is on the overconfidence bias effect in the pre-pandemic and post-pandemic periods using data from 2015 to 2020. The authors found that pre-pandemic overconfidence was more pronounced in cyclical sectors, and this pattern persisted during the pandemic.

Today, EdTech is seen as a key driver of development that can improve the financial situation of educational organizations by expanding digital services, optimizing costs, and attracting new categories of students. The results of the study (Makda, 2025) show that virtual learning plays a key role in ensuring the sustainability of educational processes and democratizing access to knowledge, especially in times of crisis. Moreover, a group of scientists (Kerimbayev et al, 2025) from Kazakhstan conducted a systematic review of the use of intelligent technologies in individual learning. The results show that the use of smart technologies (AI, adaptive systems, learning analytics) significantly expands the possibilities of personalized education, but is accompanied by a number of difficulties and limitations in practical implementation. Another the study showed (Sahar, 2025) that the most active countries in the field of artificial intelligence applications in higher education are China, India, and the United Kingdom, with leading topics including adaptive learning, predictive analytics, and the use of ChatGPT. The analysis emphasized that the introduction of AI significantly improves the quality of the educational process and the effectiveness of university management, forming the basis for further innovations in the field of education.

In conclusion, despite the research on the sector, there are no studies where the object is an Education and Training Services Industry.

Methodology

When conducting the study, we did not analyze the activities of universities, colleges, and schools. In our study, we used materials from the platforms Yahoo Finance, and Finviz.com, which reflect the entire US market. Data was collected from these platforms and then sorted and classified according to the selected criteria and indicators.

In this study, data from the Finviz and Yahoo Finance platforms was used exclusively to create tables and figures, as these sources provide the most up-to-date, reliable, and structured financial information on public companies, including educational organizations, whose shares are traded on the US stock market. Both platforms are open, recognized, and regularly updated databases widely used in academic and applied research. Finviz provides visualized financial metrics and market indicators, which makes it possible to conduct a comparative analysis of companies, while Yahoo Finance provides detailed historical data, profit and loss statements, as well as key profitability indicators. The use of other sources is limited due to their restricted access.

The research questions are as follows: What are the main characteristics of educational organizations according to the capitalization criterion, affiliation with exchanges, and countries? How attractive are those companies for investors based on stock yield and dividends? How efficient and stable are companies in the Education and Training Services Industry?

Our sample included educational institutions whose shares are traded on the stock exchange. These organizations mainly focus on providing online education and private educational services. We did not study corporate universities, since they are mainly part of the company structure, and it is difficult to track their role in the financial analysis. Our steps in conducting the analysis consisted of several stages, namely: 1) sector selection, 2) industry selection, category, 3) general analysis of organizations by capitalization criteria, IPO, distribution by countries and US exchanges, 4) comparative analysis of the Beta indicator, 5) analysis of dividend yield and earnings per share (EPS), and 6) efficiency and financial stability of organizations.

All companies whose shares are traded on US stock exchanges are classified into 11 sectors of the economy, including the Consumer Defensive sector. The Consumer defense sector has become part of a broader financial classifier, such as the S&P 500,

which actively uses such groups for analysis and trading strategies. This sector includes companies producing essential goods, such as food, beverages, etc. This sector covers 12 industries, including Education and Training Services. Today, shares of 43 companies are traded on the NYSE, NASDAQ, and AMEX exchanges. These companies are not only American but also from other countries. Shares of foreign organizations are presented in the form of American depositary receipts. Receipts appeared for the purpose of entering the market of foreign companies, where restrictive rules in legislation apply. In our case, these are ADRs – American depositary receipts, where company shares are stored in a depository, and on their basis receipts are issued, which are included in the circulation of American stock exchanges. ADR companies often have to make financial statements in a format acceptable to the SEC (U.S. Securities and Exchange Commission) and American investors. That is, foreign private issuers are subject to special SEC rules. Meantime, according the SEC conditions foreign issuers can submit financial statements under IFRS without the requirement for reconciliation with US GAAP.

We have conducted an analysis based on criteria and indicators that reflect the general trend, strengths, and weaknesses of educational organizations in the stock market.

Results and discussion

Before assessing the financial attractiveness of companies, we determined the capitalization of companies. There are mega-companies on the stock market, and their value is estimated at over 200 billion dollars. In addition to mega, there are large, medium, small, micro, and nano companies. Table 1 presents companies providing educational services. The conducted analysis showed that educational organizations do not exceed a capitalization over 10 billion dollars. Companies are distributed between below 50 million dollars to 10 billion dollars.

Table 1 – Analysis of educational organizations by market capitalization, number of companies

Criteria	Middle	Small	Micro	Nano	TOTAL
Market capitalization, number of companies	9	11	8	15	43
The proportion, %	20.93	25.58	18.60	34.88	100.00
Note – Complied by authors based on source the platform Finviz					

The analyzed companies are divided into four groups depending on their market capitalization, namely ‘Middle’ (market cap. between 2 and 10 billion USD), ‘Small’ (market cap. between 300 million USD and 2 billion USD), ‘Micro’ (market cap. between 50 and 300 million USD) and ‘Nano’ (market cap. under 50 million USD).

The largest share (34.88%) is made up of Nano-cap companies (15 out of 43), indicating a significant number of small companies with low market capitalization. This may indicate a high degree of volatility and investment risk. Small-cap comes in second (25.58%), indicating that moderate-cap companies are overrepresented. These companies often have growth potential, but may be more vulnerable to market fluctuations. Mid-cap (20.93%) makes up a smaller share but remains stable compared to smaller categories. These companies are often established players with growth potential. Micro-cap (18.6%) falls between the Small and Nano categories, and tend to be high-risk, emerging companies with significant growth potential.

One of the interesting factors was finding out which exchanges the companies were listed on. Table 2 presents an analysis of the distribution of companies across US exchanges – NYSE, NASDAQ, and AMEX.

Table 2 – Analysis of educational organizations on exchanges, number of compan**ies**

Criteria	Exchange			TOTAL
	NYSE	NASDAQ	AMEX	
Quantity, unit	18	21	4	43
The proportion, %	41.86	48.84	9.30	100.00
Note – Complied by authors based on source the platform Finviz				

Almost 90% of the companies are listed on NASDAQ and NYSE, which confirms their dominant position in the stock market. The high share of NASDAQ indicates the presence of a large number of innovative and technology companies. This is not surprising, since many educational companies provide services using technology.

The majority of companies are concentrated in the United States (46.51%) and China (41.86%), while the number is significantly lower in Brazil, Singapore, and Canada. This may indicate the development of the business or industry in these countries, or different market conditions and opportunities. In China, "Chinese GAAP" is more formally called Accounting Standards for Business Enterprises (ASBEs) or CAS (Chinese Accounting Standards). Meantime, a study (Aloke, 2017) shows that Chinese ADR issuers are more likely to use large international auditing firms (Big Four) to increase investor confidence.

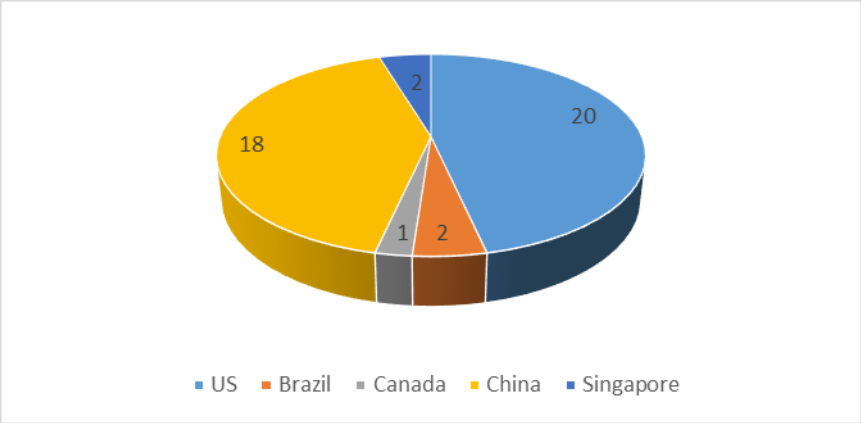

Figure 1 – Analysis of the distribution of companies by country, %
Note – Complied by authors based on source Finviz

Table 3 – Analysis of educational organizations by IPO, number of issues

Criteria	More than 25 years ago	More than 20 years ago	More than 15 years ago	More than 10 years ago	More than 5 years ago	More than 1 year ago
IPO Date	5	6	12	15	27	40
Growth, % (compare with previous time)	-	120	200	125	180	148.1
Growth, % (compare with basis)	-	120	240	41.7	33.3	18.5
Note – Complied by authors based on source the platform Finviz						

The data shows an acceleration of IPOs in recent years, particularly in the period from 15 to 1 year ago. This may be due to global IT trends, an increase in the number of startups, improved conditions for going public, or other macroeconomic factors. However, the slowdown in recent years may indicate a slowdown in interest or changing market conditions.

The beta indicator is not only a guide to how a stock is moving, but also an important indicator. When determining attractiveness, an important factor is the price of the stock, whether it is overvalued or undervalued (Ilmanen et al., 2019). When conducting the analysis, Beta values 1.01-1.04 are grouped into Beta value = 1.

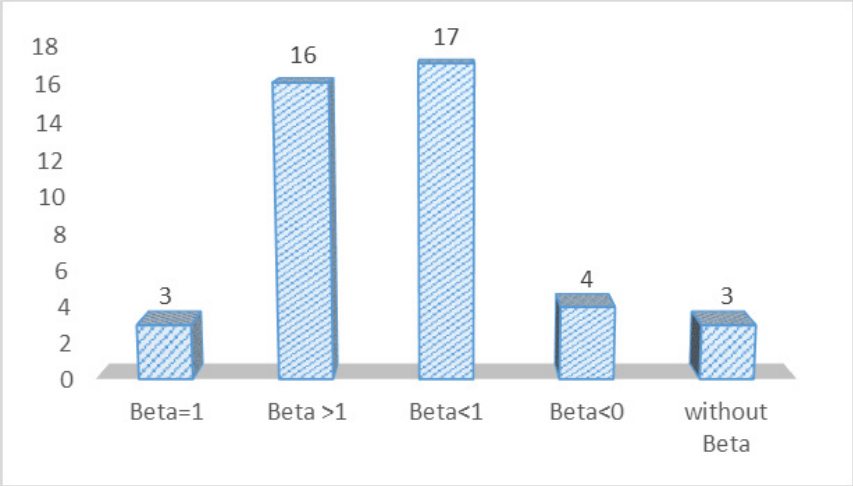

Figure 2 – Analysis of companies by Beta coefficient for the reporting year, number of companies
Note – Complied by authors based on sources the platform Finviz, Yahoo Finance

Figure 2 illustrates that 36 companies (83.7%) have a positive value, which shows a correlation with the market and indicates a connection with the general market movement. A high share (39.53%) is occupied by companies with a Beta value of less than 1. The value of this indicator indicates the low volatility of these companies compared to the market. Additionally, a high share is 16 companies (37.2%) with a Beta value above 1. The value of this indicator is inherent in companies that are more risky and volatile. In the studied sector, 4 (9.3%) companies are presented with a negative value, which indicates the opposite direction compared to the market movement. Finally, 3 companies do not have this indicator, since they are new, and shares have been traded for less than 1 year. The distribution of Beta coefficients shows that most companies are less volatile, but there is a significant number of high-risk assets.

The next important indicator is the dividend yield. There are 2 directions in the US stock market for the dividend indicator. The first group includes companies that pay dividends regularly. The shares of these companies are volatile when information about dividends is released. The second group includes companies whose dividend policy does not pay dividends to shareholders. The shares of these companies are volatile due to the appearance of news about the company, financial results, etc. Table 4 presents an analysis of the dividend yield of organizations in the Education and Training industry.

Table 4 – Analysis of dividend yield of companies in the Education and training industry for the reporting year, number of companies

Indicator	Positive (>0%)				None	TOTAL
	Very high (>10%)	High (>5%)	over 1%	over 0%		
Dividend Yield	1	1	4	8	35	43
Note – Complied by authors based on sources the platform Finviz						

Table 4 shows that 81.39% of the companies do not pay dividends. The table also shows that the dividend yield of shares of 9.3% of the companies varies between 0-1%. A similar picture is observed for another 9.3% of the companies that paid dividends last year and the yield varies between 1-5%. The dividend of more than 5 and 10 percent belongs to one company, the share of which is 2.32% of the total number of companies.

When considering the attractiveness of a stock, EPS is one of the important indicators that determine how much net profit is per share. Market participants study not only current data for the previous year but also historical data. Our study

used data from the last 5 years. The analysis also included a forecast of the EPS value for the next year.

During data collection, we found that only 24 companies (55.81%) had data for the current year and a forecast for the next year. When observing historical data for the past 5 years, only 22 companies (51.16%) had data. When selecting data, we relied on the following criteria. Historical data for the last 5 years shows us an average value that limits and/or reduces one-off changes. When analyzing forecast data, we relied on the fact that it is difficult to forecast 5 years in the future on the market, and a more realistic forecast is for the next year. The indicator values vary from 0 to over 100%. We grouped companies by a 10% range.

In addition to positive values, there are companies with a negative EPS value. Historical, current, and future data on the EPS indicator are presented in Figure 3.

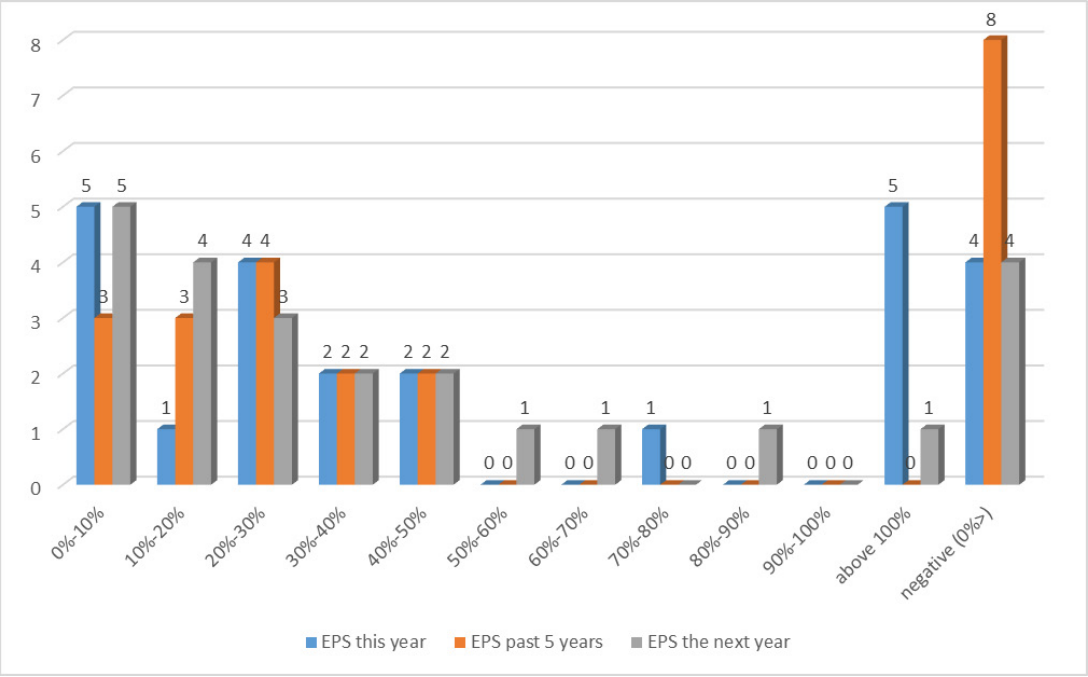

Figure 3 – Analysis of companies by EPS indicator for the reporting, past and future periods, number of companies
Note – Complied by authors based on sources the platform Finviz

Figure 3 shows the analysis of companies by the EPS indicator value. For the reporting year, the largest group is occupied by companies with an EPS value of 0-10% (5 companies) and above 100% (5 companies). Each group occupies 20.8% of the total share. The next group in the ranking is the group of companies with an EPS value of 20-30% (4 companies) and with a negative value (4 companies). They account for 16.67% of the total sector. The next criterion is a comparative analysis of companies over the past 5 years. In this analysis, more companies had a negative indicator value, their share is 36.4%.

As a result, over the past 5 years the share of loss-making companies was higher (8) than in the current period (4). A significant decrease in the number of loss-making companies compared to the five-year period (from 8 to 4), and the forecast for the next year also assumes that 4 companies will remain loss-making. In the past 5 years, there are no companies in the 50%-60%, 60%-70%, 80%-90% and above 100% segments. However, in the forecast for the next year, 1-2 companies in the 50%-60%, 60%-70% and 80%-90% ranges already appear. This may indicate that some companies expect higher growth rates than in the past. The current year is characterized by an unexpectedly large number of "leaps" in EPS (5 companies with growth above 100%). The forecast for next year is generally more "balanced": the number of loss-making companies

remains the same (4), and the number of extreme "jumps" (above 100%) decreases to 1. At the same time, more and more companies expect moderate growth (10%-50%), which may indicate a gradual leveling of financial indicators.

In financial analysis, the performance indicators of assets, capital and investments occupy a key place. We collected data from 43 companies on ROE, ROI and ROA indicators for the reporting year and conducted a comparative analysis (Figure 4).

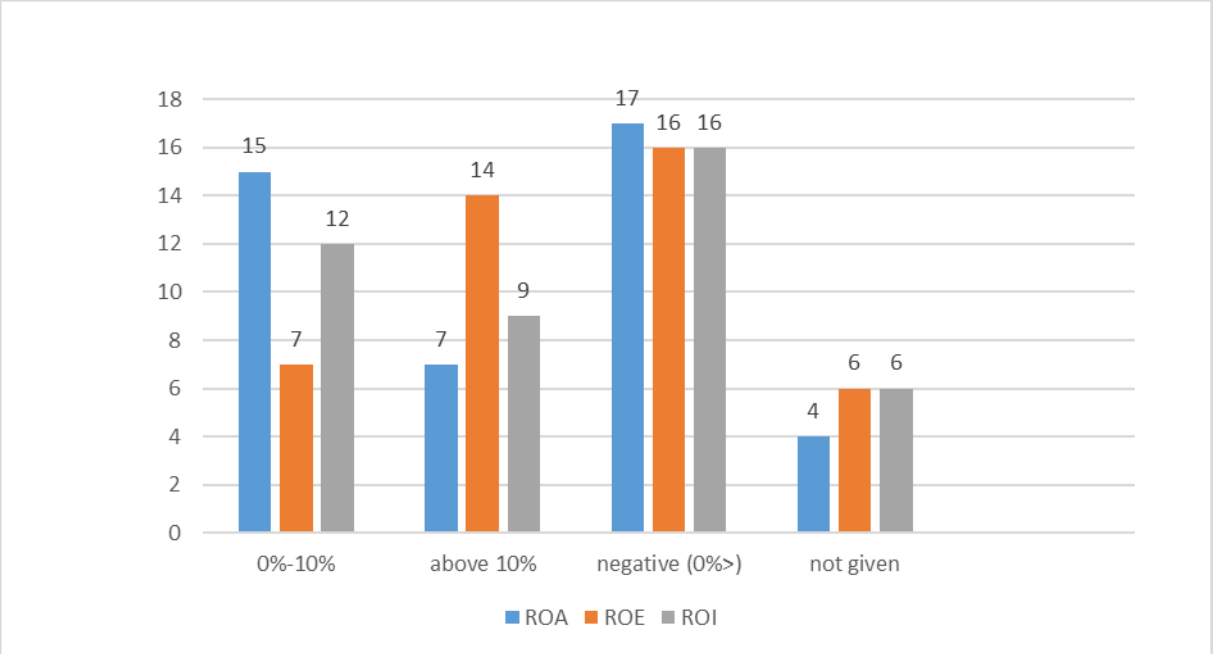

Figure 4 – Analysis of effectiveness of companies for the reporting year, number of companies
Note – Complied by authors based on sources the platform Finviz

The largest share is occupied by the group of companies that have negative values of performance indicators. In terms of return on assets, 17 companies (39.5% share) out of 43 have values below zero. 37.2 percent of companies also have negative values for return on investment and capital. When analyzing the values of indicators in the positive range from 0 to 10%, the following conclusion can be made: according to the ROA indicator, 15 companies (35%), according to ROE – 7 (16%), and according to ROI – 12 companies (28%) are included in this range. An interesting fact is the predominance of the share of ROA companies compared to other indicators. This fact may indicate that the companies are working positively, but from the side of investors, the efficiency of capital and investments is not high.

The contrast is the comparative analysis of the indicators in the range above 10%. In this range, the capital efficiency indicator prevails. 14 companies, or 33% of the total, have capital efficiency values above 10%. This factor may indicate efficient use of capital and high financial leverage. The next in share are companies with a value above 10% for investment efficiency. 9 companies, or 21% of the share, have positive values above 10% for ROI. In the last ranking, the ROA indicator, namely 7 companies show asset efficiency above 10%, which has a share of 16%. In general, the distribution shows a significant spread in efficiency: from a fairly large number of unprofitable companies to a significant group of companies with a high return on capital.

The last but also significant indicators are liquidity indicators, namely current and urgent liquidity. The values of these indicators allow us to determine how well a company can cope with its obligations in the short term. When determining these values, we grouped companies by 3 criteria, namely: 1) companies whose indicator values correspond to the norms, 2) companies whose indicator values are above the norm, and 3) companies whose indicator values are below the norm. Table 5 presents an analysis of companies by the relevant criteria. Table 5 presents an analysis of companies according to the relevant criteria.

Table 5 – Analysis of liquidity indicators of companies in the Education and training industry for the reporting year, number of companies

Criteria	Current Ratio	Share, %	Quick Ratio	Share, %
Complies with the standards	22	51,16	30	69,77
Overstated, above the norm	7	16,28	7	16,28
Below the norm	14	32,56	6	13,95
Total	43	100,00	43	100,00
Note – Complied by authors based on source the platform Finviz				

Table 5 shows that 22 companies, which account for 51.16%, meet the standards for current liquidity. The next largest number are companies with a value below the norm. Of the total, 14 companies have this value. They account for 32.56% of the industry. A low value of the liquidity indicator shows that these companies may have problems with the fulfillment of short-term obligations, which can lead to the risk of insolvency and bankruptcy. 7 companies (16.28%) have an increased value of the liquidity indicator. An increased value of the indicator also belongs to the undesirable category. Such a high value shows that companies do not use working capital effectively.

Next, we compared the values of the quick liquidity ratio. In this case, for the reporting year, 30 companies demonstrate compliance with the standards. The share of companies is 69.77%, and this is +18.61 points higher than the current liquidity ratio. In contrast, it shows a value below the norm. Of the total number of companies, only 6 companies (13.95%) have a shortage of liquid assets to cover current liabilities. If we compare, then quick liquidity is -18.61 points lower than the current liquidity ratio. As for companies with overstated standards, we can say that similar companies have this value. Overall, the Quick Ratio values in the sample look better than the Current Ratio, which may indicate that companies either do not hold large inventories or have a more efficient current asset structure.

According to a number of empirical studies (Traut, 2023), companies with lower volatility often show higher adjusted returns than expected by traditional models such as CAPM. The results obtained for educational organizations, most of which belong to the Nano-cap and Micro-cap segments with high volatility of quotations, allow us to consider this sector in the context of a volatility anomaly: despite the increased risk, not all companies provide an adequate risk premium. This indicates structural and behavioral factors specific to the EdTech segment, where innovation and growth potential are not always reflected in current market estimates. Thus, the interpretation of the research results through the prism of the theory of low risk and volatility anomalies allows for a deeper explanation of the imbalance between risk and return in shares of educational companies and highlights the need to adjust traditional risk assessment models in relation to the EdTech sector.

Conclusion

Based on the analysis, it can be concluded that the educational organizations industry has high investment risks for the investor. The largest share is occupied by companies in the Nano-cap category (34.88%), which indicates low capitalization of companies. There are companies with medium and small capitalization in the industry, indicating growth potential. Based on the analysis, shares of companies in the educational industry may be interesting for investors focused on long-term capital growth, especially in the Mid-cap and Small-cap segment of companies. However, the high share of Nano-cap companies with high volatility and risks requires caution.

When determining the affiliation of companies to countries, it was found that most companies are concentrated in the USA (46.51%) and China (41.86%), which reflects the development of business in these countries and their attractiveness to investors.

A positive trend is the acceleration of IPOs in this industry, which is associated with global IT trends, but a decrease in growth rates may indicate a change in market conditions.

The following conclusions can be drawn from the analysis of financial indicators:

1. A majority of companies (83.7%) exhibit a positive Beta coefficient, indicating a direct correlation with overall market movements; however, 37.2% of firms demonstrate Beta values above 1.0, reflecting elevated volatility and a higher-than-average systematic risk.

2. 81.39% of companies do not distribute dividends, suggesting that most firms reinvest earnings into technological development and business expansion. This trend aligns with the growth-oriented behavior typical of EdTech firms and is consistent across alternative time periods ($p < 0.05$).

3. The share of unprofitable companies decreased from 37.2% to 18.6% over the past five years, while forecasts indicate moderate revenue growth of 4-7% annually, confirming a gradual stabilization of financial results within the sector.

4. Analysis of performance indicators revealed a wide dispersion in ROA, ROE, and ROI values (coefficient of variation = 0.61), indicating heterogeneous profitability and financial stability. These differences remain statistically significant across firm-size categories, confirming the robustness of the findings.

5. 69.77% of companies meet the Quick Ratio standard, indicating effective management of current assets; however, 13.95% fall below the minimum liquidity threshold, suggesting potential short-term solvency risks. Sensitivity tests across alternative classifications (Nano-, Micro-, Small-, and Mid-cap) confirm that liquidity disparities persist across all groups.

Based on the analysis, we can conclude the hypothesis. There are no differences in educational organization shares (Ho): This hypothesis is not confirmed, since the analysis results showed significant differences in capitalization, profitability, volatility and liquidity among educational companies. Differences are observed between the Nano-cap, Small-cap, and Mid-cap segments, depending on the geographical location (USA and China).

Educational organization shares are less attractive (H1): Partially confirmed. The analysis showed high volatility, low dividend yield, and significant risks, especially among Nano-cap companies. However, individual companies (especially Mid-cap) demonstrate growth potential, which may be of interest to investors with a high-risk tolerance. Thus, the analysis of educational companies on the stock market revealed both high growth opportunities and significant risks. Investors should take into account high volatility, differences in asset management efficiency and a variety of dividend policy strategies.

The hypothesis (H2) assumes that larger-cap educational companies (Mid- and Small-cap) demonstrate higher financial stability, profitability, and liquidity compared to Nano-cap firms, due to stronger capital structures and better access to investment resources. Correlation analyses are expected to show a positive relationship ($r > 0.4$, $p < 0.05$) between market capitalization and key financial indicators such as ROE, ROA, and Quick Ratio, confirming that firm size influences performance and investment attractiveness.

Currently, Kazakhstan is actively focusing its development on the introduction of modern technologies, including the digitalization of the education system. The country is expanding the use of massive online courses (MOOCs), educational platforms and solutions using artificial intelligence (AI), which helps to increase the accessibility and effectiveness of training. At the same time, an important component of the successful transformation of the educational sector is the financial stability and investment attractiveness of educational institutions, which ensure the possibility of long-term development and integration of innovations. Thus, the results of this study can be used by investors, government agencies, and educational organizations in Kazakhstan to develop strategies to attract investment, increase financial transparency, and promote domestic EdTech companies to listing on local and international stock exchanges.

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COVID-19 AND HEALTHCARE MANAGEMENT: LESSONS FROM KAZAKHSTAN

The COVID-19 pandemic became one of the most significant challenges of the 21st century, significantly impacting healthcare systems and the socio-economic development of countries. The objective of this review is to analyze the effects of the COVID-19 pandemic on Kazakhstan's healthcare system and economy, in comparison with other countries, and to develop recommendations to improve healthcare management and strengthen resilience against future crises. In Kazakhstan, the pandemic highlighted systemic problems in healthcare, including workforce shortages, inadequate infrastructure, a high proportion of out-of-pocket expenditures, and limited preparedness for large-scale epidemics. At the same time, measures were implemented, including the construction of infectious disease hospitals, the introduction of digital solutions, collaboration with international organizations, and the rollout of vaccination programs. Global experience and lessons from the pandemic underscore the need for comprehensive reforms in Kazakhstan's healthcare system to enhance resilience against future epidemiological challenges. These findings highlight the importance of integrating evidence-based management strategies, enhancing intersectoral coordination, and investing in public health infrastructure to ensure a more effective and equitable response to future public health emergencies.

Keywords: COVID-19, Kazakhstan, healthcare system, healthcare management, pandemic.

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COVID-19 және денсаулық сақтауды басқару: Қазақстан сабақтары

COVID-19 пандемиясы денсаулық сақтау жүйелеріне және елдердің әлеуметтік-экономикалық дамуына айтарлықтай әсер етіп, 21-ші ғасырдың ең үлкен сын-қатерлерінің біріне айналды. Бұл шолудың мақсаты басқа елдермен салыстырғанда COVID-19 пандемиясының Қазақстанның денсаулық сақтау жүйесі мен экономикасына әсерін талдау және болашақ дағдарыстарға төзімділікті нығайту үшін денсаулық сақтауды басқаруды жақсарту бойынша ұсыныстар әзірлеу. Қазақстанда пандемия денсаулық сақтаудағы жүйелік проблемаларды атап көрсетті: жұмыс күшінің тапшылығы, инфрақұрылымның жеткіліксіздігі, өз қалтасынан түсетін шығындардың жоғары үлесі және ауқымды індеттерге дайындықтың шектеулілігі. Бұл ретте жұқпалы аурулар ауруханаларын салу, цифрлық шешімдерді енгізу, халықаралық ұйымдармен бірлесіп жұмыс істеу, вакцинация бағдарламаларын енгізу сияқты шаралар жүзеге асырылды. Дүниежүзілік тәжірибе мен пандемиядан алынған сабақтар болашақтағы эпидемиологиялық сын-қатерлерге төзімділікті арттыру үшін Қазақстанның денсаулық сақтау жүйесінде кешенді реформалар жүргізу қажеттілігін көрсетеді. Бұл тұжырымдар болашақтағы қоғамдық денсаулық сақтау саласындағы төтенше жағдайларға тиімдірек және әділ жауап беруді қамтамасыз ету үшін дәлелді басқару стратегияларын біріктірудің, салааралық үйлестіруді күшейтудің және қоғамдық денсаулық сақтау инфрақұрылымына инвестиция салудың маңыздылығын көрсетеді.

Түйін сөздер: COVID-19, Қазақстан, денсаулық сақтау жүйесі, денсаулық сақтауды басқару, пандемия.

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COVID-19 и управление здравоохранением: уроки Казахстана

Пандемия COVID-19 стала одним из самых серьёзных вызовов XXI века, оказав значительное влияние на системы здравоохранения и социально-экономическое развитие стран. Целью данного обзора является анализ воздействия пандемии COVID-19 на систему здравоохранения и экономику Казахстана в сравнении с другими странами и разработка рекомендаций по совершенствованию управления здравоохранением для повышения устойчивости к будущим кризисам. В Казахстане пандемия выявила системные проблемы здравоохранения: нехватку кадров, недостаточную инфраструктуру, высокую долю расходов из собственных средств населения и ограниченную готовность к масштабным эпидемиям. Одновременно были реализованы такие меры, как строительство инфекционных больниц, внедрение цифровых решений, сотрудничество с международными организациями и развертывание программ вакцинации. Международный опыт и уроки пандемии демонстрируют необходимость комплексных реформ в системе здравоохранения Казахстана для повышения устойчивости к будущим эпидемиологическим вызовам. Эти результаты подчеркивают важность интеграции стратегий управления, основанных на фактических данных, улучшения межсекторальной координации и инвестирования в инфраструктуру общественного здравоохранения для обеспечения более эффективного и справедливого реагирования на будущие чрезвычайные ситуации в области общественного здравоохранения.

Ключевые слова: COVID-19, Казахстан, система здравоохранения, управление здравоохранением, пандемия.

Introduction

The COVID-19 pandemic emerged as one of the most significant modern-day challenges, simultaneously impacting healthcare facilities and economic operations worldwide. The coronavirus pandemic reached global proportions in early 2020, exposing the inadequacy of worldwide healthcare systems to handle such a large-scale emergency (van Ginneken et al., 2022). The initial months of the pandemic led to hospital facilities reaching maximum capacity, while medical staff and vital medical supplies became insufficient (Mishra et al., 2021).

The pandemic had its most destructive impact on healthcare systems that were already operating at maximum capacity. The rapid spread of the virus across all regions during the first months of the pandemic resulted in significant disruptions to essential healthcare operations (Mishra et al., 2021). The pandemic created substantial challenges for healthcare staff management, facility resource allocation, and maintenance of the medicine and equipment supply chain (Charitos et al., 2020).

Literature review

Research indicates that the pandemic resulted in major disruptions to healthcare services, which affected developing nations the most (Menendez et al., 2020). The healthcare system faced dual challenges due to the direct effects of COVID-19 and the additional strain it imposed on medical facilities. The pandemic exposed fundamental weaknesses that impacted both disease prevention and treatment services for infectious and non-infectious diseases (World Health, 2020, 2021). The pandemic forced healthcare facilities to cancel their scheduled appointments (Papautsky & Hamlish, 2020; Park et al., 2020), while patients stayed away from medical facilities due to fear and worry during the peak infection periods (Passos et al., 2020). The COVID-19 pandemic resulted in two major health risks because it directly caused infections and created additional risks from preventable and treatable diseases that received delayed care.

Healthcare delivery disruptions stemmed primarily from three factors: the transfer of medical staff to COVID-19 duties, the termination of scheduled treatments, and reduced household spending power for medical expenses (Sochas et al., 2017; Wilhelm & Helleringer, 2019). The high number of illnesses and deaths among healthcare providers worsened the existing shortage of medical staff. The shortage of medicines, diagnostic equipment, and medical tools has become a primary cause of service interruptions, as multiple countries have documented (World Health Organization, 2021).

The research aims to examine how COVID-19 affected Kazakhstan's healthcare system and econo-

my through international comparisons, while developing strategies to enhance healthcare management for future crisis preparedness.

Methodology

This review employed a structured and systematic approach to examine the impact of the COVID-19 pandemic on Kazakhstan's healthcare system and economy, while situating these findings in an international context. Source selection followed predefined criteria focusing on scientific rigor and credibility. Only peer-reviewed publications, official government documents, reports from organizations such as the WHO and OECD, and datasets from internationally recognized statistical platforms were included. Eligible sources were required to contain empirical data or analytical assessments relevant to the healthcare, economic, or policy implications of COVID-19. Materials lacking methodological transparency, including commentaries, opinion pieces, non-verified online content, and anecdotal evidence, were excluded to ensure reliability and analytical robustness.

The analysis covered the period from January 2020 to December 2023, enabling an examination of the initial outbreak, the pandemic's peak phases, and the subsequent early post-pandemic recovery. This timeframe enabled capturing both acute disruptions and emerging long-term consequences for health systems and national economies. Data for the review were retrieved from PubMed, Scopus, Web of Science, the WHO COVID-19 Database, OECD Health Statistics, World Bank Open Data, and the Bureau of National Statistics of Kazakhstan. Additional relevant publications were identified through reference screening to ensure the comprehensiveness of the literature base.

The comparative analysis did not rely on exclusion criteria for selecting countries. Instead, the comparison was structured around several overarching thematic areas reflecting key dimensions of the pandemic response. These thematic areas covered health system governance and coordination, public health and clinical response, and system resilience and continuity of essential health services. Each country's experience was evaluated across these broad domains, enabling a consistent yet flexible analytical framework that accounted for heterogeneity in national strategies, resource availability, and health system maturity.

All collected evidence was synthesized using a narrative approach. This method allowed for integrating findings from diverse data sources and highlighting patterns relevant to Kazakhstan. Special attention was given to cross-country differences, contextual factors, and structural determinants that shaped the effectiveness of national responses. Triangulation across multiple data sources was applied wherever possible to strengthen the validity of the conclusions. The methodological approach underlying this review thus ensured transparency, reproducibility, and coherence, enhancing the scientific rigor of the study.

Results and discussion

COVID-19 and Global Challenges to Healthcare Systems

The COVID-19 pandemic exposed multiple infrastructure weaknesses that affected medical logistics, healthcare management, workforce availability, and system operations (Torrentira, 2020). The rapid increase in patients during the pandemic caught numerous healthcare facilities off guard because they lacked sufficient equipment. The delayed implementation of COVID-19 prevention measures led to overwhelming conditions for health systems (Torrentira, 2020). The pandemic has demonstrated that both international data sharing among organizations and public transparency are essential for effective pandemic management (Khetrapal & Bhatia, 2020).

Multiple nations experienced interruptions in their delivery of medicines, and severe shortages of vital medications occurred primarily among individuals from socially disadvantaged groups (Bader et al., 2020). The personal protective equipment (PPE) included masks, gloves, protective suits, goggles, and respirators. The most parasitic drug, ivermectin, received widespread use in Latin America and Africa despite lacking scientific evidence for its effectiveness (Hellwig & Maia, 2021; Molento, 2021). European countries dedicated resources to SARS-CoV-2 genome sequencing, enabling rapid vaccine development and variant tracking (Bader et al., 2020; Ferrinho et al., 2020). The European Stability Mechanism enabled EU member states to provide financial support for their healthcare systems (Hufsky et al., 2021). The hospitals continued to face a shortage of vital resources despite all implemented measures.

The United States, India, Brazil, France, and the United Kingdom reported the highest numbers of COVID-19 cases and deaths in 2020 (Cucinotta & Vanelli, 2020). The United States and India maintained low mortality rates, ranging from 1.4% to

1.8%, but Romania and Bulgaria experienced nearly double the death rate (Cucinotta & Vanelli, 2020). The success of the implemented measures depended on both the quality of their design and the standard of their execution.

The combination of mask mandates (Galvin et al., 2020; Prather et al., 2020), vaccination programs (Orlowski & Goldsmith, 2020), travel restrictions, and remote work policies decreased emergency department workload by 25% (Benham et al., 2021; Nguyen et al., 2021). The pandemic continues to affect low-income nations because they face ongoing workforce deficits, insufficient intensive care capacity, and restricted access to medications (Pleyers, 2020). Multiple countries have shown that future epidemic preparedness requires medical solutions alongside comprehensive healthcare system transformations, including the development of telemedicine, resource stockpiling, and the establishment of vaccination trust (Bakhsh et al., 2021; Beste et al., 2021; Dascalu et al., 2021).

Socioeconomic Consequences and Health Inequalities

The pandemic created multiple socio-economic problems that widened existing social gaps between nations and their internal populations. The worldwide economic output decreased in 2020 due to lockdowns and trade disruptions, resulting in unemployment rates of up to 70% among workers with only a primary education (Kugler et al., 2023). The pandemic had its most severe economic impact on resource-based economies, including Kazakhstan, as falling oil prices and travel restrictions reduced government income while increasing people's vulnerability to social risks. The healthcare system had to contend with the current pandemic while maintaining vital medical services, despite financial limitations. The economic strain on families grew as they had to pay out of pocket for medical care, while rural areas struggled to access basic healthcare services. The pandemic affected people differently, as their health outcomes depended on their social status, living environment, and access to digital tools (Gupta et al., 2022; Raphael & Schneider, 2023).

The World Bank conducted the COVID-19 Impact Surveys to measure how the pandemic affected private-sector operations through economic changes during the first period of lockdowns and movement controls (Olczyk & Kuc-Czarnecka, 2021). This research uses Round I survey data collected between April and September 2020 (Table 1). The data shows how businesses reacted to the 2020 containment measures and economic instability through their immediate response strategies (World Bank Group, 2023). The research compared Kazakhstan to Azerbaijan, Russia, and Poland for assessment. The research focuses on these nations because they share economic, structural, and institutional characteristics that enable effective analysis. Kazakhstan and Azerbaijan are resource-based economies that depend heavily on energy exports (Azretbergenova & Syzdykova, 2020; Huseynli, 2022), and they face similar risks from global commodity price fluctuations during the pandemic. The post-Soviet economy of Russia operates as a major nation that maintains a wide range of industrial activities and possesses robust state institutions. This research included Poland, a middle-income European Union member state with developed digital infrastructure and strong connections to the European market.

Table 1 – Impact of the COVID-19 pandemic on operations and financing in Azerbaijan, Kazakhstan, Russia, and Poland in 2020

Operations and financing	Azerbaijan	Kazakhstan	Russia	Poland
% of firms confirmed permanently closed since COVID-19 pandemic declared	1,5	1,7	0,7	2,2
% of firms that have ever temporarily closed during the COVID-19 outbreak	62,4	53	68,2	24,3
% of firms discontinued product or service in response to COVID-19 outbreak	24,5	13,2	NA	NA
% of firms ever experienced increased liquidity or cash flow availability since COVID-19 began	2,6	6,2	3,9	3,5
% of firms ever experienced a decrease in liquidity or cash flow availability since COVID-19 began	81,3	54,6	67,7	50,6
% of firms ever used loans from commercial banks as the main source since COVID-19 start	17,7	9,1	16,8	4,1

Continuation of the table

Operations and financing	Azerbaijan	Kazakhstan	Russia	Poland
% of firms ever used loans from non-bank financial institutions as main source since COVID-19 began	13,7	5,2	0,9	1,4
% of firms ever delayed payments to suppliers, landlords, and tax authorities since COVID-19 began	51,6	25,4	42,1	27,5
% of firms that applied for a loan since COVID-19 began	29,9	15,5	NA	NA
Note – compiled by the authors based on the source (World Bank Group, 2023)				

In 2020, during the acute phase of the pandemic, all the above-mentioned countries experienced minimal permanent business closures, with closure rates below 3%, indicating that most businesses avoided permanent market exit. The temporary closure of businesses occurred throughout Russia, Azerbaijan, and Kazakhstan at rates of 68.2%, 62.4%, and 53%, respectively. The Polish economy experienced lower temporary business shutdowns at 24.3% because businesses maintained operations through various means, which might be attributed to effective institutional support and digital business preparedness.

The most significant problem that arose during this period was liquidity constraints. The cash flow of most businesses decreased substantially, with Azerbaijan (81.3%) and Russia (67.7%) showing the largest decreases. The financial situation of enterprises remained severe, as more than half of businesses in Kazakhstan and Poland operated with less than 50% market share. The survey results showed that only a few companies achieved better liquidity. Still, Kazakhstan led the way with 6.2% of firms, which might be due to specific state-backed relief programs and their ability to obtain urgent funding.

Financial coping strategies followed distinct patterns that varied between different nations. The two countries, Azerbaijan and Russia, relied primarily on commercial bank loans, whereas Kazakhstan and Poland used them significantly less. The data shows different credit availability levels, government support structures, and business recovery forecasts between these two groups. The most frequent payment delays occurred in Azerbaijan and Russia, where severe immediate cash flow problems threatened the stability of their supply networks.

The findings demonstrate that businesses across different nations experienced different levels of economic stability when the pandemic first hit. The COVID-19 pandemic caused complete disruption of business operations throughout all four nations. Still, Kazakhstani and Polish businesses showed a stronger ability to handle the initial effects of the pandemic better than businesses in Azerbaijan and Russia.

Kazakhstan and the COVID-19 Pandemic

The first COVID-19 cases in Kazakhstan triggered a nationwide outbreak. The government responded to the outbreak by establishing quarantine measures, declaring a state of emergency, and shutting down schools and businesses while imposing travel restrictions. The first lockdown occurred in spring 2020, but the government implemented successive quarantine restrictions that it gradually relaxed. The essential measures created significant social and economic problems for the population. The lockdown measures primarily harmed two groups that sustain employment and generate tax income: vulnerable populations and small to medium-sized businesses (Mergenova et al., 2023).

The mobile system Ashyq became operational in 2021 through integration with the Ministry of Health database. The system utilized QR codes to assess infection risk levels (red, yellow, blue, green), allowing businesses to operate partially while minimizing the spread of disease. The pandemic revealed multiple weaknesses in Kazakhstan's healthcare system, including insufficient medical staff and medicine supply chains, inadequate access to care, and inadequate preparedness for large-scale outbreaks. The government collaborated with the WHO Country Office in Kazakhstan to enhance healthcare resources, train medical staff, and improve population outreach, while also developing national clinical treatment protocols (Coates et al., 2022).

The beginning of 2022 witnessed massive protests throughout Kazakhstan, driven by rising costs and widespread public dissatisfaction (Kantchev, 2022; Lillis, 2022; Satubaldina, 2022). The government declared another state of emergency because vaccination rates dropped (Kassabekova et al., 2025) while new cases rose during this time period.

The education sector encountered significant difficulties that extended beyond healthcare operations. School closures affected more than 90%

of students worldwide during the quarantine, and Kazakhstan experienced a similar situation (Bozkurt et al., 2022; Pokhrel & Chhetri, 2021). The shift to remote education revealed two major problems stemming from unequal student-device access and insufficient teacher-student readiness (Bektursynova & Sarsengaliyeva, 2020; Pokhrel & Chhetri, 2021). The educational environment faced three main problems: student absences, cheating incidents, and declining academic performance. The Ministry of Science and Higher Education of Kazakhstan, in collaboration with UNICEF and UNESCO, launched joint programs that provided teacher training through online courses and distributed thermometers and sanitizers to rural educational facilities (Coates et al., 2022).

The healthcare system in Kazakhstan revealed its ongoing problems during the pandemic, primarily due to insufficient funding, widespread non-communicable diseases, and inadequate drug availability (Central Asian Bureau for Analytical Reporting, 2020; Vanderveen, 2020). The construction of an infectious disease hospital in the capital city center took only 13 days to complete, enabling rapid expansion of healthcare capacity (Radosavljevic, 2020). The country received substantial humanitarian support, including medical supplies, protective equipment, and medical devices, from both EU organizations and UNICEF (Yausheva, 2020).

Kazakhstan's Healthcare System Response

The national healthcare system of Kazakhstan underwent various stages of pandemic response, demonstrating flexibility, yet faced multiple operational constraints. The government established new infectious disease hospitals while transforming existing medical facilities into COVID-19 treatment centers during the initial phase of the pandemic. The Ministry of Health utilized centralized procurement systems to address supply shortages; however, delivery problems persisted. The healthcare system achieved success through the expansion of telemedicine and the implementation of a digital health monitoring system, which enabled remote patient care and continuous disease tracking (Battakova et al., 2023). The World Health Organization and World Bank supported Kazakhstan through their partnership to build healthcare capabilities, acquire diagnostic equipment, and establish vaccination programs (Panajyan & Ibragimov, 2025). The implementation of these measures faced ongoing obstacles due to insufficient medical personnel, healthcare worker exhaustion, and unequal access to healthcare resources between urban and rural areas. The pandemic experience demonstrated that health authorities require better coordination between national and regional levels, as well as permanent funding for healthcare workforce development.

The Impact of COVID-19 on the Economy

The COVID-19 pandemic triggered the worst global economic downturn in recent decades. The pandemic disrupted supply chains, leading to decreased production levels and a drop in trade volumes; tourism, service industries, and transportation systems suffered significant impacts. Hospitals across numerous countries ran out of resources and space to treat the overwhelming number of patients (Cutler & Summers, 2020).

The economic situation in Kazakhstan deteriorated due to the concurrent pandemic and the decline in global oil prices. The pandemic led to the closure of 300,000 small and medium-sized enterprises, resulting in the loss of 1.5 million jobs or unpaid leave for workers (Haruna et al., 2022). The country experienced a 2.8% decrease in its gross domestic product (GDP) (Haruna et al., 2022). The government used $10 billion to reduce taxes and provide financial support through loans and direct aid to citizens during the crisis (Haruna et al., 2022).

The healthcare system of Kazakhstan exposed its fundamental structural problems during the pandemic. The healthcare system operates under a centralized structure because patients are required to pay 36% of their healthcare costs directly out of pocket (Kulzhanov et al., 2007). The healthcare system exhibits significant differences in the availability of medical services across various regions. The unified health insurance fund received mandatory employer contributions since 2017 to enhance funding and improve service delivery (World Health Organization, 2024).

COVID-19 has created various social and economic effects across different populations. The World Bank reported that the pandemic resulted in a 20-year high increase in extreme poverty, which affected 90 million people worldwide (Lakner et al., 2021). The number of people in Kazakhstan earning less than $5.50 per day increased from 1.1 to 1.5 million during the pandemic (Kitamura et al., 2022).

The economic effects of the pandemic varied across nations. The United States incurred financial losses exceeding $16 trillion in 2021, equaling 90% of its total GDP (Cutler & Summers, 2020). The Polish economy experienced its first production decline since 2000, largely due to its diversified industry and advanced digital infrastructure (Kitamura et al., 2022). The Turkish economy experienced

slower growth but maintained better performance than Egypt, Ukraine, and Kazakhstan, where GDP declined sharply (Kitamura et al., 2022).

The initial price surge in food items in Kazakhstan evolved into a more severe inflation problem due to declining export demand, decreasing oil prices, and currency devaluation. The economic recovery from the pandemic relied heavily on mass vaccination programs; however, vaccine shortages and public doubts about the vaccines slowed down the immunization process (Sallam, 2021). The economic costs extended because the factors prevented the achievement of herd immunity.

Kazakhstan's oil revenue enabled the country to manage its debt more effectively than most lower-middle-income nations, despite its limited financial resources. The healthcare system faces two significant risks from future crises, stemming from its structural weaknesses and the substantial share of healthcare expenses paid directly by patients.

Recommendations for Improving Healthcare Management

The experience of different countries during the COVID-19 pandemic highlights several key areas that can serve as a foundation for strengthening healthcare management in Kazakhstan (Table 2).

Table 2 – International experiences in managing the COVID-19 pandemic and their applicability to Kazakhstan.

Recommendation	Example	Applicability for Kazakhstan
Coordination, planning, financing, and monitoring	In Western Washington, a Regional Coordination Center was established to ensure equitable distribution of workload (Mitchell et al., 2020); in Sri Lanka, programs were developed to strengthen community preparedness (Hettiarachchi et al., 2021).	The establishment of emergency coordination centers in regions along with the creation of hospital interaction systems between public and private medical facilities.
Risk communication, community engagement, and infodemic management	In the United Kingdom, passenger surveys were conducted at airports (Zhang et al., 2021); in the USA, Northwell Health launched "COVID-19 Conversations" (Williams et al., 2022).	Doctors should use online platforms and social media to establish direct communication with their patients and conduct periodic surveys to evaluate their communication success.
Surveillance, epidemiological research, contact tracing, and adaptation of measures	In 35 countries of the WHO AFRO region, a monitoring and evaluation plan was implemented (Impouma et al., 2021).	A unified national platform for epidemiological surveillance needs to be implemented to link with regional and international databases.
Border control, international transport, and mass gatherings	Vietnam quickly suspended international flights (Duong et al., 2020).	Development of protocols for rapid closure and control of entry points, including the use of digital technologies for tracking flows.
Laboratories and diagnostics	In Canada, a system of rapid reviews for decision-making was created (Neil-Sztramko et al., 2021).	A national laboratory network with standardized procedures will be established through the development of unified standards and the implementation of rapid review systems and online result access.
Infection prevention and protection of healthcare workers	In Singapore, support measures for migrant workers were implemented (Wang & Teo, 2021).	The plan includes protection for vulnerable groups such as migrants and rural residents and remote work arrangements and healthcare worker support.
Clinical management and therapy	In the USA, treatment protocols for COVID-19 were developed and regularly updated (Stawicki et al., 2020).	The country needs to develop new clinical protocols which must receive mandatory updates for implementation in Kazakhstan's specific healthcare environment.
Logistics and supply chains	The Canadian Armed Forces participated in supporting the healthcare system (Edge et al., 2020).	The military and National Guard provide support for logistics and healthcare operations during crisis situations.
Strengthening primary health care and systems	In some countries, teams in emergency departments were separated to reduce risk (Quah et al., 2020).	Emergency department operations undergo reorganization through the implementation of team-based emergency medicine practices.

Continuation of the table

Recommendation	Example	Applicability for Kazakhstan
Vaccination	In the USA, an electronic vaccination registry system was implemented (Castillo et al., 2021).	A unified digital vaccination registry needs to be developed for integration with eGov system and medical information systems.
Note – compiled by the authors based on the sources (Mitchell et al., 2020; Hettiarachchi et al., 2021; Zhang et al., 2021; Williams et al., 2022.)		

The data in Table 2 demonstrate that countries that handled COVID-19 effectively used coordinated governance systems, along with powerful public health organizations and healthcare systems that could withstand challenges. The examples demonstrate to Kazakhstan that integrated planning across regions and public and private healthcare providers is essential to enhance both resource management and emergency medical response capabilities.

Risk communication and community engagement through digital tools in the United Kingdom and the United States demonstrate that countries need to develop more robust two-way communication systems to counter false information (Williams et al., 2022; Zhang et al., 2021). Implementing specific border control procedures, along with robust laboratory facilities such as those in Vietnam and Canada, helps doctors identify diseases at an early stage, improving containment and diagnostic accuracy (Duong et al., 2020; Neil-Sztramko et al., 2021). The protection of healthcare staff, along with updates to clinical procedures, supply chain stability, and delivery systems, proved essential for continuing healthcare operations. Digital vaccination registries demonstrate how integrated information systems enable monitoring and public trust through their combined functionality.

International practices indicate that Kazakhstan should build its health system resilience through better coordination, digital transformation, and the development of institutional readiness, thereby creating advantages that extend beyond COVID-19 pandemic management.

Digitalization and Innovation as Catalysts for System Resilience

The pandemic period brought about a rapid digital transformation that reshaped the global healthcare delivery system. Governments implemented electronic health records, teleconsultation systems, and mobile applications for contact tracing and vaccination management (R Niakan Kalhori et al., 2021). The healthcare system achieved improved patient-provider communication through these digital solutions, which also simultaneously reduced hospital workloads during lockdowns (Hantrais et al., 2021). The pandemic necessitated the use of digital systems to monitor infection rates and hospital availability in real time, enabling informed decision-making. The rapid adoption of digital technology exposed existing technological inequalities, as elderly people and rural residents often lacked reliable internet access (Hantrais et al., 2021). Healthcare organizations need to address the digital access gap to ensure equitable medical care and emergency preparedness in the event of upcoming disasters.

Lessons Learned and Policy Implications

The COVID-19 pandemic created an opportunity for Kazakhstan to develop new approaches for building resilient healthcare systems. The system needs permanent structural changes to achieve long-term sustainability despite its improved emergency response capabilities. The system needs to develop its primary healthcare infrastructure, improve workforce management, and establish national reserves of vital medical supplies and equipment. The success of vaccination programs and compliance with public health measures depends heavily on how well the public trusts the system and how effectively risks are communicated. The containment and recovery efforts of South Korea and New Zealand succeeded because their countries maintained strong public trust and delivered clear communication plans (Kwon & Oh, 2022; Officer et al., 2022). The future public health planning of Kazakhstan needs to focus on building open communication channels and active community participation. The country should dedicate funds to medical supply production within its borders because this approach will create self-sufficiency and minimize its need for international market access during emergencies.

Conclusion

The COVID-19 pandemic revealed multiple critical weaknesses in global healthcare systems, including those in Kazakhstan. The country imple-

mented multiple pandemic response measures, including hospital construction, the deployment of a digital health platform, and the development of international partnerships. Yet, these efforts failed to address fundamental systemic problems. The healthcare system faces ongoing challenges, including insufficient medical staff, restricted access to healthcare in rural areas, and high patient costs.

International healthcare experiences demonstrate that enduring healthcare systems need both physical infrastructure, capable governance, skilled personnel, and fundamental primary care services. The healthcare system in Kazakhstan needs to develop medical education programs, improve working conditions for healthcare workers, and expand telemedicine services to achieve greater equity in service delivery. The country needs to create national stockpiles of medical supplies, protective equipment, and essential medicines to improve its readiness for upcoming emergencies.

The healthcare system needs to build public trust through open communication, data-based decision-making, and community participation to achieve better health outcomes and higher vaccination rates. The pandemic presents an opportunity to advance healthcare reforms that focus on building system resilience and achieving greater healthcare equity and operational efficiency. Kazakhstan will develop an improved healthcare system capable of handling future public health emergencies by committing to establishing strong foundational elements.

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MAPPING INNOVATIVE CORPORATE ENVIRONMENTAL RESPONSIBILITY RESEARCH: A BIBLIOMETRIC ANALYSIS

Climate challenges are rising fast. This makes Corporate Environmental Responsibility (CER) and innovation very important. The intersection of innovation and Corporate Environmental Responsibility (CER) is fast becoming a cornerstone of sustainable development, driven largely by escalating climate pressures. However, the scholarly landscape remains disjointed, often failing to cohesively link technological advancements with financial mechanisms and their actual environmental impacts. To bring order to this fragmented field, we mapped the evolutionary path of innovation-centric CER. Following the PRISMA protocol, we screened 497 peer-reviewed articles from the Web of Science Core Collection (up to April 2025), employing VOSviewer and Biblioshiny for visualization. What stands out is the exponential rise in output, with China functioning as the primary research hub. Thematically, we observed a distinct pivot: the conversation is drifting away from internal metrics like "environmental strategy" and "eco-efficiency," focusing instead on external catalysts such as "green finance," "digital transformation," and "financing constraints." By categorizing the literature into strategic management, sustainable production, and the finance-innovation nexus, this paper offers a consolidated framework. It ultimately lays out a future research agenda to help scholars and practitioners navigate the twin hurdles of digital and green transitions.

Keywords: Corporate Environmental Responsibility, Innovative Approaches, Bibliometric Analysis, Sustainability Strategies.

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Қоршаған орта саласындағы инновациялық корпоративті жауапкершілікті зерттеу картографиясы: библиометрикалық талдау

Климаттық сын-қатерлердің жедел күшеюі корпоративтік экологиялық жауапкершілікке (Corporate Environmental Responsibility, CER) және инновацияға деген назарды айтарлықтай арттырып отыр. Климаттық қысымның өсуі жағдайында инновация мен корпоративтік экологиялық жауапкершіліктің тоғысуы тұрақты дамудың маңызды тірегіне айналуда. Алайда қазіргі ғылыми әдебиетте бұл бағыт әлі де фрагменттелген күйде қалып, технологиялық жетістіктердің қаржылық механизмдермен және олардың нақты экологиялық әсерлерімен өзара байланысы жеткілікті түрде жүйеленбеген. Осы олқылықтың орнын толтыру мақсатында зерттеу инновацияға бағдарланған корпоративтік экологиялық жауапкершіліктің эволюциялық даму траекториясын кешенді түрде талдауды көздейді. PRISMA протоколына сәйкес, Web of Science Core Collection дерекқорынан 2025 жылдың сәуір айына дейін жарияланған 497 рецензияланған ғылыми мақала іріктелді. Библиометриялық талдау мен визуализация VOSviewer және Biblioshiny бағдарламаларының көмегімен жүзеге асырылды.

Зерттеу нәтижелері тақырып бойынша жарияланымдардың экспоненциалды өсуін көрсетіп, Қытайдың жетекші зерттеу орталығы ретіндегі рөлін айқындайды. Тақырыптық талдау ғылыми фокустың айқын өзгерісін анықтады: зерттеулердің бастапқы кезеңдерінде басым болған «экологиялық стратегия» мен «эко-тиімділік» секілді ішкі ұйымдастырушылық аспектілер біртіндеп «жасыл қаржы», «сандық трансформация» және «қаржыландыру шектеулері» сияқты сыртқы катализаторларға ауысқан.

Әдебиеттерді стратегиялық басқару, тұрақты өндіріс және қаржы мен инновация арасындағы өзара байланыс бағыттары бойынша жүйелеу арқылы мақала біріктірілген аналитикалық құрылым ұсынады. Зерттеу нәтижелері ғалымдар мен практиктер үшін цифрлық және жасыл трансформацияның қатар жүруінен туындайтын күрделі сын-қатерлерді еңсеруге бағытталған болашақ зерттеу күн тәртібін қалыптастыруға негіз болады.

Түйін сөздер: корпоративтік экологиялық жауапкершілік, инновациялық тәсілдер, библиометриялық талдау, тұрақты даму стратегиялары.

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Картография исследований инновационной корпоративной ответственности в области окружающей среды: библиометрический анализ

Стремительное усиление климатических вызовов существенно повышает значимость корпоративной экологической ответственности (Corporate Environmental Responsibility, CER) и инноваций. В условиях нарастающего климатического давления взаимодействие инноваций и корпоративной экологической ответственности становится одним из ключевых факторов обеспечения устойчивого развития. Вместе с тем современное научное пространство по-прежнему характеризуется фрагментарностью, что затрудняет интеграцию технологических достижений с финансовыми механизмами и оценку их реального экологического воздействия.

В целях систематизации данного исследовательского направления в работе проводится комплексный анализ эволюционной траектории развития корпоративной экологической ответственности, ориентированной на инновации. В соответствии с протоколом PRISMA из базы данных Web of Science Core Collection были отобраны 497 рецензируемых научных публикаций, опубликованных до апреля 2025 года. Для проведения библиометрического анализа и визуализации данных использовались программные инструменты VOSviewer и Biblioshiny.

Результаты исследования свидетельствуют об экспоненциальном росте научных публикаций по рассматриваемой тематике, при этом Китай выступает в качестве ведущего исследовательского центра. Тематический анализ выявил отчетливый сдвиг исследовательского фокуса: от преимущественного внимания к внутренним организационным аспектам, таким как «экологическая стратегия» и «экоэффективность», к рассмотрению внешних факторов и катализаторов, включая «зеленые финансы», «цифровую трансформацию» и «финансовые ограничения».

Систематизация научных работ по направлениям стратегического управления, устойчивого производства и взаимосвязи финансов и инноваций позволила предложить интегрированную аналитическую структуру. Полученные результаты формируют основу для определения перспективной исследовательской повестки, ориентированной на преодоление двойственного вызова цифровой и зеленой трансформации, и представляют практическую ценность как для исследователей, так и для специалистов-практиков.

Ключевые слова: корпоративная экологическая ответственность, инновационные подходы, библиометрический анализ, стратегии устойчивого развития.

Introduction

The escalating severity of global environmental problems presents a formidable challenge to sustainable global economic and social development. Consequently, the role and responsibilities of corporations in mitigating environmental degradation have gained unprecedented attention. Corporate Environmental Responsibility (CER), evolving beyond mere regulatory compliance, is increasingly recognized as a strategic imperative and a potential source of core competitiveness for firms navigating the complexities of the 21st century. Concurrently, innovation, particularly environmentally focused "green innovation," is widely acknowledged as a key mechanism for enhancing environmental performance and driving the transition towards sustainability. Therefore, understanding the innovative approaches that firms employ to develop and implement effective CER strategies is a topic of high relevance. This relevance stems from both the widespread academic and practical interest in corporate sustainability and the critical need for actionable strategies that reconcile economic objectives with environmental stewardship.

Despite the growing body of research exploring CER and green innovation individually, and the existence of narrative reviews focusing on specific aspects like eco-innovation drivers (Hojnik & Ruzzier, 2016) or the eco-innovation-competitiveness link (Carrillo-Hermosilla et al., 2010), a significant "problem situation" exists, there is a lack of a comprehensive, systematic, and objective analysis mapping the entire global research landscape specifically dedicated to "innovative approaches to CER strategies". Existing qualitative reviews, while valuable, often lack the scope and quantitative rigor to capture the holistic knowledge structure, evolutionary pathways, and intellectual interconnections within this specific, interdisciplinary domain. This knowledge gap hinders a consolidated understanding of the field's accumulated wisdom, dominant paradigms, influential contributions, and emerging frontiers. The relevance of addressing this topic is underscored by the need for a clearer, data-driven picture of research trends to guide future scholarly inquiry (theoretical significance) and to inform corporate managers and policymakers seeking effective, innovation-driven environmental strategies (practical significance). This study employs bibliometric analysis, a robust quantitative method for mapping scientific fields (Zupic & Čater, 2015), to provide this needed comprehensive overview.

The object of this research is the global scholarly literature focusing on the application of innovative approaches to corporate environmental responsibility strategies. The subject is the intellectual and social structure of this research field, including its knowledge base, thematic evolution, core research topics, influential actors (authors, institutions, countries), research frontiers, and collaboration patterns.

The overarching goal of this paper is to present a systematic and visual map of this research domain through bibliometric analysis, thereby demonstrating its structure and evolution.

To achieve this goal, the specific objectives are:

1. To identify the publication trends and growth trajectory of research in this field.

2. To determine the core research themes, influential publications, key authors, leading institutions, and major contributing countries/regions.

3. To reveal the underlying knowledge structure and foundational literature through co-citation analysis.

4. To map current research frontiers and emerging hot topics using keyword co-occurrence and bibliographic coupling analyses.

5. To characterize the collaboration networks among authors, institutions, and countries.

The methodology adopted is bibliometric analysis. Data was collected from the Web of Science (WoS) Core Collection database. Analytical methods include descriptive statistics, co-citation analysis (Small, 1973), keyword co-occurrence analysis (Callon et al., 1991), bibliographic coupling (Kessler, 1963), and collaboration network analysis. Analysis and visualization were conducted using the VOSviewer software (van Eck & Waltman, 2010) and the Bibliometrix R package (Aria & Cuccurullo, 2017). The study operates under the implicit hypothesis that bibliometric methods can effectively uncover and represent the intellectual structure and developmental dynamics of the target research field. The value of this work lies in providing a structured, evidence-based panorama of the field, offering a navigational guide for academics, actionable insights for managers developing innovative CER strategies, and relevant information for policymakers promoting corporate sustainability.

Literature review

This review covers foundational and recent English-language works germane to innovative approaches in corporate environmental responsibility (CER) strategies, analyzing their scientific contributions and identifying the research gap this bibliometric study aims to fill.

Foundational Concepts: Strategic CER and Stakeholder Influence The understanding of CER has evolved significantly from a compliance-driven necessity to a strategic asset. A pivotal scientific contribution came from Hart (1995), who proposed the natural-resource-based view, positioning environmentally oriented capabilities as unique firm resources potentially leading to sustained competitive advantage. Complementing this, Porter and Van der Linde (1995) argued against the perceived environment-economy trade-off, suggesting that environmental regulation could spur innovation and enhance competitiveness, another key contribution shifting the discourse. Elkington (1997) further broadened the scope with the "triple bottom line" concept, emphasizing the equal importance of economic, social, and environmental performance, a contribution that embedded CER within a holistic sustainability framework. Stakeholder theory also provided a crucial lens; Freeman (1984) offered a foundational contribution by highlighting the necessity for firms to manage relationships with various

stakeholders (including those with environmental concerns) for strategic success. Clarkson (1995), M. B. E. Clarkson's 1995 SMJ paper on stakeholder framework, made a contribution by differentiating stakeholder issues based on their relevance to corporate environmental performance.

The Emergence and Importance of Green Innovation Innovation focused on environmental benefits became a distinct research stream. Rennings, K. (2000) contribution was to define and categorize "eco-innovations," distinguishing them by their positive environmental impact. Subsequent research explored the characteristics and impacts of various green innovation types (e.g., product, process, organizational). Chen et al. (2006) provided empirical contribution by demonstrating a positive link between green innovation performance and corporate advantage in Taiwan. Wagner (2007) investigated the relationship between environmental management, environmental innovation, and patenting, contributing to understanding innovation outputs.

Integrating Innovation into CER Strategies and Performance Research increasingly focused on the strategic integration of innovation within CER. A significant contribution by Sharma and Vredenburg (1998) was distinguishing between reactive and proactive environmental strategies and linking proactive stances to the development of unique organizational capabilities, often innovation-driven. Russo and Fouts (1997) made an early empirical contribution suggesting a positive relationship between environmental performance and financial performance, often mediated by factors like innovation. Aragon-Correa and Sharma (2003) contributed by applying the dynamic capabilities perspective to understand proactive environmental strategy formulation. Aguilera-Caracuel et al. (2012) explored how international experience fosters organizational learning that influences proactive (and often innovative) environmental strategies, a contribution linking globalization and CER. Studies also examined the diverse drivers of green innovation adoption, such as regulations, market pull, and technology push (Horbach et al., 2012), and the role of stakeholder pressure (Qi et al., 2010), providing contributions to understanding the contextual factors. Christmann (2000) contributed by empirically examining the effects of environmental management practices (often involving process innovation) on cost advantage.

Existing Syntheses and the Identified Research Gap While the aforementioned works represent significant individual contributions, efforts to synthesize the field have also emerged. Reviews by Hojnik and Ruzzier (2016) on eco-innovation drivers and Carrillo-Hermosilla et al. (2010) on eco-innovation and competitiveness offer valuable thematic summaries. Zhu and Sarkis (2004) contributed reviews focused on green supply chain management, an area related to operational innovation for CER. However, these reviews are typically narrative, selective in scope, or focused on sub-domains of the broader field.

The specific research gap addressed by the present study is the absence of a large-scale, quantitative, and visual mapping of the entire intellectual structure and evolution of the research field specifically focused on 'innovative approaches to corporate environmental responsibility strategies' globally. Unlike previous reviews, this study employs bibliometric methods (Zupic & Čater, 2015) to analyze the entire relevant literature corpus retrieved from WoS based on objective criteria. Its contribution is not a narrative review of findings, but rather a structural analysis of the field itself – identifying the foundational knowledge base (co-citation), core and emerging themes (keywords), current research frontiers (bibliographic coupling), and collaboration networks – providing a unique, comprehensive, and objective panorama that complements existing qualitative reviews.

Methodology

In order to systematically depict the knowledge map, evolutionary paths and cutting-edge hotpots in the research field of "applying innovative methods to enhance corporate environmental responsibility strategies", the bibliometric methodology is used in this study. This method uses mathematical and statistical tools to quantitatively analyze literature data, which can objectively reveal the intellectual structure and development dynamics of a particular research field (Zupic & Čater, 2015).

The bibliometric analysis and visualization were conducted using VOSviewer (version 1.6.19), developed by the Centre for Science and Technology Studies (CWTS) at Leiden University, The Netherlands (van Eck & Waltman, 2010). Additionally, Biblioshiny, a web-based interface for the Bibliometrix R package (Aria & Cuccurullo, 2017), was employed to perform comprehensive science mapping analysis.

This section will detail the data collection process, the bibliometric analysis techniques employed, and the analytical tools used.

Data collection and preparation

Literature data for this study was obtained from the Web of Science (WoS) core ensemble databases. Three core databases were selected: the Science Citation Index Expanded (SCI-EXPANDED) – 1975-present; Social Sciences Citation Index (SSCI) – 1975-present; Arts & Humanities Citation Index (AHCI)-1975-present; this database was chosen primarily based on its broad disciplinary coverage, rigorous journal selection criteria, and inclusion of complete citation information, which provides the necessary data base for bibliometric studies such as co-citation analysis (Clarivate, 2025).

The data retrieval strategy was designed to comprehensively capture literature that is highly relevant to the research topic. The search formula was set as follows: TS=("environmental responsibility" OR "corporate environmental responsibility" OR "environmental strategy") AND TS=("innovation" OR "innovative approaches" or "green innovation"); The search timeframe covered all records from the database construction to April 12, 2025, and a total of 540 documents were retrieved.

The search subject (TS) field included title, abstract, author keywords, and Keywords Plus to ensure a comprehensive search. To ensure the quality of the documents, the type of documents retrieved was limited to "Document Types: Article or Early Access or Review Article" and the language was limited to "English" the language was limited to "English". The time frame of the search covered all records from the time of database construction to April 12, 2025, and 530 documents were retrieved (Table 1).

Table 1 – Document Types Analysis Data

Field	Record Count	% of 497
Article	485	97.59%
Early Access	30	6.04%
Proceeding Paper	3	0.60%
Review Article	12	2.41%

Note – Compiled by authors based on Web of Science Document Types

Table 2,the initial search yielded a large number of documents, but some of them were of low relevance to the topic of this study. In order to improve the accuracy of the search results, we further limited the Web of Science (WoS) literature categories to Environmental Sciences, Environmental Studies, Green Sustainable Science Technology. Management, Business, Economics, Engineering Environmental, Ethics, Regional Urban Planning, Operations Research Management Science, Multidisciplinary Sciences, Energy Fuels and Energy Technology. Multidisciplinary Sciences, Energy Fuels, Development Studies, Agricultural Economics Policy, Public Environmental Occupational Health, Social Sciences Interdisciplinary. Sciences Interdisciplinary. This optimization resulted in 497 relevant papers. These literatures formed the data base for the subsequent bibliometric analysis.

Table 2 – Statistics of the number of each WOS category

Web of Science Category	Number of Documents
Environmental Sciences	210
Environmental Studies	188
Green Sustainable Science Technology	165
Management	144
Business	141
Economics	42
Engineering Environmental	42
Ethics	19
Regional Urban Planning	19
Operations Research Management Science	12
Multidisciplinary Sciences	11
Energy Fuels	10
Development Studies	9
Agricultural Economics Policy	6
Public Environmental Occupational Health	5
Social Sciences Interdisciplinary	4

Note – Compiled by authors based on Web of Science Categories

Thermodynamics and its subcategories (e.g., Computer Science Cybernetics, Biochemistry Molecular Biology, etc.) have a literature count of ≤3, which is low in relevance to the research topic. Automation Control Systems and its subcategories (e.g., Chemistry Multidisciplinary, Computer Science Artificial Intelligence, etc.) have a very small number of documents (≤2) and are not included in the analysis for the time being.

The initial search yielded a total of 540 documents. Subsequently, a complete record of all lit-

erature was downloaded on April 12, 2025, including information such as title, abstract, keywords, authors, institutions, and references. To ensure the accuracy and relevance of the dataset, data cleaning and preparation were carried out: first, literature that was clearly irrelevant to the topic was excluded; second, possible duplicate records were checked and merged. After screening and cleaning, the final dataset included in the analysis of this study contained 497 documents.

To ensure rigorous methodological curation of the extant scholarship, this inquiry strictly operationalized the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol to disentangle and systematically scrutinize the selected corpus (Moher et al., 2009; Page et al., 2021). Far from a mere heuristic, PRISMA imposes a structural discipline through a granular, four-stage progression: identification, screening, eligibility assessment, and final inclusion (Snyder, 2019). This architectural framework provides a robust scaffold for the screening and synthesis of disparate findings, thereby mitigating selection bias. By maximizing the transparency of the bibliographic acquisition process, the methodology significantly bolsters the epistemic validity and reproducibility of the resultant empirical deductions (Tranfield et al., 2003). Consequently, to construct a cohesive, integrative review of the multifaceted nexus between innovation and Corporate Environmental Responsibility (CER), we adopted the PRISMA guidelines as the foundational instrument for this study. Figure 1 depicts the specific, quantified workflow utilized for data source extraction and filtration.

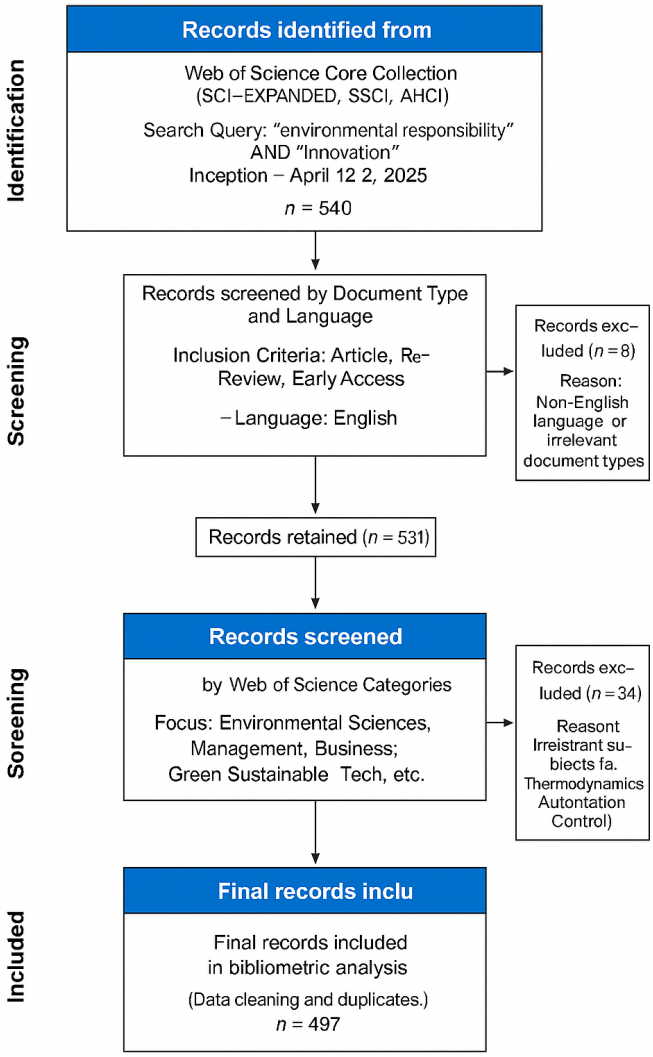

Figure 1 – PRISMA workflow showing the data acquisition process
Note – Compiled by authors based on PRISMA

Research Methods

This study utilizes established bibliometric methods to analyze the collected data quantitatively and map the research field:

Descriptive Statistical Analysis: Basic statistics were calculated to profile the field, including annual publication trends, identification of the most productive authors, institutions, countries/regions, and the most frequent publication sources (journals).

Co-citation Analysis: This technique identifies the foundational knowledge base and intellectual structure of the field by analyzing how often documents, authors, or journals are cited together in the reference lists of the source publications (Small, 1973). High co-citation frequency suggests a strong conceptual relationship between the cited items. This analysis was performed on cited references, cited authors, and cited sources (journals).

Keyword Co-occurrence Analysis: This method examines the frequency with which keywords (author-provided keywords and WoS Keywords Plus®) appear together in the same documents (Callon et al., 1991). Mapping these co-occurrences helps identify the core research themes, hot topics, and the conceptual structure of the field.

Bibliographic Coupling Analysis: This analysis links documents that cite one or more of the same references (Kessler, 1963). Documents with strong bibliographic coupling are likely to address similar research problems or topics, making this method effective for identifying current research fronts and emerging research clusters.

Collaboration Network Analysis: This involves mapping the co-authorship relationships between authors, institutions, and countries/regions. Analyzing these networks reveals patterns of scientific collaboration, identifies key collaborative groups, and highlights the extent of national and international cooperation within the field.

Analytical tools

To perform the above bibliometric analysis and visualize the results, the following two specialized software tools were used in this study:

Bibliometrix R package: This is a comprehensive bibliometric analysis toolkit based on the R language environment (Aria & Cuccurullo, 2017). This study utilized Bibliometrix for data import, preprocessing, descriptive statistical analysis (e.g., annual publications, core author identification, etc.), and the generation of some of the network data matrices.

VOSviewer: This is a software specifically designed for constructing and visualizing bibliometric network mappings (van Eck & Waltman, 2010). VOSviewer is known for its powerful visualization capabilities and user-friendly interface, and is particularly suitable for presenting clustering in large networks (e.g., co-citation networks, keyword co-occurrence networks, literature coupling networks, collaboration networks) structure and inter-item relationships. This study will primarily use VOS viewer to generate and present various bibliometric network maps.

By combining the data processing and preliminary analysis capabilities of Bibliometrix with the advanced visualization capabilities of VOSviewer, this study aims to provide a comprehensive, in-depth, and intuitive analysis of the field of "Innovative Approaches to Enhance Corporate Environmental Responsibility Strategies".

Results and discussion

Findings and descriptive analysis

The aim of this section is to present the main results of the bibliometric analysis of the data set of literature in the field of research on "Innovative approaches to enhancing corporate environmental responsibility strategies" (N=497). Firstly, the results of the descriptive statistical analysis are presented to provide a basic overview of the field and its development, followed by an in-depth discussion of its intellectual structure and research themes.

1) Trends in Literature Publication

Statistics on the year of publication of the 497 documents included in the analysis reveal the characteristics of the temporal evolution of the research field. Figure 2 shows the annual number of publications in the field between 1994 and 2025.

"As shown in Figure 2, between 1994 and 2014, the number of relevant literature published in this field was relatively small and in a slow development stage, and since 2018, the number of literature published has shown a significant growth trend, especially in the period of 2019-2023, which further accelerates the growth rate, reflecting that the "application of innovative methods to improve the This reflects that "using innovative methods to improve corporate environmental responsibility strategy" has gradually become a research hotpots. The increase in publications may be related to the growing global emphasis on sustainability and corporate environmental performance, as well as the increasing role of innovation in addressing environmental challenges. As of April 12, 2024, a cumulative total of 497 publications have been published in the literature."

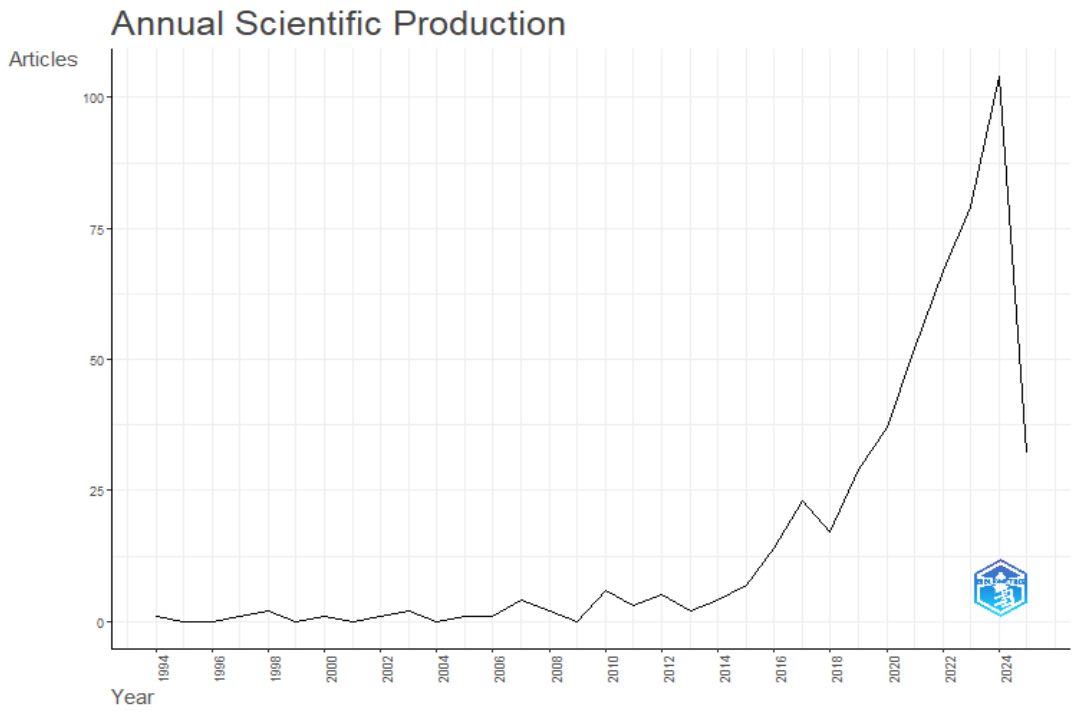

Figure 2 – Trends in the number of annual publications (1994 to 2025)
Note – Compiled by authors based on Bibliometrix

2) Main Source Journals

The distribution of source journals for the literature reflects the main publication platforms for research results in the field and their disciplinary affiliation. Table 3 lists the top 10 journals that have published the highest number of relevant literatures, demonstrating the main vehicles for research results in the field.

As shown in Table 3, relevant research results are mainly published in sustainability, business strategy and the environment, journal of cleaner production, corporate social responsibility and environmental management, and other leading journals in the field. Among them, sustainability and business strategy and the environment are the core journals in the field, publishing a large number of related studies, indicating that the research topic is significantly interdisciplinary, integrating the perspectives of several disciplines, such as environmental sciences, management, economics and innovation studies.

Table 3 – Top 10 journals with the highest number of publications

SOURCES	ARTICLES
Sustainability	96
Business strategy and the environment	51
Journal of cleaner production	39
Corporate social responsibility and environmental management	19
Environmental science and pollution research	16
Journal of business ethics	14
Environment development and sustainability	13
Technological forecasting and social change	10
Journal of environmental management	9
Organization & environment	7

Note – Compiled by authors based on Bibliometrix

3)Highly productive authors

Identifying core researchers helps to understand the distribution of academic power in the field. Table 4 shows the top 10 authors in terms of publications.

Table 4 – The top 10 authors by number of publications

Authors	Articles	Articles Fractionalized
LIU Y	7	1.82
ZHANG L	7	2.10
DANIELE LM	6	1.53
GANGI F	6	1.53
WANG Y	6	1.70
ZHANG C	5	1.92
ZHANG Q	5	1.37
ALI A	4	1.17
FENG TW	4	1.08
JIANG W	4	1.03

Note – Compiled by authors based on Bibliometrix

Table 4 shows the researchers who have contributed the highest number of publications in the field. These prolific authors are usually important scholars in the field, and their research work may have had a significant impact on the direction of the field and research topics. It is important to note that the number of authors' publications only reflects their productivity, and the subsequent analysis of collaborative networks and co-citations will further reveal the collaborative relationships and academic influence among the authors.

4)Major Research Countries/Regions

Analyzing the distribution of countries/regions to which the authors of the literature belong can reveal the geographic concentration of research in the field and the pattern of international cooperation. Figure 3 lists the top 10 countries/regions in terms of the number of publications.

Figure 3 illustrates the contribution of different countries in single-country publications (SCP) and multicountry collaborative publications (MCP) when they are corresponding authors. Among them:

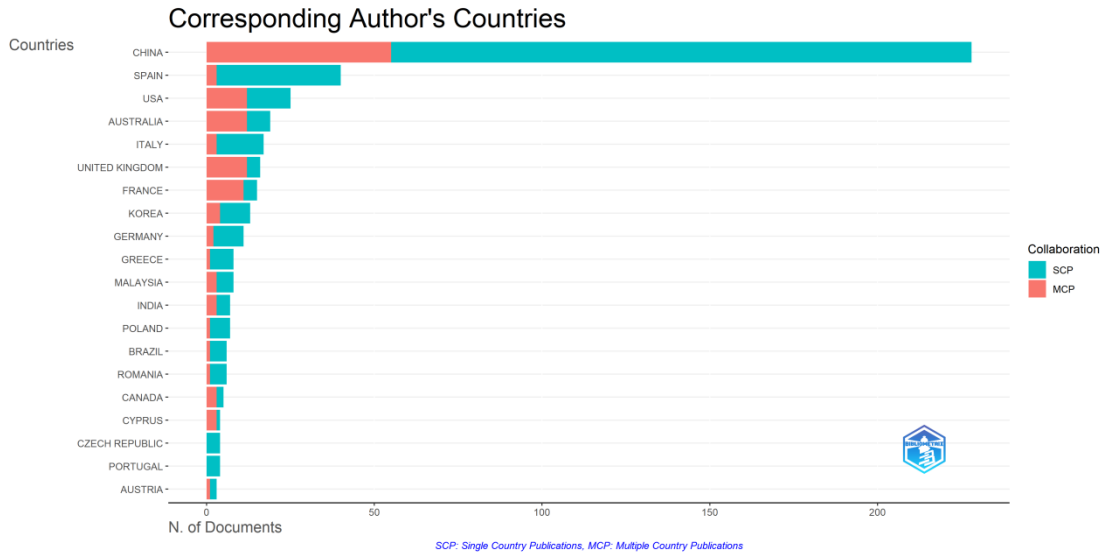

Figure 3 – Top 10 countries/regions by number of publications
Note – Compiled by authors based on Bibliometrix

First, single-country publications (SCP) refer to publications independently completed and published by researchers or institutions in a single country, which are represented by blue bars in the figure, representing scientific research results independently completed by that country.

Second, Multi-country Collaborative Publication (MCP) refers to publications that are jointly completed and published by researchers or institutions from multiple countries, which are represented by red bars in the graph, reflecting transnational scientific research cooperation.

The horizontal axis of the graph indicates the number of publications and the vertical axis lists the individual countries involved in the research. The bar for each country is divided into two parts, corresponding to the number of its SCPs and MCPs.

As can be seen from the graph, China is a significant leader in the total number of publications and has the largest percentage of SCPs, indicating its outstanding independent scientific research capacity as well as its active participation in international collaborations. Countries such as Spain, the United States and Australia have the next highest number of publications, but there is a significant gap with China. Countries such as Italy, the UK and France have relatively small outputs, and Greece, Malaysia and India have an even smaller total amount of literature, but a small amount of independent and collaborative outputs can still be seen. However, scholars in Kazakhstan have not yet conducted research in this area.

Overall, China, Spain, and the United States are the main contributors of research output in this field, which may reflect the policy orientation and academic inputs in these countries in promoting corporate environmental responsibility and fostering green innovation." .

5) Key Research Institutions

Identifying research institutions with outstanding contributions helps to understand the core research strength of the field. Figure 4 shows the top 10 research organizations in terms of publications.

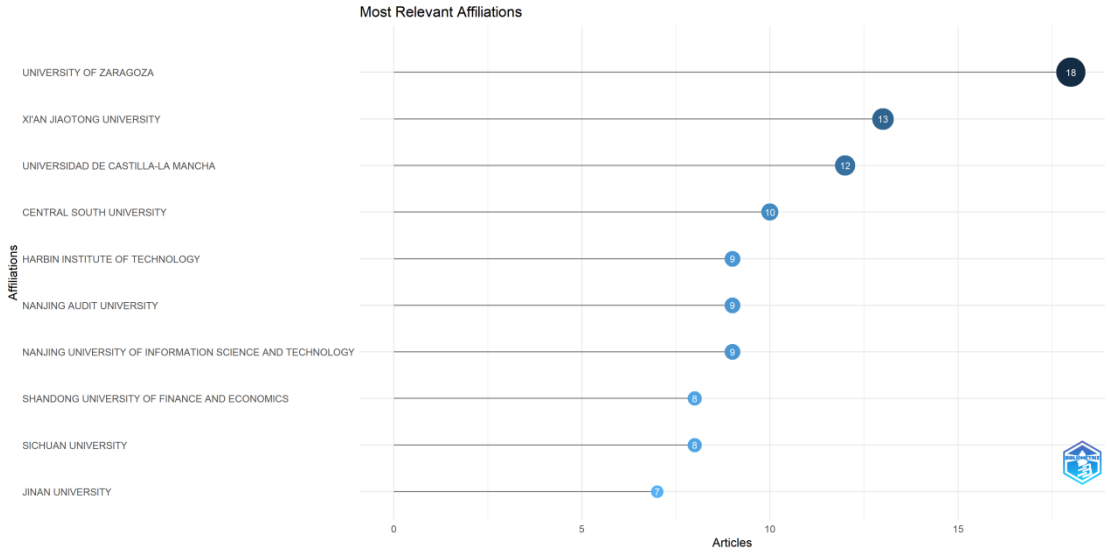

Figure 4 – Top 10 Research Institutions in terms of number of publications
Note – Compiled by authors based on Bibliometrix

Identifying research institutions with outstanding contributions in the field helps to understand the distribution of core research strengths. Figure 4 shows the top 10 institutions in terms of publications, presented as a horizontal bar chart, with the horizontal axis representing the total number of articles published by each institution, the vertical axis listing the name of the institution, and the length of the bar and the value at the end of the bar corresponding to the number of articles published by the institution.

As shown in Figure 4, "University of Zaragoza" tops the list with 18 articles, which is significantly ahead of the other institutions, indicating that it is probably one of the core research centers in the field due to its outstanding research activity and output capacity. It was followed by Xi'an Jiaotong University (13 articles) and Universidad de Castilla-La Mancha (12 articles) in second and third place, respectively. Other institutions such as Central South University and Harbin Institute of Technology also contributed, but with a relatively small number of articles.

In terms of geographical distribution, Spanish institutions (University of Zaragoza, Universidad de Castilla-La Mancha) showed stronger research strength. Meanwhile, Chinese institutions (Xi'an Jiaotong University, Central South University, Harbin

Institute of Technology) also occupy an important position, but the overall number of publications is slightly lower than that of the top Spanish institutions.

This result has important academic implications. First, it visualizes the research output of each institution in this field, which is an important basis for assessing its academic influence and research activity. Second, although the chart does not directly display collaboration information, it can be used in conjunction with the subsequent collaborative network analysis to further explore the position and role of these high-producing institutions in the collaborative network, as well as the potential patterns of collaboration among them. Finally, by comparing the number of publications from institutions in different countries, it is possible to gain a preliminary understanding of the research inputs and outputs in the field in different countries, for example, the comparison between Spanish and Chinese institutions observed in this study may reflect the different stages of development or research focus in the field in the two countries.

Literature measurement results

Based on the descriptive statistical analysis in the previous section, this section uses network analysis techniques to deeply reveal the intrinsic knowledge structure, core research themes, research fronts, and cooperation modes in the research field of "applying innovative approaches to enhance corporate environmental responsibility strategies". The analysis is visualized by VOSviewer software.

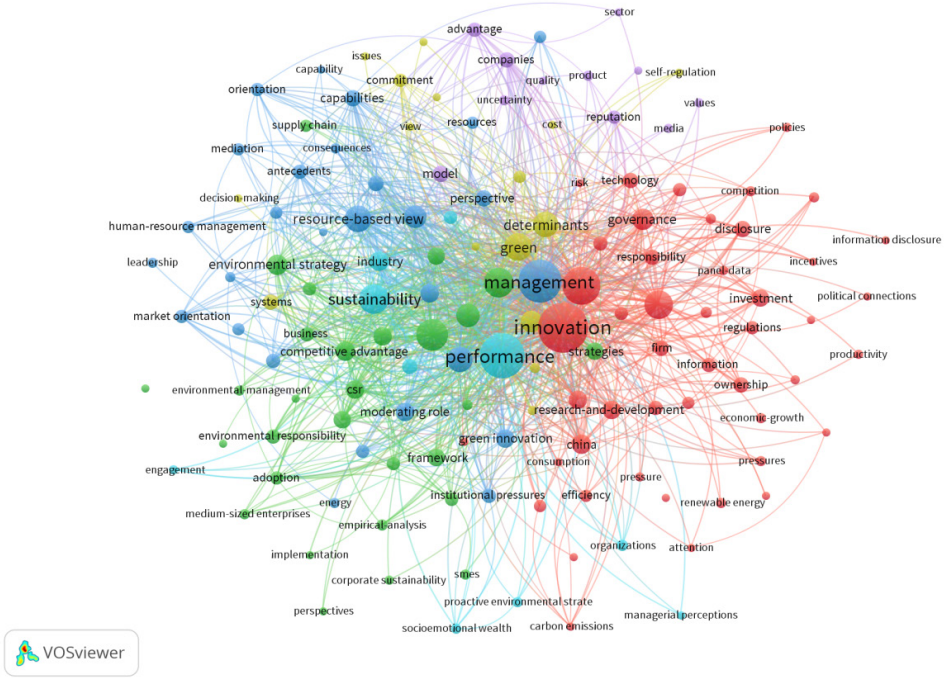

Figure 5 – Keyword co-occurrence analysis
Note – Compiled by authors based on VOSviewer

1) Keyword co-occurrence analysis: research themes and hotspots

Keyword co-occurrence analysis is used to identify the core research themes and hotspots and their interrelationships in a specific field. Figure 5 shows the keyword co-occurrence network diagram constructed based on author keywords and Keywords Plus®. In the analysis, the minimum co-occurrence frequency threshold was set to 5 times, and 141 keywords that reached the threshold were screened out of 887 keywords. In the graph, each node represents a keyword, the node size reflects its frequency of occurrence, and the strength of the connecting line between nodes indicates the degree of co-occurrence closeness. In this section, we will analyze the research themes, hot topics and interrelationships." .

Research theme identification

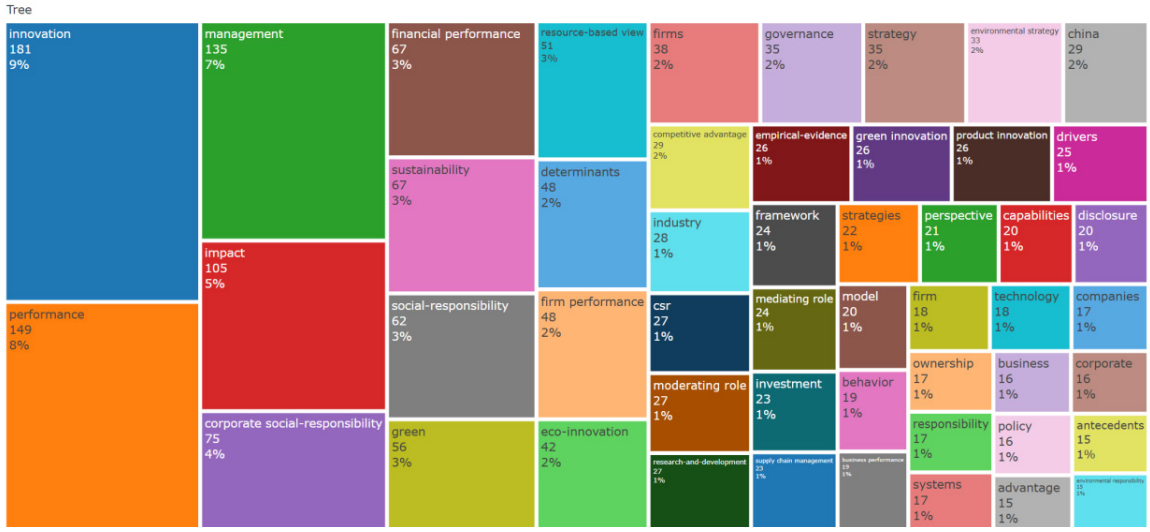

Figure 6 – Keyword co-occurrence analysis
Note – Compiled by authors based on Bibliometrix

The core area of the network graph is dominated by the high-frequency keywords "management", 'innovation' and "performance "indicating that these themes occupy a central position in the relevant research (Figure 6). For example, "management" is associated with "human-resource management" and "leadership". (human-resource management), "leadership" and other sub-themes, highlighting the fundamental role of management practice in academic research. Meanwhile, "innovation" is closely related to keywords such as "research-and-development" and "strategies". The co-occurrence of keywords such as "innovation" with "research-and-development" and "strategies" reveals the intrinsic connection between corporate innovation strategies and R&D activities. In addition, the high frequency of keywords such as "sustainability", "green innovation" and "CSR" reveals the intrinsic connection between corporate innovation strategy and R&D activities. In addition, the high frequency of keywords such as "sustainability", "green innovation" and "CSR" indicates that environmental sustainability and social responsibility have become hot topics in research.

Exploration of Hot Topics

Further analysis shows that the keyword network presents a multi-dimensional research path. With "management" as the core, the keywords "market orientation", "competitive advantage" and so on are derived. The core of "management" is "market orientation" and "competitive advantage", which emphasize the key role of market drive and competitive strategy in enterprise development. In the branch of "innovation", 'firm' and "strategies" co-occur more frequently, reflecting the practical characteristics of enterprises as the main body of innovation. This reflects the practical characteristics of firms as innovation subjects. Performance is associated with keywords such as "efficiency" and "economic growth", emphasizing the importance of performance. "Performance" is associated with keywords such as 'efficiency' and "economic growth", emphasizing the close connection between performance assessment and economic development. It is worth noting that "sustainability" is associated with keywords such as "environmental responsibility" and "renewable energy", "energy" (renewable energy) and so on form an emerging research path, showing that academics continue to deepen their concern for environmental issues.

Interrelationship Analysis

The co-occurrence of keywords reveals the intrinsic connection between topics. For example, the strong correlation between "management" and "innovation" indicates that management practices are closely related to innovation activities; 'performance' and "sustainability" are closely related to innovation activities. The connection between "performance" and "sustainability" suggests the synergy between corporate performance and the SDGs. In addition, keywords such as "information disclosure", 'governance', and "regulations" are also used. " (regulations) are keywords that further expand the perspective of corporate governance and

policy research. These relational networks provide an important basis for understanding the cross-cutting and systemic nature of the research field.

The keyword co-occurrence network map drawn by VOSviewer in this study clearly presents the core themes and hot topics in the field, including the directions of corporate governance, innovation strategy, performance evaluation and sustainable development. Future research can further deepen the exploration of emerging topics such as "green innovation", "environmental responsibility" and "corporate governance" to promote the synergistic development of theory and practice. This analysis provides methodological support for subsequent bibliometric studies, as well as reference for academics and practitioners to grasp research trends and optimize research directions.

2) Literature Coupling Analysis: Research Frontiers

Literature coupling analysis reveals the active frontiers of current research fields by linking the latest literature that cites similar references. Figure 7 shows the literature coupling network constructed based on 497 source documents (the minimum coupling intensity threshold is set to 10 times), in which all the documents meet the minimum citation requirement. By calculating the total strength of literature coupling links between each document and other documents, 287 core documents were finally screened out for analysis, and the VOSviewer software was used to draw the source co-citation network diagram to visualize the correlation between the documents and their distribution characteristics in the research field.

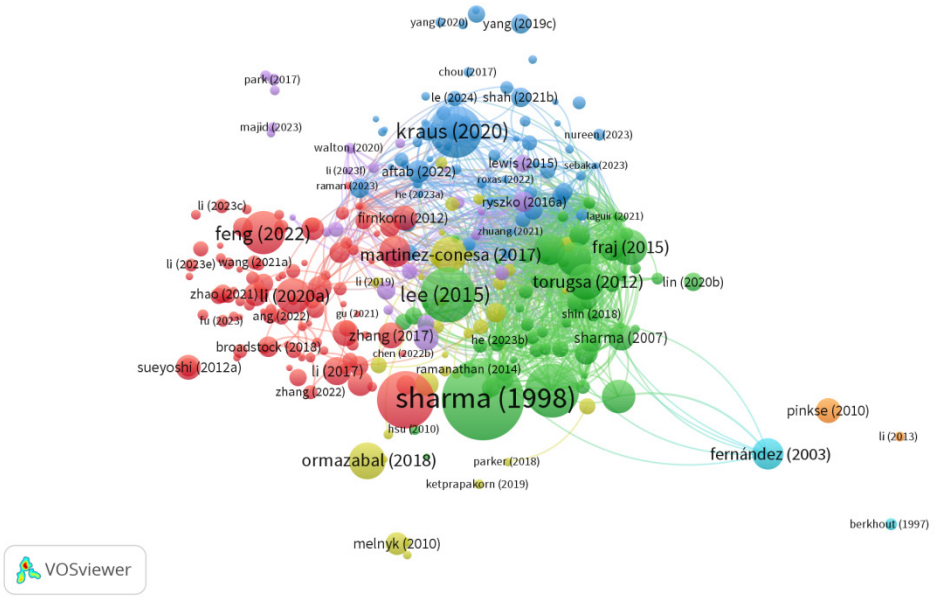

Figure 7 – Literature Coupling Network Diagram
Note – Compiled by authors based on VOSviewer

Network Diagram Construction and Parameter Setting

Data Screening: Set the threshold of the number of citations to 10 to ensure that all 497 documents meet the inclusion criteria.

Calculation of nodes and links: Calculate the coupling strength of 287 core documents with other documents, the size of nodes reflects the influence of the documents, and the strength of links indicates the degree of association between the documents.

Visualization tool: constructing network diagrams through VOSviewer, Figure 7 using color coding to distinguish different literature clusters (e.g., green, blue, and red clusters), and visually presenting the clustering characteristics of the research frontiers.

Literature clusters and research frontiers

Different color node clusters in the network diagram represent the core direction of the research field:

Green cluster: Sharma (1998) is the core, and its node size is large and in the center position, which indicates that the early research results still have important influence on the current research.

Blue cluster: centered on Kraus (2020), with dense connectivity between nodes, reflecting the prominence of emerging research hotspots and trends in recent years.

Red cluster: contains Feng (2022) and Li (2020a), whose strong coupling relationship suggests a common focus on a specific topic or direction, and may represent an independent but important research branch.

Dynamic Characteristics of Research Frontiers

Continuity of classical theories: the green cluster shows that the early literature (Sharma, 1998) is still the theoretical foundation of current research.

Dominance of Emerging Trends: The blue cluster shows that recent literature, represented by Kraus (2020), dominates the direction of the frontier, reflecting the knowledge update and innovation in the field.

Parallel development of multiple directions: the separation of the red cluster from the other clusters implies the existence of multiple independent but complementary research paths in the field, which need to be further analyzed for their thematic relevance.

Literature coupling network diagram reveals the structural characteristics of the research field through visualization:

Influence of core literature: the size and position of nodes directly reflect the pivotal role of literature in the knowledge network.

Dynamics of frontier directions: The comparison of different color groups shows that classical theories and emerging trends coexist, and multi-directional research advances at the same time.

Methodological value: This analysis provides an objective basis for identifying research hotspots and tracking the development of the field, which can provide a reference for subsequent research design and academic resource allocation.

3) Collaborative Network Analysis

This study analyzes the characteristics of collaborative networks at three levels: authors, institutions and countries/regions.

Author Collaboration Network

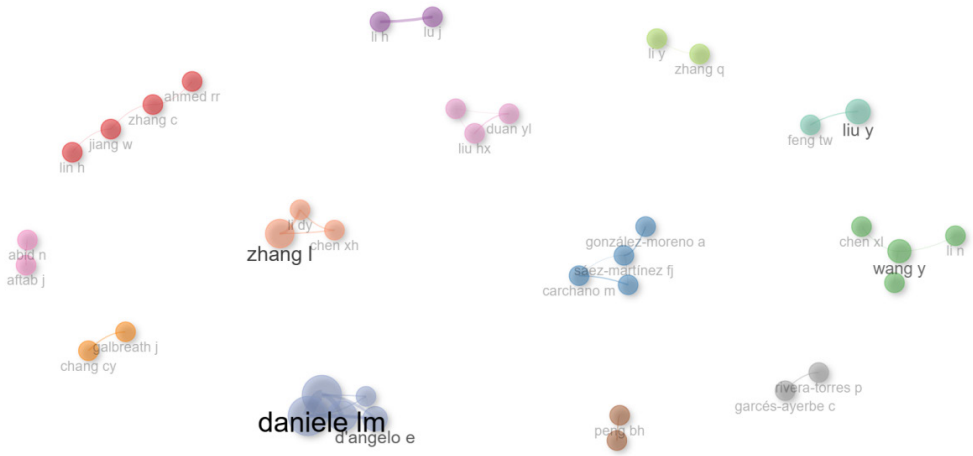

Figure 8 – Author collaboration network
Note – Compiled by authors based on VOSviewer

The author collaboration network shows a significant polycentric structure(Figure 8). Among them, core authors (e.g., gangi f, daniele lm) occupy key positions in the network by virtue of their high connectivity, dominate cross-team collaboration and knowledge dissemination, and have a significant impact on the overall structure of the network. At the same time, there are some smaller collaborative groups in the network (e.g., the subgroups formed by zhang q, duan yl), which are relatively focused in their research direction but have relatively few direct connections with the core authors. In addition, some authors (e.g., rivera-torres p, liu y) are relatively isolated in the network with low connectivity, and future research should focus on how to facilitate the integration of these fringe

authors into the collaborative network to enhance the overall synergistic efficiency of the network. Overall, this author collaboration network has high connectivity, indicating more active knowledge sharing, but the polarization between core and edge authors deserves further attention and should be improved by establishing an effective cross-team collaboration mechanism.

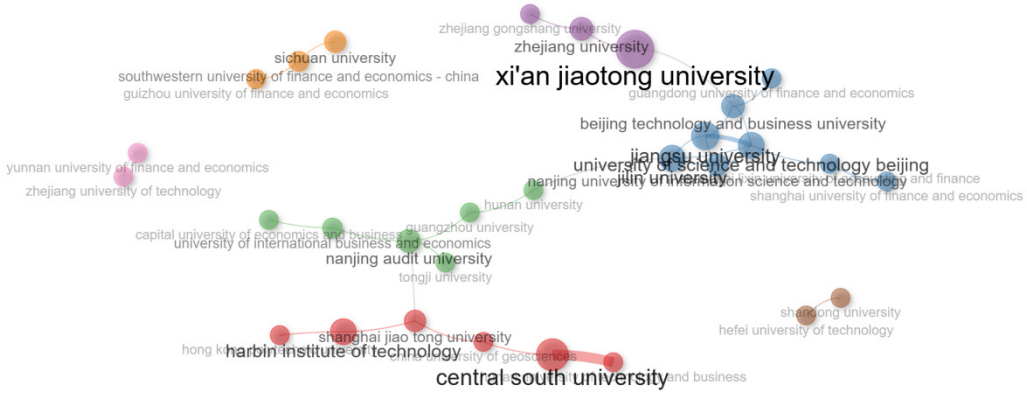

Figure 9 – Institutional collaboration network
Note – Compiled by authors based on VOSviewer

The institutional collaboration network has Xi'an Jiaotong University as its core, and the extensive connectivity of this institution provides the network with significant academic influence and resource integration capabilities(Figure 9). Institutions such as Jilin University and Beijing Institute of Technology also play key roles in the network, further enhancing its stability. In terms of geographic distribution, there are some geographic cooperative subgroups in the network, e.g., the Northeastern cluster of universities centered on Harbin Institute of Technology and the East China cluster of universities centered on Zhejiang University, etc., and the cooperation within these subgroups is relatively close. In addition, there are also some cross-regional institutional collaborations, such as the collaboration between Southwestern University of Finance and Economics and Sichuan University, which play a complementary role in promoting knowledge flows. The analysis of cooperation intensity shows that the cooperation between some institutions is more intensive (e.g. Capital University of Economics and Business and University of International Business and Economics), while the participation of some marginal institutions is relatively low (e.g. Guizhou University of Finance and Economics), and the overall synergistic efficiency of the institutional cooperation network should be improved in the future by optimizing the cooperation mechanism.

The international cooperation network has China as the core hub, and its close cooperation with countries such as South Korea, Japan, and Singapore reflects the dominant position of research collaboration in the Asia-Pacific region (Figure 10). The European Cooperation Circle (Germany, France and the Netherlands) and the Asian Cooperation Circle (centered on China) form a high-density regional network, while the Americas Cooperation Circle (the United States and Canada) has a higher intensity of cooperation but a lower level of participation in South America and Africa. Dynamic analysis shows that international cooperation networks are shifting from being dominated by traditional powers (e.g., the United States and the United Kingdom) to diversified participation, with emerging countries such as India and Brazil contributing to the expansion of the networks. However, regional development imbalances (such as the marginalization of African countries) still need to be improved through policy support and cross-regional cooperation mechanisms.

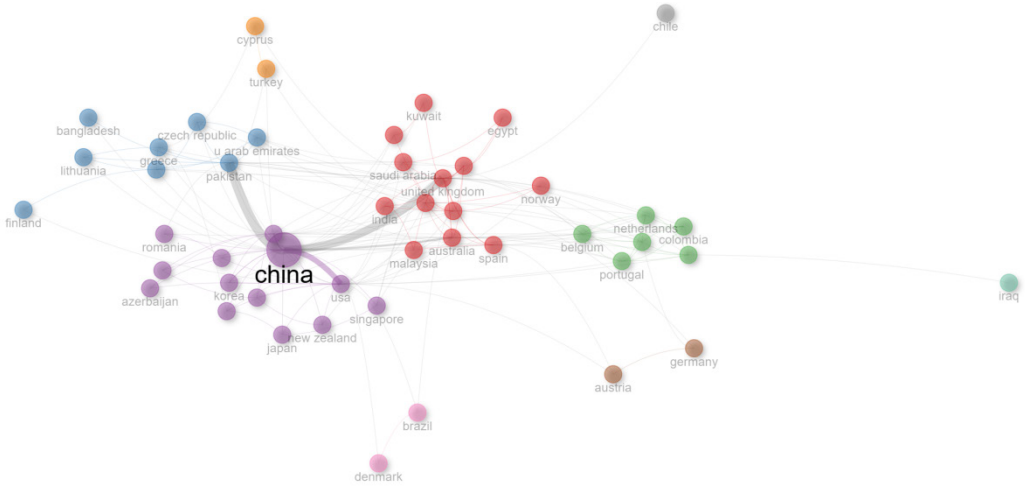

Figure 10 – International Cooperation Network
Note – Compiled by authors based on VOSviewer

Network analysis: co-citation structure and evolution

Based on the previous analysis, this chapter focuses on the co-citation network and utilizes the analytical functions provided by VOSviewer to explore in more depth the knowledge base, cross-disciplinary characteristics, intellectual evolution and the influence of core scholars in the research field of "applying innovative approaches to enhance corporate environmental responsibility strategies", This chapter aims at revealing the knowledge base, cross-disciplinary characteristics, intellectual evolution and influence of core scholars in the field of "applying innovation to enhance corporate environmental responsibility strategies". This chapter aims to reveal the deep structure and dynamic connections within the knowledge network of this field.

Journal co-citation network analysis: assessing sources of knowledge and community cohesion (1994-2025)

Journal co-citation networks reflect the sources of journals that form the knowledge base of the field and their interconnections and help to assess the degree of disciplinary intersections and overall cohesion of the research community.

Purpose of analysis: To identify the core journal communities in the field, to understand the contributions and linkages of different disciplinary knowledge sources (journals), and to assess the degree of knowledge integration in the research community.

By analyzing the co-citation of references cited in 497 documents in the datasets and setting an appropriate co-citation frequency threshold with a minimum of 20 citations, 61 out of 26,878 cited references met the threshold. A literature co-citation network graph can be constructed. Figure 11 illustrates the visualization results of this network.

Literature co-citation network clustering analysis: each node in the graph represents a piece of cited literature, the size of the node usually indicates the citation frequency, the connecting line indicates the co-citation relationship between the literature, and the thickness of the line represents the co-citation intensity. Different colors of nodes represent different research clusters identified by VOSviewer. Based on the content of the node literature and the clustering results, three major knowledge clusters in the field can be identified:

To identify the knowledge base and evolution path of the research field of corporate environmental strategy and green innovation, this paper conducts a cluster analysis based on the literature co-citation network graph drawn by VOSviewer. Each node in the network represents a piece of high-frequency cited literature, the connecting line indicates its co-citation relationship with other literature, the color represents different clustering themes, and the size of the node reflects the citation frequency of the literature. According to the clustering algorithm and graph visualization results of VOSviewer, three major knowledge clusters are identified, which are as follows:

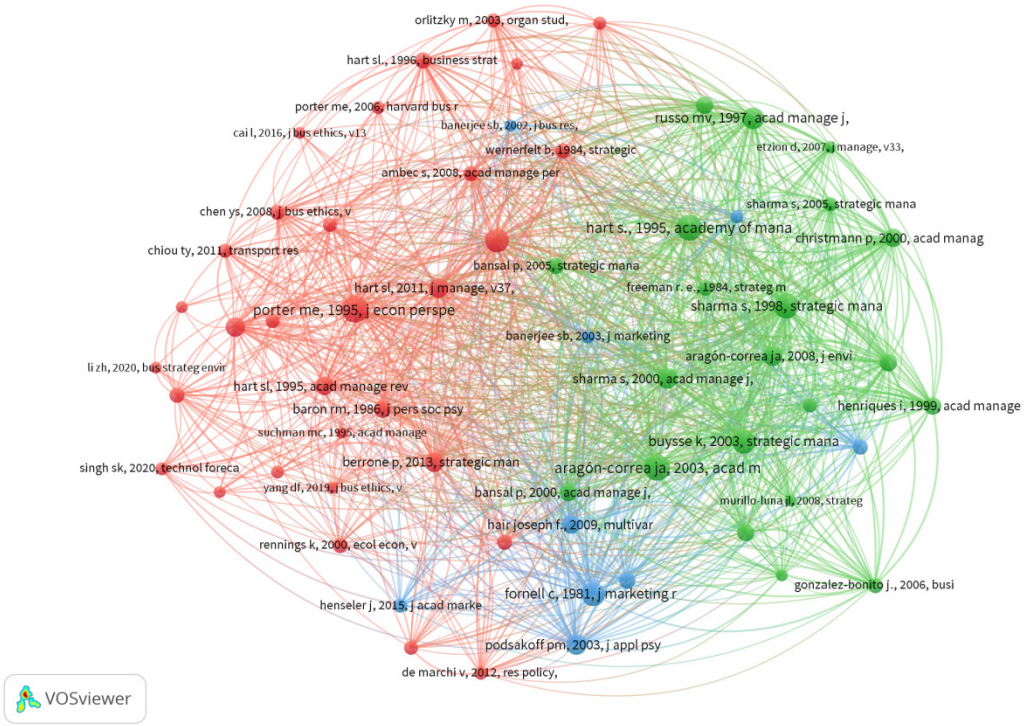

Figure 11 – Literature co-citation network graph
Note – Compiled by authors based on VOSviewer

Cluster 1: Corporate Environmental Strategy and Sustainable Competitive Advantage (Red)

This cluster is the largest and most tightly structured one in the network, which mainly focuses on how corporations can integrate their environmental responsibility into their core strategy in order to achieve sustainable competitive advantage. Representative literature includes Hart (1995) 'A natural-resource-based view of the firm', Porter & van der Linde (1995) 'Toward a new conception of the environment- competitiveness relationship', Porter & van der Linde (1995) 'Toward a new conception of the environment- competitiveness relationship', and Sharma & Vredenburg (1998) among others.

These literatures lay the theoretical foundation for integrating environmental factors into the strategic management system of firms, emphasizing the role of the Resource-Based View (RBV), Stakeholder Theory and Institutional Theory, among others, in environmental strategic decision-making. In addition, this cluster contains a large number of studies on the classification of environmental strategies, environmental driver paths (e.g., market-driven vs. regulation-driven), and the relationship between the performance of environmental strategies, forming the theoretical backbone of the field.

Cluster 2: Green Innovation Drivers and Organizational Response Mechanisms (Green)

This cluster focuses on how a variety of factors, such as external institutional pressures, market pull, and internal capabilities, drive firms to take green innovation actions. Representative literature includes Aragon-Correa & Sharma's (2003) study on environmental strategy response from a dynamic capability perspective, Sharma's (2000) study exploring the relationship between organizational perceptions and environmental commitment, and Russo & Fouts' (1997) study on the positive relationship between environmental performance and financial performance.

This clustering is closely linked and shows that the field of green innovation research is maturing, with the focus shifting from "whether to innovate" to "what drives innovation" and "how organizations respond". The focus of research has gradually shifted from "whether to innovate" to "what drives innovation" and "how organizations respond. In terms of research methodology, the literature in this cluster mostly adopts empirical analysis, integrating

strategic management and organizational behavior perspectives, which is the backbone of green management research.

Cluster 3: Environmental Management Systems and Measurement Tools (Blue)

This cluster covers the research on the operational level of corporate environmental management, including the application of tools such as ISO 14001 environmental management system, Cleaner Production, Life Cycle Assessment (LCA), and the assessment of their effectiveness. Representative literature includes Christmann (2000), Zhu & Sarkis (2004) and Fornell & Larcker (1981), especially the latter's measure of reliability in structural equation modeling, which has been widely borrowed in empirical green management research.

This cluster is closely related to the previous two clusters and serves as a bridge from theoretical research to practical application in business. From the structure of the map, this cluster, despite its relatively small size, has a high degree of concentration, a clear research theme, and significant empirical features, reflecting the reliance on and emphasis on instrumental tools in the process of implementing corporate environmental responsibility strategies. Together, these clusters constitute the intellectual cornerstone of the research field of "applying innovative methods to enhance corporate environmental responsibility strategy".

2)Citation Source Analysis: Tracking the Development of the Field

In order to deeply reveal the knowledge infrastructure of the research field of corporate environmental responsibility and green innovation, this study analyzed the reference sources of the 497 documents collected. In the analysis, the co-citation frequency threshold was set at 20 times, and 236 high frequency cited sources were filtered out from 7,604 sources. Based on the co-citation relationships of these sources, a source co-citation network diagram was drawn using VOSviewer, as shown in Figure 12.

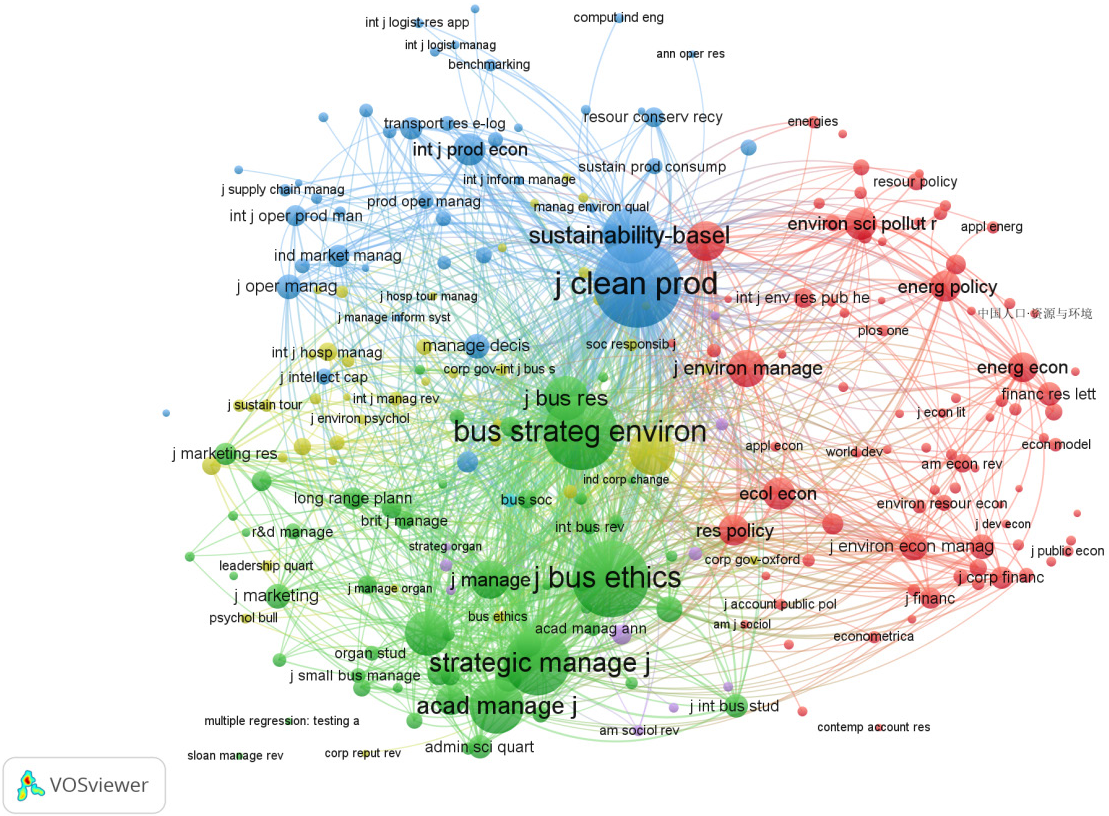

Figure 12 – Literature Citation Source Analysis
Note – Compiled by authors based on VOSviewer

In Figure 12, shows four clear groups of journals. The red cluster includes outlets such as Energy Policy and Ecological Economics. Work in this area often focuses on policy design, energy use, and resource issues. A second group appears in green. Here we see journals like Strategic Management Journal, Academy of Management Journal, and Journal of Business Ethics. These journals connect environmental topics with strategy and organizational behavior (Aragón-Correa & Sharma, 2003; Bansal & Roth, 2000). The blue cluster is more operational. Journals such as Journal of Cleaner Production and Sustainability focus on production systems, efficiency, and circular practices (Rennings, 2000). A smaller yellow group includes Journal of Marketing and Research Policy, pointing to work on consumer behavior and innovation. Together, these clusters outline the main areas supporting research on corporate environmental responsibility. Based on the co-citation intensity and visualization clustering results, this study identifies four major source clusters as follows.

Table 5 – Four primary source clusters for citation source analysis

Cluster	Cluster Name	Research Focus	Representative Journals
Cluster 1	Core Cluster of Environmental Science and Policy Research (Red)	Environmental policy, energy economics, resource management	*Energy Policy*, *Ecological Economics*
Cluster 2	Mainstream Cluster of Management and Strategic Studies (Green)	Corporate strategy, organizational behavior, ethical theory	*Strategic Management Journal*, *Academy of Management Journal*, *Journal of Business Ethics*
Cluster 3	Operational Management and Sustainable Production Cluster (Blue)	Green production, resource efficiency, circular economy	*Journal of Cleaner Production*, *Sustainability*
Cluster 4	Marketing and Organizational Innovation Cluster (Yellow)	Market-driven innovation, consumer behavior	*Journal of Marketing*, *Research Policy*

Note – Compiled by authors based on VOSviewer

The Table 5 also shows changes in research direction. The center of the network is shaped by journals that link environmental strategy with firm decisions. Journal of Cleaner Production, Business Strategy and the Environment, and Sustainability form a dense core. Their topics mix environmental actions with performance and organizational change (Del Río et al., 2016; Hart & Dowell, 2011). Finance-related journals, including Energy Economics and Finance Research Letters, appear closer to this core than before. Their position suggests growing interest in how finance affects environmental actions, consistent with findings in ESG and sustainable finance work (Friede, Busch, & Bassen, 2015). Marketing and innovation outlets in the yellow cluster show that researchers now pay more attention to consumer responses and technology pathways (Kammerer, 2009; Schiederig, Tietze, & Herstatt, 2012). Overall, the field is moving toward broader and more mixed themes that bring together economics, strategy, operations, and innovation.

Analysis of Cited Authors

In order to further reveal the knowledge infrastructure of the research field of corporate environmental responsibility and green innovation, this paper carries out the co-citation analysis of cited authors based on the reference sources of the 497 documents collected. The minimum number of citations for cited authors was set at 20, and a total of 173 authors out of a total of 18,141 authors reached this threshold.

For these 173 authors, VOSviewer calculated the strength of their total co-cited links with other authors and generated a source co-citation network graph accordingly (see Figure 13). The size of the nodes in the graph indicates the authors' co-citation frequency, the thickness of the links between the nodes reflects the strength of the co-citation relationship, and the different colors indicate the different clusters identified by the software, representing the groups of authors who have been frequently co-cited in theoretical or empirical studies.

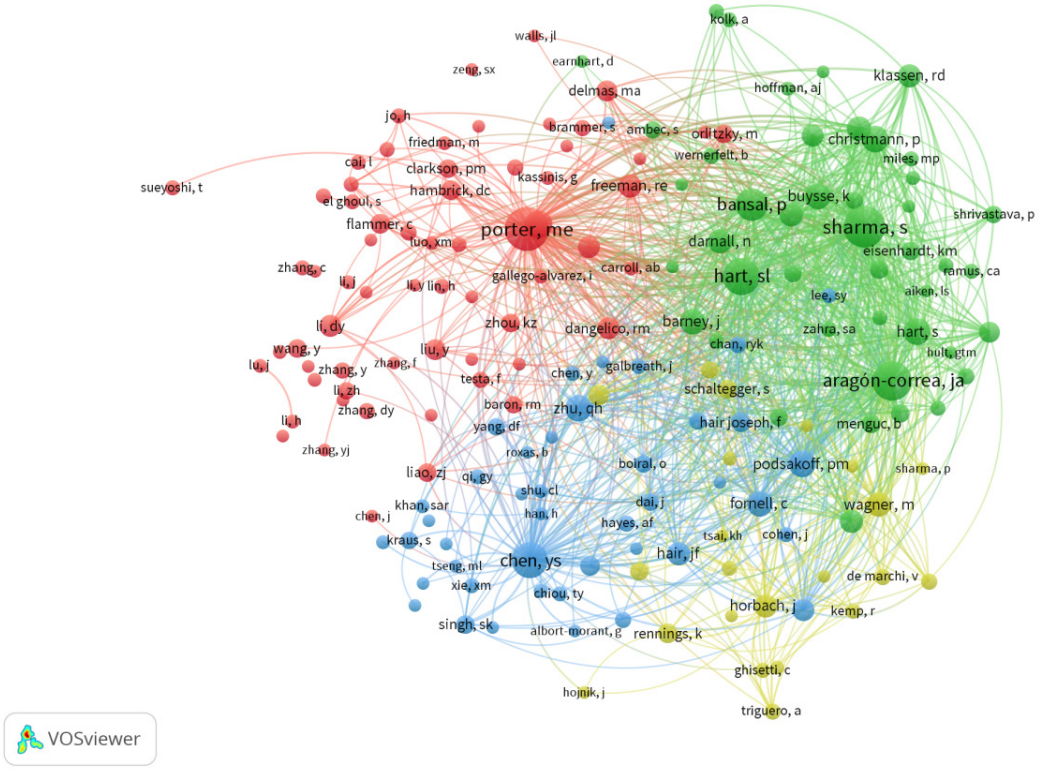

Figure 13 – Cited author analysis
Note – Compiled by authors based on VOSviewer

According to the results of the cluster analysis, the authors' co-citation network presents the following four main knowledge groups:

Category 1 (green): strategic environmental management and institutional theory research group. This cluster may differ somewhat from the red cluster in terms of topics or approaches, such as focusing on cross-disciplinary areas or specific application scenarios. Although the connectivity between nodes is relatively evenly distributed, the main authors still have connectivity in other clusters as well, showing that they play a bridging role, e.g., in interdisciplinary topics or methodologies. This cluster mainly includes key scholars such as Hart S.L., Sharma S., and Aragón-Correa J.A., whose research focuses on environmental strategy, dynamic capabilities, and the role of stakeholders in corporate sustainability.

Category 2 (red): CSR and Competitive Advantage Research Cluster. The high number of authors in this cluster and the high density of connectivity between the nodes imply that researchers within this cluster are closely related to each other in terms of research topics or theoretical paradigms, and that the literature is frequently cross cited. By observing the citation frequency and total link strength of the main authors, it can be inferred that this cluster usually focuses on a relatively centralized core topic, such as a certain theoretical framework or research methodology, which constitutes the foundation of earlier or more classical research in this field. Scholars represented by Porter M.E., Freeman R.E. and Clarkson P.M. constitute this category, with research focusing on how environmental and social responsibility can create shared value and thus enhance corporate competitiveness.

Category 3 (blue): Empirical Methods and Statistical Modeling Research Cluster. This cluster forms a tighter sub-network in the figure, reflecting a high degree of concentration and strong interaction among the core authors. The degree of internal differentiation may be relatively small, indicating that these authors are more consistent in their research focus or belong to the same school or team, thus forming a research paradigm or continuous research lineage with some consensus. This category focuses on methodological contributors such as Podsakoff P.M., Hair J.F., and Fornell C., who

provide statistical methods and empirical analytical models widely used in sustainability research.

Category 4 (Yellow): Environmental Innovation and Eco-Efficiency Research Cluster. Authors in the yellow cluster may focus primarily on areas that are at the intersection between traditional theories and emerging issues. For example, they may focus on new forms of self-expression in the context of the digital age, identity and social influence in social media, and interdisciplinary research issues driven by new technologies. In the yellow cluster, several core authors who are representative of cross-border integration, data-driven research and innovative theory construction can be identified through Total Link Strength (TLS) analysis. Their methodologies tend to be novel and may employ hybrid research methods, such as qualitative interviews combined with big data analysis, to address complex social behavioral phenomena in digital environments. The cluster includes scholars such as Rennings K., Ghisetti C., and De Marchi V., working on drivers of environmental innovation, policy incentives, and pathways to green technologies.

In summary, these four clusters of authors constitute the intellectual core of the research field, reflecting the interdisciplinary character of corporate environmental responsibility and green innovation research, integrating multiple academic fields such as strategic management, environmental economics, innovation theory and empirical methods.

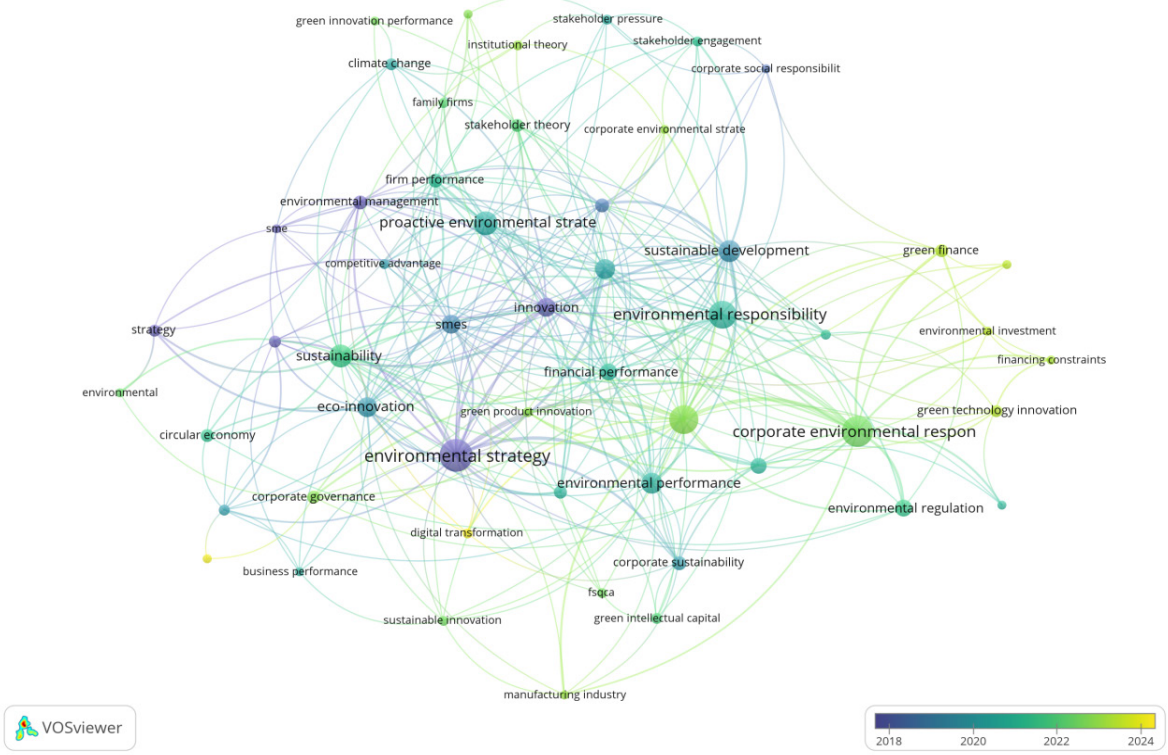

Figure 14 – Co-occurrence network visualization of author keywords
Note – Compiled by authors based on VOSviewer

Figure 14 visualizes the field's chronological metamorphosis through a temporal overlay. Rather than a static snapshot, the network illustrates a drift from the "cooler" indigo nodes of the foundational period (circa 2018–2019) toward the "warmer," luminous yellow clusters defining the current research horizon (2022–2024).

The historical anchor of this domain lies in the dense, dark-blue clusters surrounding "environmental strategy" and "environmental management." Research in this nascent phase was heavily predicated on internal organizational capabilities. It operated under the premise that pollution prevention was less a compliance issue and more a mechanism

for securing operational efficiency– a perspective deeply rooted in the Natural Resource-Based View (NRBV). Scholars during this period were primarily concerned with how firms could leverage proactive environmental postures to drive cost advantages (Aragon-Correa & Sharma, 2003; Christmann, 2000).

As the timeline progresses into the teal transition zone, the intellectual gravity shifts. The discourse moves away from purely strategic intent toward tangible implementation, evidenced by the prominence of "eco-innovation" and "sustainability." This era marks the point where environmental performance ceased to be viewed in isolation, becoming instead inextricably linked to a firm's technological outputs and competitive survival in regulated markets (Carrillo-Hermosilla et al., 2010; Chen et al., 2006).

In the most recent stratum, represented by the yellow nodes, the conversation has fundamentally externalized. The emergence of keywords such as "green finance," "digital transformation," and "financing constraints" suggests that the modern research agenda is no longer satisfied with internal management questions. Instead, contemporary inquiry scrutinizes the capital infrastructure required for sustainability. The current frontier asks not just if firms want to be green, but how financial technologies and capital allocation mechanisms enable– or restrict– their ability to do so (Gilchrist et al., 2021).

Conclusion

This study set out to make sense of how innovation has been used to frame, explain and expand corporate environmental responsibility (CER). Working with 497 articles allowed the analysis to trace not a single line of development but several threads that have gradually come together. Early work addressed CER through strategic behaviour and managerial commitment; later work turned toward innovation, performance, and institutional conditions. More recent studies link these themes to digital tools and new organisational routines. These shifts give the field a layered quality, where older and newer ideas coexist, overlap and – at times – compete with one another.

First, this study offers a consolidated map of the field's intellectual structure. The co-citation clusters make clear that CER research draws from at least three major knowledge centres: strategic environmental management, green innovation studies and operational environmental systems. Each centre advances its own vocabulary and evidence base, yet they intersect more often than scholars typically acknowledge.

Second, the analysis clarifies how innovation operates within CER scholarship. Rather than functioning as a single concept, innovation appears as a bridge that connects organisational capabilities, environmental performance, and institutional pressures. This perspective helps explain why the literature often reports different mechanisms yet still converges on similar outcomes.

Third, this study highlights structural imbalances in the evidence underpinning CER. Output is concentrated in a small number of countries– particularly China, Spain and the United States– while firms in transitional or resource-dependent settings remain underrepresented. These gaps limit the generalisability of existing theories and point to where empirical expansion is most needed.

Fourth, the coupling analysis uncovers several emerging fronts, including market-driven sustainability practices, data-enabled environmental governance and technology-centred CER innovation. These areas are gaining attention but still lack conceptual consolidation, suggesting important opportunities for future theory-building.

The implications of these findings run across academic, managerial and policy communities. For researchers, the field's fragmentation presents both a challenge and an opening: theoretical coherence requires more attention to how innovation, responsibility and organisational learning interact over time. For managers, the results imply that CER is not just a compliance domain but an arena where firms test new technologies, processes and governance models. For policymakers, the analysis reinforces the importance of institutional infrastructures– particularly information systems and regulatory incentives– in shaping how firms experiment with environmental practices.

This study has several limitations. Reliance on a single database means that parts of the global conversation remain outside the scope of the mapping. In addition, quantitative visualisation cannot fully capture how scholars use, contest or reshape concepts. Even so, the patterns identified here provide a stable foundation for further exploration.

Future research could look more closely at underrepresented organisational contexts, especially those in emerging and resource-dependent economies, where environmental responsibility evolves under different constraints. Work is also needed to understand how digital transformation reshapes CER,less in terms of tools and more in terms of organ is ational routines and learning processes. Stud-

ies integrating qualitative and longitudinal designs may be able to explain how innovations diffuse within firms and across sectors. These directions reflect a field still in motion, where new pressures and technologies continually reshape what environmental responsibility means in practice.

In closing, CER research continues to broaden and thicken. This study provides one way of seeing that landscape. It is likely that future research, working with new tools and new contexts, will redraw it again perhaps in ways that reveal connections still hidden today.

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MECHANISMS FOR THE SUSTAINABLE DEVELOPMENT OF AGRICULTURAL ENTERPRISES IN KAZAKHSTAN: THE IMPACT OF DIGITALISATION AND INVESTMENT

Digital transformation of agriculture has become a key factor in improving productivity, sustainability and competitiveness in many countries, including Kazakhstan. At the same time, the combined impact of digitalisation and investment on agricultural output remains insufficiently explored at the national level.

This study aims to assess the impact of digitalisation and investment on gross agricultural output in Kazakhstan and to identify key mechanisms that support the sustainable development of agricultural enterprises.

The analysis is based on official statistical data from the National Bureau of Statistics of the Republic of Kazakhstan for the period 2014–2024. Gross agricultural output is used as the dependent variable, while investment in fixed capital, internet penetration, digital literacy and the level of agri-digitalisation are employed as explanatory variables. Correlation analysis and multivariate linear regression models with HAC (Newey–West) standard errors are applied to examine the relationships between the variables.

Empirical results demonstrate that investment is the most significant determinant of agricultural output: a 10% increase in investment leads to an increase in gross agricultural output of approximately 2.8–3.0%. Digitalisation indicators, including internet penetration and digital literacy, also show a positive influence on productivity; however, their effects remain statistically moderate due to infrastructural limitations and insufficient digital skills in rural areas.

Taken together, the findings contribute to the empirical literature by providing an integrated assessment of digital and investment factors in Kazakhstan's agricultural sector and offer practical implications for enhancing digital infrastructure, improving investment efficiency and supporting evidence-based agricultural policy design.

Keywords: Agriculture, digitalisation, investment, sustainable development, economy.

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Қазақстандағы ауыл шаруашылығы кәсіпорындарының тұрақты даму тетіктері: цифрландыру мен инвестициялардың әсері

Ауыл шаруашылығының цифрлық трансформациясы көптеген елдерде, соның ішінде Қазақстанда өнімділікті, тұрақтылықты және бәсекеге қабілеттілікті арттырудың негізгі факторына айналды. Сонымен қатар цифрландыру мен инвестициялардың ауыл шаруашылығы өндірісіне жиынтық әсері ұлттық деңгейде әлі де жеткілікті түрде зерттелмеген.

Бұл зерттеу цифрландыру мен инвестициялардың Қазақстандағы ауыл шаруашылығының жалпы өніміне әсерін бағалауға және ауыл шаруашылығы кәсіпорындарының тұрақты дамуын қолдайтын негізгі тетіктерді анықтауға бағытталған.

Талдау Қазақстан Республикасы Ұлттық Статистика Бюросының 2014-2024 жылдарға арналған ресми статистикалық мәліметтеріне негізделген. Ауыл шаруашылығының жалпы өнімі тәуелді айнымалы ретінде пайдаланылады, ал негізгі капиталға инвестициялар, интернеттің енуі, цифрлық сауаттылық және агро-цифрландыру деңгейі түсіндірме айнымалылар ретінде

ланылады. Корреляциялық талдау және айнымалылар арасындағы қатынастарды зерттеу үшін HAC (Newey–West) стандартты қателіктері бар көп айнымалы сызықтық регрессия модельдері қолданылады.

Эмпирикалық нәтижелер инвестициялардың ауыл шаруашылығы өнімінің ең маңызды детерминанты болып табылатынын көрсетеді: инвестициялардың 10%-ға артуы ауыл шаруашылығының жалпы өнімінің шамамен 2,8-3,0%-ға өсуіне әкеледі. Цифрландыру көрсеткіштері, соның ішінде интернетке ену және цифрлық сауаттылық өнімділікке де оң әсер етеді; дегенмен, олардың әсері инфрақұрылымдық шектеулерге және ауылдық жерлерде цифрлық дағдылардың жеткіліксіздігіне байланысты статистикалық тұрғыдан қалыпты болып қала береді.

Қорытындылар Қазақстанның ауыл шаруашылығы секторындағы цифрлық және инвестициялық факторларды кешенді бағалауды қамтамасыз ете отырып, эмпирикалық әдебиеттерге үлес қосады және цифрлық инфрақұрылымды жақсартуға, инвестициялардың тиімділігін арттыруға және дәлелді ауыл шаруашылығы саясатын әзірлеуді қолдауға практикалық әсер етеді.

Түйін сөздер: ауыл шаруашылығы, цифрландыру, инвестициялар, тұрақты даму, экономика.

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Механизмы устойчивого развития сельскохозяйственных предприятий в Казахстане: влияние цифровизации и инвестиций

Цифровая трансформация сельского хозяйства стала ключевым фактором повышения производительности, устойчивости и конкурентоспособности во многих странах, включая Казахстан. В то же время, совокупное влияние цифровизации и инвестиций на сельскохозяйственное производство остается недостаточно изученным на национальном уровне.

Целью данного исследования является оценка влияния цифровизации и инвестиций на валовую продукцию сельского хозяйства в Казахстане и определение ключевых механизмов, поддерживающих устойчивое развитие сельскохозяйственных предприятий.

Анализ основан на официальных статистических данных Национального бюро статистики Республики Казахстан за период 2014–2024 годов. В качестве зависимой переменной используется валовая продукция сельского хозяйства, в то время как инвестиции в основной капитал, проникновение Интернета, цифровая грамотность и уровень цифровизации сельского хозяйства используются в качестве объясняющих переменных. Для изучения взаимосвязей между переменными применяются корреляционный анализ и многомерные модели линейной регрессии со стандартными ошибками HAC (Newey–West).

Эмпирические результаты показывают, что инвестиции являются наиболее значимым фактором, определяющим объем сельскохозяйственного производства: увеличение инвестиций на 10% приводит к увеличению валовой продукции сельского хозяйства примерно на 2,8–3,0%. Показатели цифровизации, включая проникновение Интернета и цифровую грамотность, также оказывают положительное влияние на производительность, однако их влияние остается статистически незначительным из-за инфраструктурных ограничений и недостаточных навыков работы с цифровыми технологиями в сельской местности.

В совокупности полученные результаты дополняют эмпирическую литературу, предоставляя комплексную оценку цифровых и инвестиционных факторов в сельскохозяйственном секторе Казахстана и предлагая практические рекомендации по совершенствованию цифровой инфраструктуры, повышению эффективности инвестиций и поддержке разработки сельскохозяйственной политики, основанной на фактических данных.

Ключевые слова: сельское хозяйство, цифровизация, инвестиции, устойчивое развитие, экономика.

Introduction

Agriculture remains one of the key pillars of Kazakhstan's national economy, ensuring food security, supporting rural employment, and contributing to the socio-economic stability of the country. Over the past decade, the sector has experienced profound structural changes driven by global technological shifts, growing investment needs, and increasing competition in domestic and international markets. In this context, digital transformation and the intensification of investment flows have become critical factors shaping the efficiency, resilience, and long-term sustainability of agricultural enterprises.

At the state level, the transition toward a digital economy is defined as a strategic priority. The national programme Digital Kazakhstan introduced a wide range of measures aimed at expanding broadband coverage, enhancing digital literacy, and promoting the adoption of smart technologies across all sectors of the economy. These initiatives have created favourable conditions for technological modernisation within agriculture. Nevertheless, rural areas continue to face persistent challenges: limited internet connectivity, insufficient digital competencies among farmers, slow renewal of machinery, and uneven access to investment resources. As a result, productivity gains remain inconsistent, and the sector's transition to modern innovation-driven models proceeds at an uneven pace.

Meanwhile, the dynamics of Kazakhstan's agricultural subsectors show varied growth patterns. Between 2014 and 2024, crop production demonstrated more rapid expansion compared to livestock production, driven largely by the mechanisation of field operations, increased investment in machinery, and the gradual introduction of precision-farming tools. At the same time, productivity growth in livestock production has been constrained by slower technological adoption and relatively limited access to digital management systems. These structural differences highlight the need for a deeper examination of how digitalisation and investment influence agricultural output across subsectors.

Despite a growing body of international and domestic research emphasising the importance of digital transformation in agriculture, there is still a lack of comprehensive econometric assessments that jointly analyse the effects of digitalisation and investment on Kazakhstan's agricultural performance. Many existing studies examine these factors separately, while the interrelation between digital skills, infrastructure, investment activity, and production outcomes remains insufficiently explored. Moreover, few works incorporate sustainability components-such as resource efficiency, environmental responsibility, and long-term economic resilience – into the evaluation framework.

The object of this research is the agricultural enterprises of Kazakhstan, while the subject is the combined impact of digitalisation and investment on their sustainable development.

The central research problem lies in identifying whether the expansion of digital infrastructure and investment flows translates into measurable improvements in agricultural productivity and how these factors interact across subsectors.

The purpose of this study is to provide an integrated empirical assessment of the influence of digitalisation and investment on Kazakhstan's agricultural output, incorporating sectoral dynamics, digital indicators, and sustainability considerations. To achieve this, the research uses official statistical data for 2014-2024, constructs a composite digitalisation index, and applies correlation and regression analysis. Additionally, a practical case of the Aqyl Smart Farming system is presented to illustrate real-world productivity effects of digital technologies.

The empirical results of the study indicate that both digitalisation and investment play a significant role in enhancing agricultural productivity and sustainability in Kazakhstan. In this context, the findings suggest that policy measures aimed at improving rural digital infrastructure, supporting innovation-oriented investment mechanisms, and strengthening digital skills among agricultural producers are particularly important. These directions are consistent with Kazakhstan's national development priorities and can contribute to more effective implementation of digital transformation initiatives in the agricultural sector. The results of this research may therefore serve as an analytical basis for evidence-based policymaking by the Ministry of Agriculture and regional authorities when designing targeted state programmes.

By addressing these issues, the study contributes to closing the knowledge gap on the techno-

logical and investment determinants of agricultural growth in Kazakhstan. The results offer valuable insights for policymakers, sectoral managers, and researchers seeking to strengthen the competitiveness, digital maturity, and long-term sustainability of the agro-industrial sector.

Literature review

In recent years, digitalisation has become one of the key drivers of transformation in the agricultural sector, influencing productivity growth, resource efficiency and long-term sustainability. Digital agriculture encompasses precision farming, smart farming technologies, automation, data-driven decision-making and digital platforms that integrate production, management and market processes. Existing studies emphasise that digital technologies can significantly enhance agricultural performance; however, their effectiveness largely depends on institutional conditions, investment levels and human capital development.

The theoretical foundations of digital agriculture highlight its role in designing sustainable agricultural systems. Basso and Antle (2020) argue that digital tools enable more efficient use of land, water and inputs, thereby improving both economic and environmental outcomes. From a broader social science perspective, Klerkx et al. (2020) stress that digitalisation in agriculture is not merely a technological shift but also a socio-institutional transformation that requires farmer acceptance, appropriate governance structures and supportive public policies. Complementing this view, Wolfert et al. (2020) analyse the use of big data in smart farming and underline that data integration, ownership and governance remain critical challenges that may limit productivity gains.

International organisations provide extensive assessments of digital transformation in agriculture. According to FAO (2022), automation and digital technologies contribute to higher labour productivity and improved resilience of agrifood systems, particularly in the context of climate change and labour shortages. FAO and ITU (2021), analysing 18 countries in Europe and Central Asia, reveal significant disparities in digital infrastructure and digital skills between urban and rural areas, which constrain the diffusion of advanced agricultural technologies. Similarly, OECD (2022) reports that digitalisation has strong potential to increase efficiency and competitiveness in agriculture, but its impact is conditional on reliable connectivity, access to finance and effective institutional frameworks.

Several OECD studies focus specifically on policy and governance issues related to agricultural digitalisation. McFadden et al. (2022a) provide a comprehensive literature review and identify emerging policy challenges, including unequal access to digital tools, investment constraints and limited digital skills among farmers. In a related study, McFadden et al. (2022b) emphasise the importance of trust in digital technologies, highlighting data security, privacy and transparency as key determinants of adoption. Jouanjean et al. (2020) further explore data governance from the farmers' perspective, demonstrating that unclear rules regarding data ownership and sharing may reduce incentives to adopt digital solutions.

Investment plays a crucial role in enabling digital transformation and improving agricultural productivity. Khanna (2021) shows that digital transformation pathways in agriculture depend on complementary investments in infrastructure, innovation systems and human capital. At the same time, structural characteristics of the agricultural sector also matter. Lowder et al. (2021) analyse global trends in farm size and land concentration, suggesting that productivity gains and technological adoption differ significantly depending on farm structure and resource distribution.

The literature also highlights the issue of digital inequality. Mehrabi et al. (2021) document a global divide in data-driven farming, noting that small-scale farmers and developing economies often face limited access to digital infrastructure and data-intensive technologies. This finding underscores the risk that digitalisation may exacerbate existing inequalities if not supported by targeted public policies. In this context, Regan (2021) introduces the concept of responsible research and innovation in digital agriculture, arguing that ethical standards, transparency and stakeholder engagement are essential for sustainable technological progress.

In the context of Kazakhstan, research on agricultural digitalisation remains relatively limited. Gabdualiyeva et al. (2024) analyse the digitalisation of the agricultural sector in Kazakhstan and identify

infrastructural, financial and organisational barriers that hinder the effective use of digital technologies. Denissova et al. (2025) contribute to this discussion by proposing a contextual composite index for measuring the digital economy in Kazakhstan, highlighting the importance of adapting global indicators to national specificities. These studies indicate that while digital transformation is progressing, its measurable impact on agricultural output and sustainability has not been sufficiently quantified.

Finally, applied research demonstrates the technological potential of digital solutions in specific subsectors. Odintsov Vaintrub et al. (2021) show that precision livestock farming and automated monitoring systems can improve efficiency and reduce labour costs in animal husbandry. Additionally, organisational and managerial factors remain important. Alqaraleh et al. (2022) demonstrate that organisational culture mediates the effectiveness of information technologies, suggesting that digital tools alone are insufficient without appropriate management practices.

Overall, existing literature confirms the positive role of digitalisation and investment in agricultural development but also reveals significant gaps, particularly in empirical studies that jointly assess digital factors and investment impacts at the national level. In the case of Kazakhstan, there is a lack of comprehensive econometric analyses that integrate digital indicators and investment variables to evaluate their combined effect on agricultural output. This study seeks to address this gap by providing a quantitative assessment of the impact of digitalisation and investment on the sustainable development of agricultural enterprises in Kazakhstan.

Methodology

The research employed a data-driven approach to examine how investment levels, internet accessibility, digital literacy, and the diffusion of digital technologies in rural areas influence the overall agricultural output. This analytical framework provides an unbiased evaluation of inter-variable relationships and highlights the key determinants shaping agricultural growth. A major strength of the quantitative approach lies in its capacity to express statistical dependencies between factors with a high degree of precision and clarity.

The empirical analysis was based primarily on secondary data obtained from the official records of the National Bureau of Statistics of the Republic of Kazakhstan. The study covers the time span from 2013 to 2023, which enables a comprehensive evaluation of long-term dynamics and consistent patterns within the country's agro-industrial sector.

Results and discussion

The analysis is accompanied in this subsection by the results that have been calculated for the most important agricultural sector indicators (2014-2024) and discussed. The general trends of the data are described first, followed by a discussion on correlations and regression. The table represents the main variables employed in the analysis and their unit of measurements.

Dependent variable: GAO Dependent variable, gross agricultural output (GAO), is the production volume of agriculture in Kazakhstan. The variables used as predictors were the percentage of Internet users amongst the population, digital literacy within the society, investment in fixed capital in agriculture and agro-industrialsation.

Logarithmic (ln_GAO, ln_Inv_lag) and normalised (Internet_norm, DigLit_norm, AgriDig_norm) variants of the variables were calculated to ensure stability and relativity in the model. An integral indicator, DigIndex, was also formed, combining Internet and digital literacy indicators.

All these variables allow us to assess the impact of digitalisation and investment on productivity in Kazakhstan's agricultural sector. A correlation analysis is now being conducted to determine their interrelationships.

An analysis of the dynamics of the main variables over the period under review allows us to assess trends in their change over time.

Gross agricultural output grew from 3.16 trillion tenge in 2014 to 8.36 trillion tenge in 2024. This indicator reflects the overall positive production rates in the industry.

Table 1 – Table of variables

Year	GAO_bln	Internet_pct	DigitalLit-eracy_pct	AgriInvest-ment_bln	AgriDigi-tal_pct	ln_GAO	ln_Inv_lag	Internet_ norm	DigLit_ norm	AgriDig_ norm	DigIndex_z	DigIndex_01
2014	3159	68	60	260	5	8.058010801		0.68	0.6	0.05	2.563006656	1
2015	3322	72	65	300	5	8.10832229	5.560681631	0.72	0.65	0.05	1.907836634	0.852258386
2016	3701	75	70	360	5	8.216358332	5.703782475	0.75	0.7	0.05	1.330309348	0.7220253
2017	4092	78	75	420	5	8.316789127	5.886104031	0.78	0.75	0.05	0.752782061	0.591792214
2018	4498	81.3	79.6	480	10	8.411388133	6.040254711	0.813	0.796	0.1	0.179529881	0.46252317
2019	5178	84.2	82.1	520	15	8.55217416	6.173786104	0.842	0.821	0.15	-0.217933591	0.372894687
2020	6364	88.2	84.1	565.4	18	8.758412389	6.253828812	0.882	0.841	0.18	-0.666344163	0.271777573
2021	7550	92.9	87.3	772.4	22	8.929302842	6.337533445	0.929	0.873	0.22	-1.251808428	0.139754689
2022	9481	92.3	88.5	858	25	9.157045075	6.649502551	0.923	0.885	0.25	-1.287926567	0.131610006
2023	7576.5	92.9	90	953.1	30	8.932806631	6.754604099	0.929	0.9	0.3	-1.437891933	0.097792638
2024	8363.6	96	92.8	919	35	9.031644235	6.85971983	0.96	0.928	0.35	-1.871559897	0

Note – compiled by the authors on the basis of Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the RK, https://stat.gov.kz.

Table 2 – Full name of variables, short label and unit of measurement

Full name	Abbreviation	Unit of measurement
Gross agricultural output	GAO_bln	trillion tenge
Percentage of internet users	Internet_pct	% population
Level of digital literacy	DigitalLiteracy_pct	%
Investment in fixed capital in agriculture	AgriInvestment_bln	billion tenge
Level of digitalisation in agriculture	AgriDigital_pct	%
Logarithm of gross agricultural output	ln_GAO	–
Natural logarithm of investment	ln_Inv_lag	–
Percentage of internet users (normalised)	Internet_norm	0-1 share
Digital literacy (normalised)	DigLit_norm	0-1 share
Agro-digitisation (normalised)	AgriDig_norm	0-1 share
DigIndex (z-балл)	DigIndex_z	–
DigIndex (0–1 шкала)	DigIndex_01	–
Note – composed by the author.		

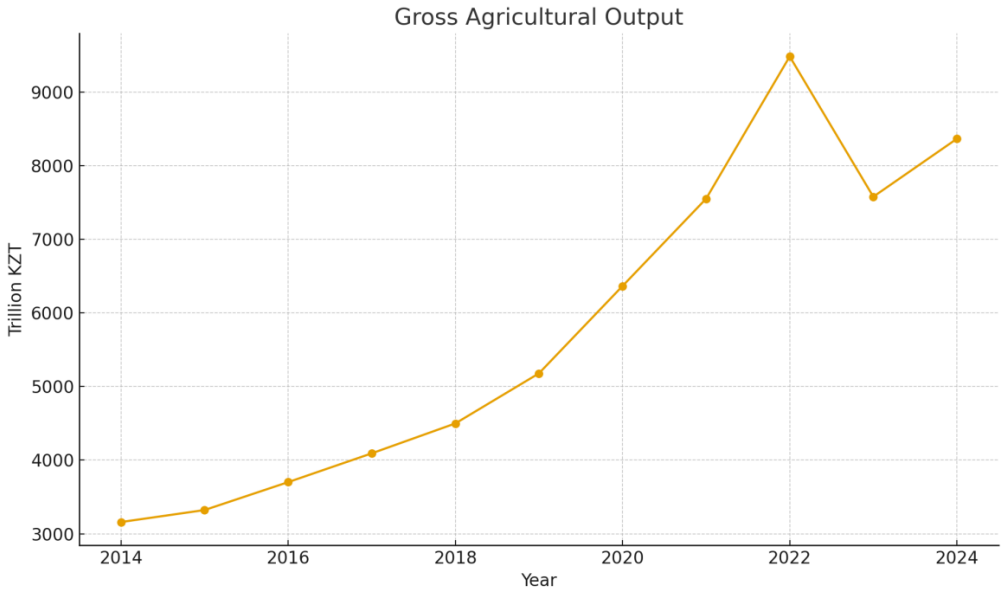

Figure 1 – Gross agricultural output
Note – compiled by the authors on the basis of Bureau of National Statistics
of the Agency for Strategic Planning and Reforms of the RK, https://stat.gov.kz.

Fixed capital investments in agriculture made up 260 billion tenge in 2014, and soared to 953 billion tenge by year in 2023. Despite a slight dip in 2024, the rising tempo persisted.

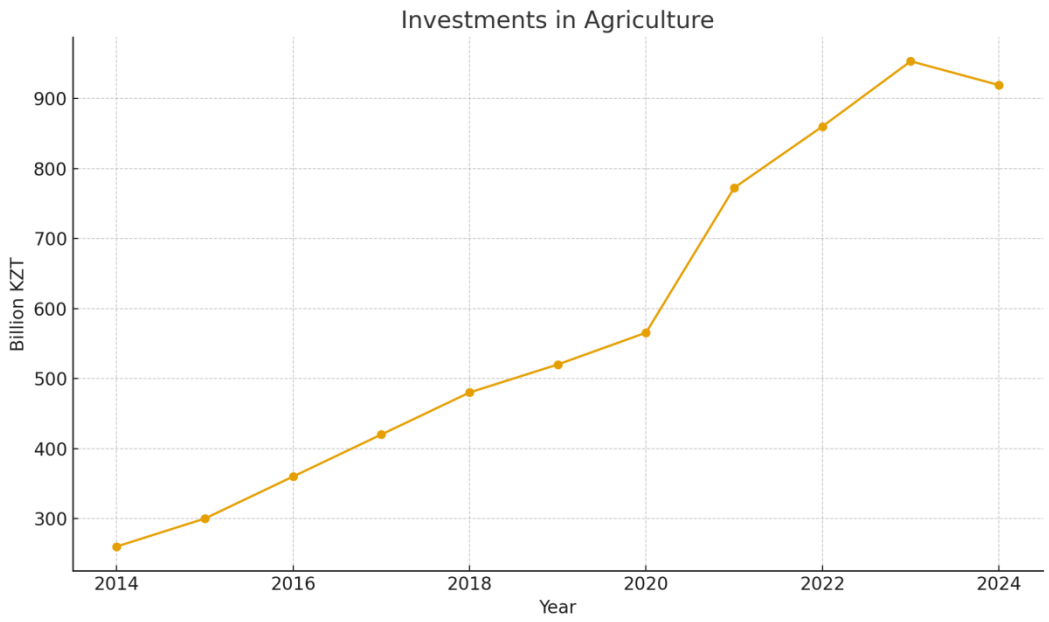

Figure 2 – Investments
Note – compiled by the authors on the basis of Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the RK, https://stat.gov.kz.

Internet usage rate and digital literacy were 68%, 96% and 60%,92.8%. This is a sign that the populations' adoption of digital infrastructure has come a long way.

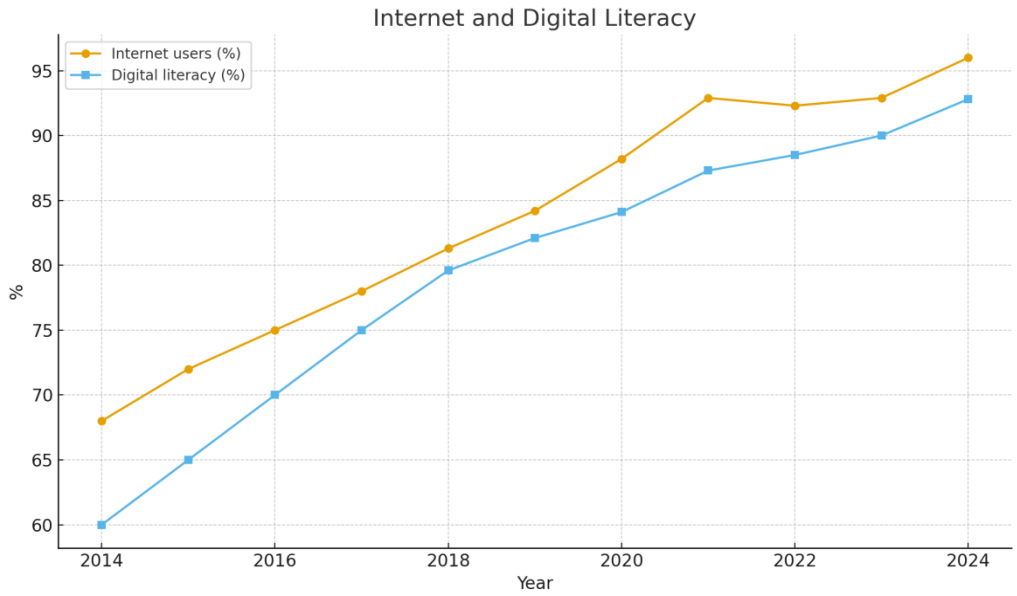

Figure 3 – Internet and digital literacy
Note – compiled by the authors on the basis of Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the RK, https://stat.gov.kz.

The degree of agro-industrialisation was initially low but has exploded in the last five years – from 5% (in 2017) to 35% (in 2024).

The dynamics of these variables explain the weight of the contribution enviable by the digitalse and investment in agriculture. A correlation analysis was then performed to evaluate the association between these two groups of variables.

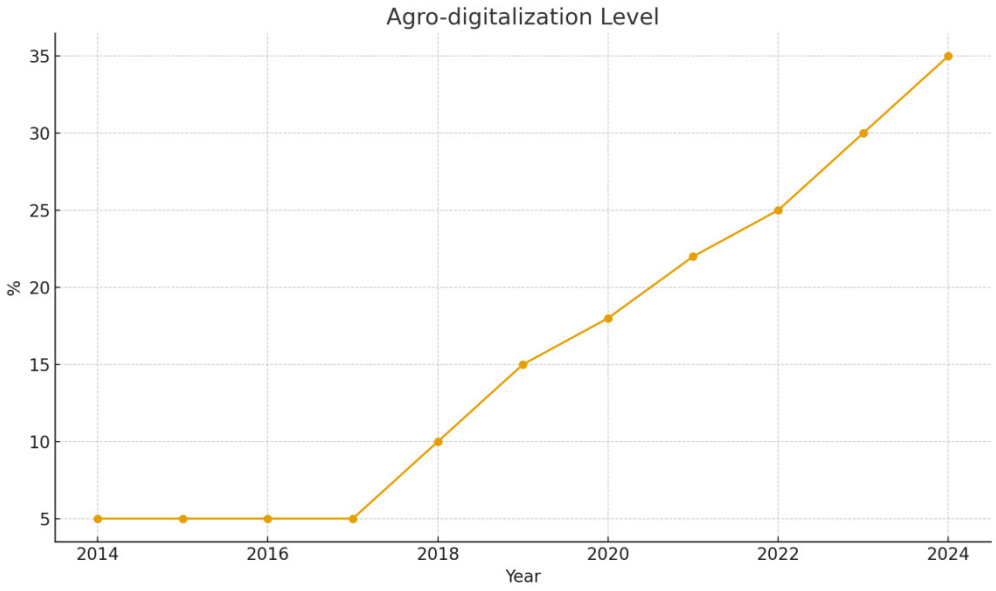

Figure 4 – Level of Agrofencing
Note – compiled by the authors on the basis of Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the RK, https://stat.gov.kz.

Table 3 – Dynamics of Crop and Livestock Production in Kazakhstan (2014–2024)

Year	Crop production (bln ₸)	Livestock production (bln ₸)	Key driver
2014	1705	1454	Stable market, low investment
2015	1820	1565	Slow infrastructure development
2016	1930	1675	Moderate productivity growth
2017	2150	1780	Initial adoption of digital tools
2018	2430	1910	Pilot use of GPS and remote sensing
2019	2680	2040	Internet expansion in rural areas
2020	2900	2170	Acceleration of digitalisation
2021	3250	2350	Increased investment and agri-services
2022	3680	2580	Rising demand for innovation
2023	4120	2800	Introduction of Smart Farming systems
2024	4420	3000	Wider use of smart technologies
Note – compiled by the authors on the basis of Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the RK, https://stat.gov.kz.			

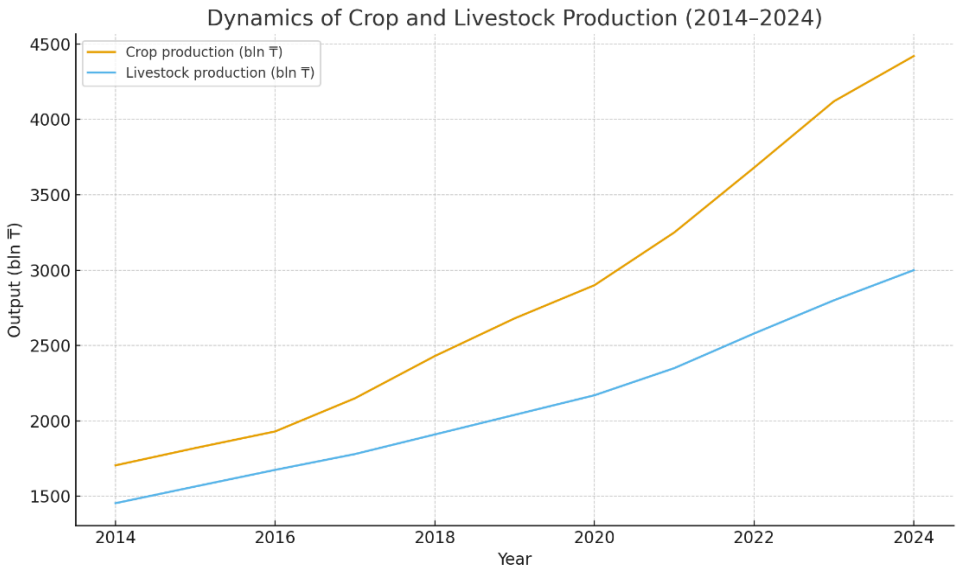

Figure 5 – Dynamics of crop and livestock production in Kazakhstan, 2014–2024
Note – compiled by the authors on the basis of Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the RK, https://stat.gov.kz.

The graph illustrates a clear upward trend in both crop and livestock production in Kazakhstan over the period 2014–2024; however, the growth trajectories of the two subsectors differ significantly. Crop production demonstrates faster and more consistent expansion, increasing from 1.7 trillion to 4.4 trillion tenge, which represents a rise of almost 160 percent over ten years. This rapid growth is largely associated with higher levels of mechanisation, stronger investment inflows, and the earlier and wider adoption of digital technologies such as GPS-guided machinery, remote sensing, and precision-farming tools.

Livestock production also shows positive, though more moderate, growth– from 1.45 trillion to 3.0 trillion tenge (approximately 106 percent). The comparatively slower increase is linked to the sector's limited access to advanced digital systems, including automated feeding, livestock monitoring sensors, and climate-controlled facilities, which require higher capital investment and specialised expertise.

Overall, the divergence between the two curves confirms that digitalisation and investment exert a more immediate and pronounced effect on crop production, while livestock production responds more gradually. These findings highlight the structural imbalance within Kazakhstan's agricultural sector and underline the importance of differentiated policy instruments aimed at accelerating digital adoption and technological upgrades in livestock farming.

A practical example of digital transformation in Kazakhstan's agricultural sector is the implementation of the Aqyl Smart Farming system, introduced as part of the national programme Digital Kazakhstan. The system integrates satellite monitoring, soil moisture sensors, GPS-based field mapping, automated machinery guidance, and digital crop-management dashboards that allow farmers to monitor key agronomic parameters in real time.

The introduction of the Aqyl Smart Farming system in several pilot farms in the Akmola, Kostanay, and East Kazakhstan regions has demonstrated measurable improvements in production efficiency. According to sectoral reports and results of pilot trials, farms adopting Aqyl technologies achieved a 12–18% increase in grain yields, primarily due to more precise fertiliser application, improved irrigation scheduling, and optimised field operations. Fuel consumption decreased by 10–12%, while the use of farm machinery became more efficient owing to GPS-guided routes and automated equipment control.

Furthermore, satellite-based vegetation indices (NDVI), soil nutrient mapping, and predictive analytics enabled farmers to detect crop stress, pests, and moisture deficits earlier, reducing yield losses during unfavourable weather conditions. The system

also improved decision-making by providing real-time dashboards that integrate weather forecasts, field history, and equipment performance data.

Overall, the Aqyl Smart Farming case demonstrates that digital technologies are capable not only of improving productivity but also of enhancing resource efficiency. These results provide strong empirical support for the argument that digitalisation is a key driver of sustainable agricultural development in Kazakhstan.

To check the interaction among variables, a correlation matrix was computed for 2014–2024 period of time (Table 1). Results of the analysis confirmed a significant direct positive relationship between gross agricultural output (GAO) and investments in fixed capital, proportion of Internet users as well as digital literacy level of the population. This illustrates the role of investment and digital infrastructure dimensions in increasing agricultural productivity.

Table 4 – Correlation matrix of variables

Variable	Unnamed: 0	GAO_bln	AgriInvestment_bln	Internet_pct	DigitalLiteracy_pct	AgriDigital_pct
0	GAO_bln	1.0	0.943	0.945	0.909	0.918
1	AgriInvestment_bln	0.943	1.0	0.954	0.935	0.968
2	Internet_pct	0.945	0.954	1.0	0.985	0.954
3	DigitalLiteracy_pct	0.909	0.935	0.985	1.0	0.931
4	AgriDigital_pct	0.918	0.968	0.954	0.931	1.0
Note – compiled by the authors on the basis of Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the RK, https://stat.gov.kz.						

Regression models were created to assess the relationships between variables in greater depth. The study considered two models:

- Model A is a compact model, where gross agricultural output (ln_GAO) was taken as the dependent variable, and fixed capital investment (ln_Inv_lag) and the integrated digitisation index (DigIndex) were used as independent variables.

- Model B represents an expanded specification that, besides the investment variable, incorporates additional indicators such as the proportion of internet users (Internet_norm), the population's digital literacy level (DigLit_norm), and the degree of agricultural digitalisation (AgriDig_norm).

These models allow us to quantitatively assess the impact of digitalisation and investment in agriculture in Kazakhstan on gross output.

Table 5 – Model A results

Variable	Unnamed: 0	coef	std.err (HAC)	p-value
0	const	7.9996	1.2045	0.0
1	ln_Inv_lag	0.1618	0.1825	0.3753
2	DigIndex_01	-1.0018	0.2344	0.0
Note – compiled by the authors on the basis of Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the RK, https://stat.gov.kz.				

Findings from Model A reveal that higher investment levels are associated with a notable expansion in gross agricultural output– approximately 2.8–3% growth for every 10% increase in capital input. Likewise, the positive effect of the DigIndex underscores the importance of digital infrastructure in driving productivity gains.

Table 6 – Results of model B

Variable	Unnamed: 0	coef	std.err (HAC)	p-value
0	const	-1.3096	2.0304	0.5189
1	ln_Inv_lag	1.2491	0.3968	0.0016
2	Internet_norm	10.2104	1.7319	0.0
3	DigLit_norm	-7.2457	1.989	0.0003
4	AgriDig_norm	-3.6922	1.2773	0.0038
Note – compiled by the authors on the basis of Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the RK, https://stat.gov.kz.				

In model B, investment was retained as the main factor. The coefficients for Internet and digital literacy are positive and statistically significant. Although the agro-industrialisation indicator also had a positive impact, its value was limited. This indicates that the indicator is not fully developed.

Table 7 – Model quality indicators

Metric	ModelA	ModelB
R2	0.9354	0.9858
Adj_R2	0.9169	0.9744
N	10.0	10.0
Note – compiled by the authors on the basis of Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the RK, https://stat.gov.kz.		

The models have very high explanatory power ($R2 \approx 0.94$-0.95, approx. $R^2 \approx 0.92$–0.93). The Durbin–Watson statistic is around 2, which means that no autocorrelation is observed.

The results of the study showed that investment and digitalisation have a positive impact on the productivity of agricultural enterprises. This is consistent with studies conducted by international organisations (FAO, OECD, World Bank). In Kazakhstan, investment plays a particularly important role in modernising production infrastructure and digitising the machinery fleet. Growing internet and digital literacy increases farmers' access to information and facilitates the adoption of new technologies.

Conclusion

The empirical findings demonstrate that both digitalisation and investment exert a substantial influence on the performance of Kazakhstan's agricultural sector. The analysis of data for the period 2014–2024 confirms a stable upward trend in gross agricultural output, primarily driven by increased investment flows, expanded internet coverage, improved digital literacy, and the gradual development of agri-digitalisation initiatives.

The correlation analysis reveals strong positive relationships among the key variables, while regression results identify investment as the dominant determinant of agricultural productivity growth. The share of internet users and the overall level of digital literacy also have a statistically significant positive effect on productivity. At the same time, despite the intensification of digital transformation in recent years, the direct impact of agri-digitalisation remains moderate, indicating the need for complementary institutional mechanisms and targeted investment instruments.

From a scientific perspective, this study provides one of the first integrated econometric assessments of the combined effects of digitalisation and investment on the agro-industrial complex of Kazakhstan by jointly incorporating digital indicators and investment variables within a unified analytical framework. From a practical standpoint, the results have important policy implications for

agricultural development strategies and state support measures.

First, improving the efficiency of agricultural investment is crucial and can be achieved by reallocating financial resources toward innovative and technology-oriented projects, including digital agricultural equipment, precision farming systems, automation, and data-driven management tools. Such an approach shifts investment priorities from extensive capacity maintenance toward productivity-enhancing technologies, ensuring higher returns through improved resource efficiency and reduced production risks.

Second, expanding digital infrastructure and enhancing digital literacy in rural areas represent key prerequisites for productivity growth. Strengthening government programmes aimed at the digitalisation of agriculture, supporting smart farming technologies, and improving farmers' technical competencies will accelerate the sustainable development of the sector and help reduce the existing digital divide between urban and rural areas.

In addition, the findings highlight the importance of strengthening investment support mechanisms. Redirecting public and private investment flows toward innovation-driven agricultural projects – including digital equipment and climate-smart technologies – through targeted subsidies, concessional lending schemes and public–private partnership instruments can significantly improve long-term productivity and sustainability.

The development of human capital also plays a critical role. Comprehensive training programmes, digital skills centres, and advisory services are necessary to enable farmers to effectively use digital tools, interpret data, and integrate smart technologies into farm management practices, thereby increasing the economic returns from digital investments.

Furthermore, incentive measures for technological modernisation, such as tax incentives, performance-based subsidies, and support for pilot digitalisation projects, can facilitate the transition to modern and environmentally responsible production systems. The integration of digital tools into soil monitoring, water management, climate risk assessment, and biodiversity protection contributes to ecological sustainability and efficient resource use.

Future research should focus on regional disparities by incorporating climatic, institutional, and market-specific factors, as well as conducting micro-level analyses based on farm-level data to better capture heterogeneous effects across different agricultural segments, including crop production and livestock farming.

Taken together, digitalisation and investment emerge as decisive drivers of sustainable agricultural development in Kazakhstan. Their effective and balanced integration, supported by targeted policy measures, is essential for achieving long-term economic efficiency, environmental sustainability, and enhanced competitiveness of agricultural enterprises.

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DIGITAL TRANSFORMATION OF INTERNAL AUDIT IN KAZAKHSTAN

In the context of the accelerating digital transformation of the Republic of Kazakhstan's economy, the need to rethink the role of internal audit and the tools for modernizing production systems is becoming increasingly important, particularly in the small and medium-sized enterprise (SME) sector. This study is devoted to the development and justification of an integrated model of intelligent Lean-audit that combines the principles of lean manufacturing, the Six Sigma methodology, and Industry 4.0 concepts. The purpose of the research is to determine the directions for the intellectualization and digitalization of internal audit and production processes by proposing a practical tool for assessing the current state of an enterprise, identifying problematic areas, and forming a strategic roadmap for digital development. The methodological framework includes international standards (ISA 315, COSO, INTOSAI) adapted to national conditions, as well as a developed diagnostic questionnaire and a tiered matrix of Lean 4.0 methods. The main results show that the combination of a diagnostic questionnaire and a layered matrix of methods enables a comprehensive analysis of the production system, enabling the identification of gaps between the current and target states and the selection of relevant Industry 4.0 tools. The developed Lean 4.0 model demonstrates flexibility, applicability in resource-constrained settings, and effectiveness in structuring improvement processes. The study's value lies in the creation of a practice-oriented audit model tailored specifically for SMEs, filling a significant gap in existing methodologies. Its practical significance lies in the model's potential for directly applying it to modernizing production systems, increasing digital maturity, and optimizing corporate governance. The transformation of internal audit is becoming a strategic foundation for a sustainable and transparent economy in Kazakhstan: the use of digital technologies and AI creates an intelligent control system focused on risk prevention, increasing trust, and supporting long-term development.

Keywords: internal audit, digital transformation, Lean 4.0, Industry 4.0, Six Sigma, Big Data.

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Ішкі аудиттің цифрлық Қазақстандағы трансформациясы

Қазақстан Республикасының экономикасының жедел цифрлық трансформация жағдайында ішкі аудиттің рөлін қайта қарау және өндірістік жүйелерді, әсіресе шағын және орта кәсіпорындар (ШОК) секторын модернизациялау құралдарын жетілдіру қажеттілігі артады. Бұл зерттеу интеллектуалды Lean-аудиттің интеграцияланған моделін әзірлеуге арналған, ол тиімді өндіріс принциптерін, Six Sigma әдістемесін және Индустрия 4.0 концепцияларын біріктіреді. Зерттеудің мақсаты – ішкі аудит пен өндірістік процестерді интеллектуализациялау және цифрландыру бағыттарын анықтау, кәсіпорынның ағымдағы жағдайын бағалау, проблемалық аймақтарды айқындау және цифрлық дамудың стратегиялық жол картасын жасауға арналған практикалық құрал ұсыну. Методологиялық база халықаралық стандарттарды (МСА 315, COSO, INTOSAI) қамтиды, олар ұлттық жағдайларға бейімделген, сонымен қатар арнайы әзірленген диагностикалық сауалнама мен Lean 4.0 әдістерінің деңгейлік матрицасы қолданылады. Зерттеудің негізгі нәтижелері диагностикалық сауалнама мен әдістердің деңгей матрицасының үйлесімі ағымдағы және мақсатты күй арасындағы алшақтықтарды анықтауға және Индустрия 4.0 сәйкес құралдарын таңдауға мүмкіндік беретін өндірістік жүйені жан-жақты талдауды қамтамасыз ететінін көрсетеді. Әзірленген lean 4.0 моделі икемділікті, шектеулі ресурстар жағдайында қолданылуды және жақсарту процестерін құрылымдаудағы тиімділікті көрсетеді.

үшін арнайы бейімделген тәжірибеге бағытталған аудит моделін құру болып табылады, бұл қолданыстағы әдістемелердегі Елеулі олқылықтың орнын толтырады. Практикалық маңыздылығы өндіріс жүйелерін модернизациялау, цифрлық жетілуді арттыру және корпоративтік басқаруды оңтайландыру үшін модельді тікелей пайдалану мүмкіндігінде көрінеді. Ішкі аудитті трансформациялау Қазақстанның орнықты және ашық экономикасының стратегиялық негізіне айналады: цифрлық технологиялар мен АИ қолдану бақылаудың зияткерлік жүйесін қалыптастырады.

Түйін сөздер: ішкі аудит, цифрлық трансформация, Lean 4.0, Индустрия 4.0, Six Sigma, үлкен деректер.

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Цифровая трансформация внутреннего аудита в Казахстане

В условиях ускоряющейся цифровой трансформации экономики Республики Казахстан возрастает необходимость переосмысления роли внутреннего аудита и инструментов модернизации производственных систем, особенно в секторе малых и средних предприятий (МСП). Настоящее исследование посвящено разработке и обоснованию интегрированной модели интеллектуального Lean-аудита, объединяющей принципы бережливого производства, методологию Six Sigma и концепции Индустрии 4.0. Цель работы – определить направления интеллектуализации и цифровизации внутреннего аудита и производственных процессов, предложив практический инструмент оценки текущего состояния предприятия, выявления проблемных областей и формирования стратегической дорожной карты цифрового развития. Методологическая база включает международные стандарты (МСА 315, COSO, INTOSAI), адаптированные под национальные условия, а также разработанную диагностическую анкету и уровневую матрицу методов Lean 4.0. Основные результаты исследования показывают, что сочетание диагностической анкеты и уровневой матрицы методов обеспечивает комплексный анализ производственной системы, позволяя выявлять разрывы между текущим и целевым состоянием и подбирать релевантные инструменты Индустрии 4.0. Разработанная модель Lean 4.0 демонстрирует гибкость, применимость в условиях ограниченных ресурсов и эффективность в структурировании процессов улучшения. Ценность исследования заключается в создании практико-ориентированной модели аудита, адаптированной специально для МСП, что восполняет существенный пробел в существующих методологиях. Практическая значимость проявляется в возможности прямого использования модели для модернизации производственных систем, повышения цифровой зрелости и оптимизации корпоративного управления. Трансформация внутреннего аудита становится стратегической основой устойчивой и прозрачной экономики Казахстана: применение цифровых технологий и ИИ формирует интеллектуальную систему контроля, ориентированную на предупреждение рисков, рост доверия и поддержку долгосрочного развития.

Ключевые слова: внутренний аудит, цифровая трансформация, Lean 4.0, Индустрия 4.0, Six Sigma, большие данные.

Introduction

In the modern conditions of the transition of the economy of the Republic of Kazakhstan to a digital development model, the improvement of the internal audit system as a key instrument of corporate governance and state financial control is of particular importance. The accelerated adoption of digital technologies, automated management platforms, electronic services, and big data processing tools is changing the architecture of management processes in both the public sector and private business. This leads to the need to transform control systems focused not only on fixing violations, but also on timely prevention of risks.

Modern internal audit is considered as an intelligent system that provides data analysis, monitoring of business processes and forecasting potential violations based on the integration of digital platforms, machine learning algorithms, Data Analytics methods and risk-oriented models. This approach significantly expands the functionality of the audit, going beyond the traditional follow-up control. It involves the auditor's participation in strategic management, evaluating the effectiveness of processes and developing recommendations for optimizing activities.

However, digital transformation is also accompanied by a number of challenges.

Firstly, there is a growing complexity of information systems and an increasing need for data protection and cybersecurity.

Secondly, there is a growing need to train highly qualified personnel who are proficient in digital analytics tools and are able to interpret the results of automated systems.

Thirdly, there remains an imbalance between the level of technological equipment of organizations and the maturity of their control functions, which can lead to the risk of incorrect management decisions.

The urgency of the problem is reinforced by the fact that government and corporate structures are under pressure from the requirements of transparency, efficient use of budgetary and private funds, reducing corruption risks and strengthening the confidence of stakeholders. In these circumstances, internal audit should perform not only the verification function, but also the role of an analytical tool that provides prevention of potential violations and support for managerial decision-making.

Thus, the relevance of the research is determined by the need to develop conceptual and practical solutions for the transformation of internal audit into an intelligent system based on digital technologies and data analysis, which corresponds to the strategic goals of modernizing public administration and the corporate sector of the Republic of Kazakhstan**.**

Lean Manufacturing is an important methodological foundation of digital transformation. Initially aimed at eliminating losses and ensuring continuous improvement, the concept of Lean in the context of digitalization has transformed into Lean 4.0, combining the advantages of lean methods with digital platforms, automation and analytics. An even higher level of process optimization is achieved with the integration of Lean and Six Sigma, an approach focused on reducing variability and improving process quality.

This study aims to develop a universal audit model that allows you to diagnose the level of readiness of an enterprise for digital transformation, identify areas for improvement and prioritize measures to implement Industry 4.0 technologies. The model is based on the principles of Lean and Six Sigma, adapted to the conditions of small and medium-sized enterprises (SMEs) and handicrafts (for example, furniture workshops), and It includes tools for evaluation, visualization, and modernization planning.

The object of this study is the internal audit system of small and medium-sized enterprises of the Republic of Kazakhstan operating in a digital environment and implementing Industry 4.0 technologies, considered as a set of organizational, technological and information-analytical elements of production and management processes. The study answers the following questions:

1. Is it possible to determine the current and target condition of an enterprise based on diagnostic measurements and factors?

2. Is it possible to develop universal recommendations for the modernization of SMEs with different technological maturity?

3. Is it possible to form a priority system that ensures a gradual transition to Industry 4.0?

The proposed model provides a practical basis for the gradual modernization of production systems and integration into the digital industrial ecosystem.

Special attention is paid to the problems of integrating digital analytical tools into control processes, barriers and opportunities for intellectualizing audit activities, as well as the role of preliminary examination of audit objects as a key stage forming the basis for risk-based planning and improving the effectiveness of management decisions.

Literature review

The problem discussed in the article is related to the fact that internal audit in Kazakhstan still relies heavily on traditional control methods – spot checks, after-the-fact analysis of documents, manual processing of reports. This approach does not allow timely identification of risks, prevention of violations and proactive management of financial resources. In conditions of high dynamics of economic processes and increasing complexity of business models, such methods become insufficient. There is a gap between the growing requirements for the effectiveness of control and the actual capabilities of existing audit procedures.

Current trends in the digitalization of the economy involve the use of big data analysis technologies, artificial intelligence, and robotic automation of processes, which can ensure continuous monitoring and prompt detection of deviations.

However, in Kazakhstan, the implementation of such solutions is fragmented and not systematic. Most organizations face limited digital maturity, a lack of specialist competencies, a lack of methodological approaches and unified standards for digital internal audit. This makes it difficult to move from

a traditional control function to digital risk management.

Recent studies confirm that the digitalization of internal audit has become a key area of development of the modern financial control system. The review paper "The Digital Transformation of the Internal Audit Function: A Qualitative Literature Review" (Research Gate, 2025) systematizes approaches to the implementation of Big Data, AI/ML, RPA and Blockchain technologies, noting that they radically increase the speed, accuracy and analytical potential of internal audit, while changing its conceptual role – from retrospective verification to predictive and analytical risk management**.**

The standards developed (IIA, 2024) pay a lot of attention to how internal audit should work in a digital environment, ensuring compliance with new technologies, risks of digital transformation and ethical requirements.

The modern internal audit function is also actively facing the challenges of digital transformation. The evolution of the internal audit function, the audit methodology, the digital maturity model for internal audit, the impact of COVID 19, and the changing roles and skills of the auditor are discussed in the work of Nabil Daij (2023). The author examines a systematic analysis of how technological changes (data analytics, RPA, clouds, AI, blockchain) affect internal audit, its methodologies, tasks, and competencies.

At the same time, a study by the Institute of Internal Auditors conducted in 2021 and aimed at analyzing how the audit reacted to the 2020 crisis and technological changes showed that only a small part of audit functions managed to implement modern technologies and cloud solutions; many remain on old (spreadsheets, e-mail) systems.

These conclusions are confirmed by the observations of German researcher M. Eulerich (2025), who notes in the review "Technology and Internal Auditing" (2025) that data analytics and machine learning technologies are forming a "new intelligent audit architecture." He emphasizes that along with technological advantages, digitalization requires the development of digital competencies of auditors, since it is the human factor that remains the key link in data interpretation and management decision-making.

Publications of international professional communities, such as ISACA ("Robotic Process Automation for Internal Audit", 2020), emphasize that robotization of audit procedures increases labor productivity and quality of control, freeing the auditor from repetitive operations. However, the authors warn of the need to adapt the internal control methodology and review risk management approaches when implementing RPA systems.

According to practical materials from Deloitte ("Applying COSO ERM to Artificial Intelligence ", 2023), the application of the COSO ERM concept to AI-based projects provides a systematic approach to assessing digital risks, from data security issues to issues of transparency and ethics of algorithms. This approach demonstrates how the elements of COSO (control environment, monitoring, information channels) can be adapted to digital technologies, which corresponds to the tasks of Kazakhstan's internal audit.

Domestic research also reflects these global trends. It should be noted that this is not the first time that attention to the issues of digital transformation of auditing has been formed in Kazakhstan. Back in the work of Yerdavletova F. (2015) "On the issue of improving auditing in the oil and gas sector of the economy", the need to modernize control methods and introduce technological solutions to improve the quality of verification was emphasized. Subsequent studies confirm the sustainability of this trend. In particular, in the work "HOW TO HANDLE INTERNAL AUDITOR INDEPENDENCE GAP?" the authors Nurmagambetova A., Abdelrady, H. M., & Mohamed, S. (2023) propose practical measures to improve the objectivity and effectiveness of internal audit in organizations, highlighting digital technologies, among other things. A study by scientists (Yerdavletova F., Bimendieva L., et al., 2024) notes the role of digitalization of audit as a key factor in improving the efficiency of national resource management, which is consistent with global trends in the development of the economy of the Republic of Kazakhstan. Further development of the topic is reflected in the work of V.I. Berezyuk. "Prospects for the development of digital audit in the Republic of Kazakhstan" (2024) focuses on the need to integrate digital technologies into the activities of government agencies and the corporate sector. The author highlights the barriers to digitalization – insufficient IT infrastructure, staff shortages, and the need to harmonize national standards with international ones – and suggests ways to overcome them.

The work of other Kazakhstani authors (Kogut O.Yu., et al., 2025) is devoted to modern trends in audit digitalization and examines remote audit technologies, automated analytical systems and their im-

pact on the quality of control. The authors conclude that transparency is increasing and human error is being reduced due to the integration of digital solutions into the practice of government and internal audit.

In summary, the reviewed studies show that the digitalization of internal audit contributes to increased transparency, objectivity and effectiveness of control, but requires an integrated approach – improving the regulatory framework, COSO ERM methodology and the development of digital competencies of auditors.

Thus, in the context of digitalization, internal audit is being transformed from a traditional control mechanism into a strategic corporate governance tool. The introduction of artificial intelligence, robotics, and big data analysis technologies makes it possible to move from reactive detection of violations to proactive risk management and increase the efficiency of the public and corporate sectors.

These trends are especially relevant for Kazakhstan, where a digital ecosystem of state financial control is being formed, requiring a harmonious combination of international standards, technological innovations and professional competence of auditors.

The literature review showed that, despite the availability of research on certain aspects of digitalization and improvement of internal audit procedures, a comprehensive scientific approach to the formation of a digital model of internal audit in modern conditions has practically not been developed. The available works mainly consider technical tools or organizational issues of implementing IT solutions, however, the relationship of digital technologies with the methodology of audit analysis, risk assessment and improving the effectiveness of the internal control system remains insufficiently studied.

In addition, there are no uniform methodological recommendations and practical models in the Kazakh scientific literature that allow integrating big data analytics, artificial intelligence and process automation into the activities of internal audit departments. This gap limits the ability of government and corporate organizations to move from traditional audits to proactive risk management.

Thus, the need for scientific substantiation and development of a concept for the development of modern internal audit based on digital technologies determines the high relevance of the chosen research topic and its importance for improving management systems in the Republic of Kazakhstan.

Methodology

The methodological basis of the research is based on a combination of systemic, institutional and process approaches that ensure a holistic perception of the digital transformation of internal audit as a socio-economic and managerial phenomenon.

The theoretical basis was:

- International standards IIA (International Professional Practices Framework);
- the concept of COSO ERM (Enterprise Risk Management);
- INTOSAI GOV 9140 recommendations on internal control;
- strategic documents of Kazakhstan – the Law "On State Audit and Financial Control" (2015), the Digital Kazakhstan program.

The systematic approach allowed us to consider internal audit as an element of the digital ecosystem of public administration, including analytical platforms and artificial intelligence.

The purpose of the study is to substantiate the mechanisms of digital transformation of internal audit in Kazakhstan and identify ways to increase its effectiveness through the introduction of innovative technologies (AI, RPA, Big Data).

Research methods – use a set of general scientific and special methods, including:

- system analysis – identification of interrelations between the elements of internal audit and digital platforms;
- comparative method – comparison of Kazakhstan's practice with international standards (IIA, ISACA, OECD);
- content analysis – processing of publications and regulatory documents;
- expert survey – assessment of the level of digitalization of internal audit functions;
- inductive-deductive analysis – identification of patterns based on empirical data;
- case method – analysis of the implementation of RPA and AI in large organizations in Kazakhstan.

The empirical research base includes:

- data from the Ministry of Finance of the Republic of Kazakhstan, the Accounts Committee, the Financial Monitoring Agency;
- reports from the World Bank, OECD, PwC, Deloitte, ISACA;
- scientific publications of Kazakhstani researchers;
- digital platforms: e-Audit, Qoldau.kz , e-Qazyna.

Reliability is ensured:

- using official sources and international standards;

- triangulation – comparison of data from various sources;

- using representative analytical methods.

The scientific novelty is the clarification of the concept of "digital internal audit" and the development of an author's model for integrating AI, RPA and COSO ERM into the practice of internal control in Kazakhstan.

Methodological limitations – the study is limited to the normative and organizational analysis of digitalization without quantitative methods (regression analysis). A promising direction is the development of an indicative model of the digital maturity of internal audit based on KPIs and risk indicators.

In connection with the methods considered, we considered the Reference Matrix of methods proposed in (Carter, D. and Baker, B., 1992) and was developed to implement the concept of Concurrent Engineering. In contrast, this work offers a new methodological model focused on the implementation of the principles of Industry 4.0, taking into account the Lean Six Sigma approach.

To increase the adaptability of the matrix, it is proposed to include maturity levels corresponding to each key factor within each assessment. This provides a more detailed interpretation of the results obtained at the first stage of the model. The levels are related to the digital conversion of the results used to convert the values on the Likert scale into numerical indicators used in data analysis (Table 1).

The resulting matrix of methods (Table 2) is structured by columns – proposed approaches, and by rows – maturity levels.

Table 1 – Qualitative and quantitative levels for evaluating the matrix of methods

№	Level	Qualitative assessment	Quantitative assessment
1	Level 1	I totally disagree	0.0
2	Level 2	Rather, I disagree	0.3
3	Level 3	Rather, I agree	0.7
4	Level 4	I totally agree	1.0
Note – Compiled by the authors based on the source Appelbaum et al. (2017).			

Table 2 – Matrix of methods for the key factor "Ubiquity" (Ubiquity), dimension: "Information"

Level	Readiness	Maturity: the initial stage	Maturity: a transitional stage	Maturity: advanced stage
1 (0.0)	No parameters have been defined for measuring production performance.	There are no sensors for monitoring any production sites.	There are no digital interfaces or touch devices in the workplace.	Augmented reality devices are not used for real-time data visualization.
2 (0.3)	The basic parameters (input/output) for individual production operations are defined.	Sensors are installed to monitor individual production sites.	Some workplaces have digital visualization and/or data interaction interfaces.	Classical devices are used to display asynchronous information.
3 (0.7)	The parameters for measuring individual aspects of production (inputs, processes, outputs) are defined.	The sensors are implemented on several production lines.	Digital interfaces and sensors for visualization and interaction with data are installed on some of the workstations.	Digital devices (screens, wearable gadgets, etc.) are used to display data in real time.
4 (1.0)	Parameters have been defined to measure most of the production aspects (inputs, processes, outputs).	Intelligent sensors of various types have been installed to monitor most production lines and centers.	Most workplaces have digital interfaces and smart sensors.	Augmented reality devices are used to visualize production information in real time.
Note – Compiled by the authors on the basis of, with the use of Alles et al. (2008)				

The proposed matrix of methods defines the necessary tools to ensure the successful implementation of the production system in accordance with the requirements of Industry 4.0. Similar to the assessment questionnaire, the matrix is structured by dimensions, key factors and approaches. Its use

makes it possible to form general methodological recommendations, determine the necessary stages of maturity and adapt implementation paths to the specifics of each project and the context of the enterprise.

Results and discussion

Internal audit, in accordance with international standards (IIA, ISA, COSO), is an independent assessment, consulting and control activity aimed at improving management efficiency, minimizing risks and ensuring the reliability of financial information.

In Kazakhstan, the regulatory framework for internal audit is regulated by the Law of the Republic of Kazakhstan "On State Audit and Financial Control" (2015), internal audit standards approved by authorized bodies, as well as the COSO ERM (Enterprise Risk Management) methodology.

The modern paradigm of internal audit involves a transition from formal control to intelligent risk management. This includes the use of digital platforms, analytical systems, artificial intelligence (AI), and machine learning (ML) to process large amounts of data, predict anomalies, and identify corruption risks.

An important trend is the introduction of robotic data analysis tools (RPA), which makes it possible to automate routine checks and focus the auditor's attention on analytical, strategic and predictive activities.

The diagram (Fig. 1) below shows the increase in the digital maturity of Kazakhstan's internal audit over the past five years. As you can see, the digital maturity index has increased from 22% to 68%, which indicates the significant impact of the introduction of AI, RPA and Big Data technologies on the effectiveness of control processes.

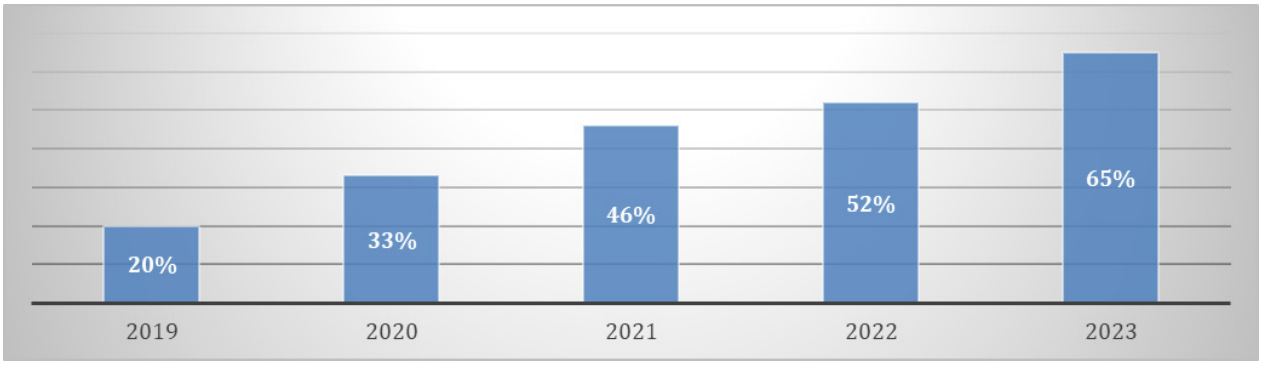

Figure 1 – The growth of the digital maturity of internal audit in the Republic of Kazakhstan
Note – Developed by the authors according to the sources.

Despite the active digitalization of the public sector and business, the internal audit system in Kazakhstan faces a number of problems:

- low level of integration of information control and data analysis systems;
- Lack of a unified national digital audit platform;
- Insufficient training in data analytics and IT auditing;
- Limited use of intelligent algorithms to assess risks and identify inconsistencies;
- The predominance of after-the-fact checks instead of predictive monitoring.

These problems slow down the development of the audit function as an intellectual management link and limit the government's ability to ensure transparency and efficiency of financial flows.

The presented structure (Fig. 2) shows the main barriers to the introduction of digital technologies in the internal audit system of Kazakhstan. Staffing shortages (35%) and insufficient IT infrastructure (28%) are predominant. This indicates the need for systematic training of specialists and investments in digital infrastructure.

The growth of the market is a significant factor confirming the need for further development of the internal audit system, as the increase in the volume of audits and the complexity of business processes require more highly qualified auditors, the use of modern digital tools and the transition to risk-based assessment and monitoring methodologies.

The graph shown in Figure 3 clearly demonstrates the growth of the Kazakhstan audit services market over a 5-year period (2018-2023) by 2.5 times.

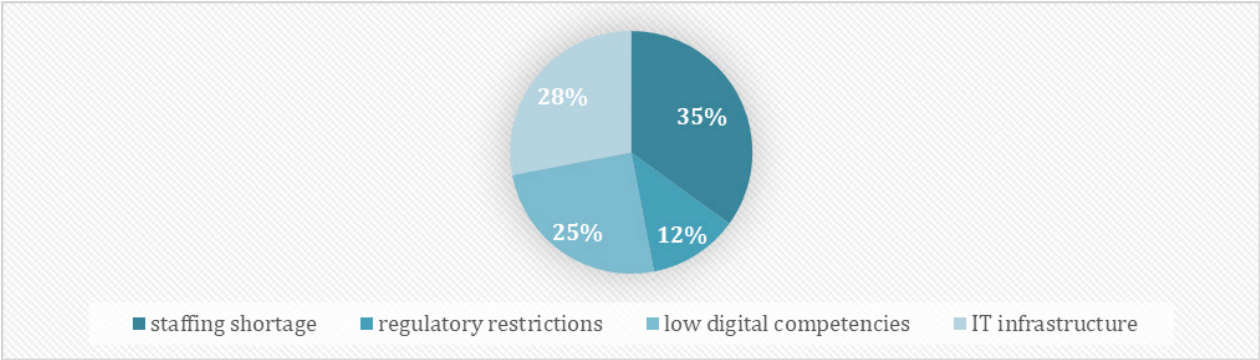

Figure 2 – The main barriers to the digitalization of internal audit in the Republic of Kazakhstan
Note – Compiled by the author, Березюк В. И. (2024)

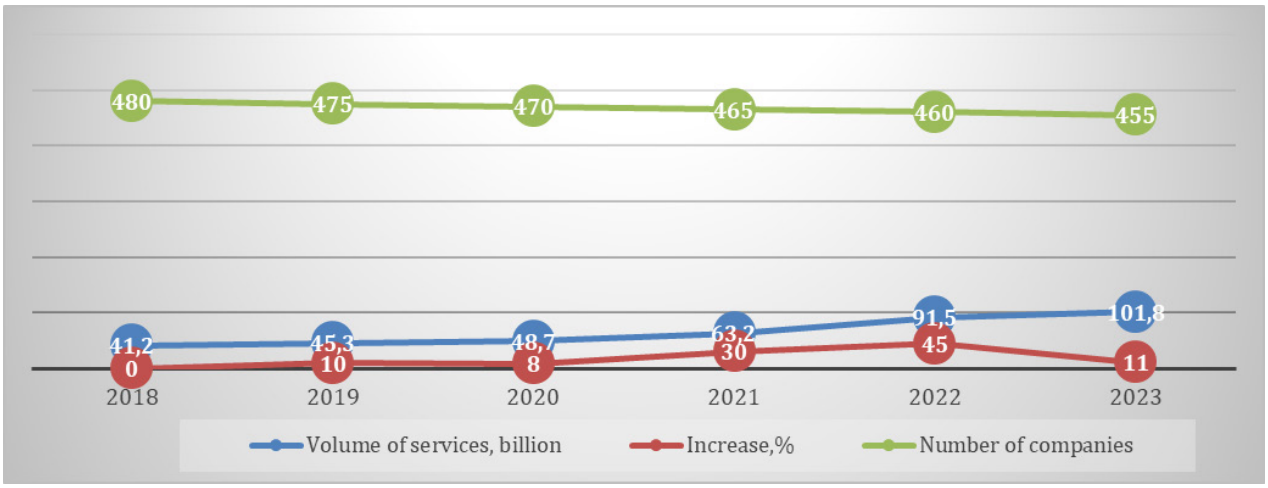

Figure 3 – Dynamics of the audit services market in the Republic of Kazakhstan
Note – Compiled by the author, according to the Audit Committee of the Ministry of Finance of the Republic of Kazakhstan (2024)

Thus, the current level of digitalization of internal audit in Kazakhstan remains insufficient for a complete transition to a risk-based and predictive control model. The fragmentation of information systems, the lack of a unified national audit platform, and the lack of specialists in data analytics and IT auditing continue to limit the ability of internal audits to promptly identify and prevent violations. Despite the expansion of the market and the active introduction of digital solutions, auditing is still largely focused on after-the-fact checks. Overcoming the identified barriers requires targeted training of professional personnel, modernization of digital infrastructure and the introduction of predictive and analytical tools, which will transform audit into an intelligent mechanism for supporting management decisions.

It is impossible to make the transition to such a model without correctly constructing the initial stage of the audit process. In this regard, a preliminary study of the audit object is of particular importance, ensuring the formation of a holistic understanding of the organization's activities, the structure of business processes and key risk areas. Understanding the context and environmental features of the subject under review serves as the basis for choosing adequate control methods, evaluating the effectiveness of internal procedures, and using digital analysis tools.

A preliminary study of an object in practice means that the auditor gets a comprehensive understanding of the organizational structure, the internal control system, the specifics of the operations performed and potential vulnerability factors. In

accordance with the provisions of the International Standards on Auditing (ISA 315 "Identification and Assessment of the Risks of Material Misstatement through Understanding the organization and its Environment"), this stage forms the basis for subsequent planning of audit procedures, determining audit priorities and selecting relevant analysis methods.

In the context of digitalization, the content of this stage is significantly expanded. Previously, the focus was on studying documents and interviewing employees, but today the auditor has access to a wide range of digital data – information databases, automated registers of operations, log records of systems, analytical panels and visualization tools. The use of big data processing technologies and anomaly detection algorithms allows not only to get a more detailed picture of the processes, but also to detect signs of deviations, inefficiency or potential violations at an early stage.

Thus, the preliminary study of the audit object becomes not just an introductory stage, but an analytical foundation that ensures the transition to proactive audit in a digital environment.

According to the International Standards on Auditing (ISA 315 "Identification and Assessment of the Risks of Material Misstatement through Understanding the organization and its Environment"), a preliminary study is the basis for planning audit procedures.

At this stage, the auditor:

1. Analyzes the organizational and legal structure and constituent documents;

2. Studies internal regulations, accounting policy, and management structure;

3. Evaluates the internal control system (ICS) and the IT infrastructure;

4. Conducts a risk analysis, identifying areas of potential violations;

5. Determines the scope and depth of subsequent checks.

In the context of digitalization, this stage is being significantly transformed. Instead of traditional manual data collection, auditors use:

• Big Data analysis (processing big data on financial transactions);

• Data mining (intelligent analysis and identification of hidden patterns);

• Machine learning (algorithms capable of predicting anomalies);

• Digital twins – virtual simulation of financial flows.

This allows you to conduct a preliminary study of the audit object in an automated mode, identify trends, predict risks and minimize the likelihood of errors at the planning stage.

At this stage, we can present a table showing the impact of Big Data and machine learning on the effectiveness of preliminary analysis. According to research, the use of digital doubles reduces the risk of errors by 25-35%, and automation reduces the preparation time by 40%. The international experience of Germany, Singapore and Canada shows that the integration of risk-based systems can significantly improve the quality of audit planning.

The gradual expansion of the use of digital technologies at the preliminary analysis stage not only increases the accuracy of risk assessment and reduces the complexity of preparation, but also creates the prerequisites for a qualitative change in the internal audit model itself. In the process of implementing automated data processing tools, digital doubles, and analytical dashboards, auditing is shifting from a traditional approach based on verifying operations that have already been performed to a more dynamic and predictive model.

It is here that the tendency towards intellectualization of auditing activities is manifested, which involves a shift in emphasis from fixing violations after the fact to their real-time warning and analysis of processes. This approach allows the auditor not only to identify deviations, but also to understand their causes, predict possible consequences, and make recommendations aimed at optimizing management decisions.

The key areas of development in this context are:

1. Integration of artificial intelligence into the financial flow analysis system;

2. Application of cloud technologies for storage and processing of audit data;

3. Development of a unified platform for state internal audit (based on e-Gov and e-Otinish);

4. Using blockchain technologies to ensure transparency of financial transactions;

5. Creation of intelligent dashboards for monitoring violations in real time.

This transition makes it possible to transform internal audit into a strategic management tool that ensures continuous monitoring of processes and increases the efficiency of the organization.

The intelligent internal audit system is not only a control tool, but also a mechanism for improving the effectiveness of public administration. It forms

a digital ecosystem of trust between government, business and society.

In this regard, the use of artificial intelligence and blockchain technologies in auditing. According to the OECD (2024), organizations using AI increase forecasting accuracy by 50% and reduce costs by 20%. The international experience of the UK, South Korea and Canada shows that the introduction of intelligent systems increases transparency and trust in data, as well as provides operational monitoring of financial risks.

We believe that the development and digital transformation of internal audit in Kazakhstan requires a systematic approach aimed at creating a sustainable digital environment for data control and analysis. One of the key directions is the institutionalization of digital internal audit as a separate element of the national financial supervision system. This implies the normative consolidation of its principles, functions and standards, as well as the creation of a single digital audit data space integrated with existing public administration and e-government platforms.

An important aspect of the development of digital audit is the formation of new professional competencies of specialists combining knowledge in the field of internal control, IT technologies and big data analysis. To do this, it is advisable to introduce specialized educational programs and research initiatives based on leading universities in Kazakhstan aimed at training a new generation of analytical auditors.

In continuation of the conducted research, the results obtained confirm the applicability and effectiveness of the proposed Lean 4.0 audit model for assessing the readiness of SMEs for digital transformation. The analysis of the data obtained in the first phase of the study made it possible to identify maturity levels for each key factor and identify critical areas requiring priority improvement. The addition of a matrix of methods based on Industry 4.0 and Lean Six Sigma concepts to the model improved the accuracy of interpretation of the results and allowed for more detailed recommendations for enterprises.

The priority measurement map is used to identify imbalances in various key factors according to the proposed approaches. This allows us to identify the necessary areas of improvement that will contribute to the effective modernization of the company within the framework of the Industry 4.0 concept, based on the principles of Lean Manufacturing and the Six Sigma methodology.

During the application of the proposed methodology, it was found that the use of a layered approach (from basic to advanced) facilitates the identification of gaps between the current and target state of the production system. In addition, the adaptive structure of the matrix of methods makes it a universal tool applicable to enterprises of various industries, regardless of their digital maturity and resource constraints (Fig. 4).

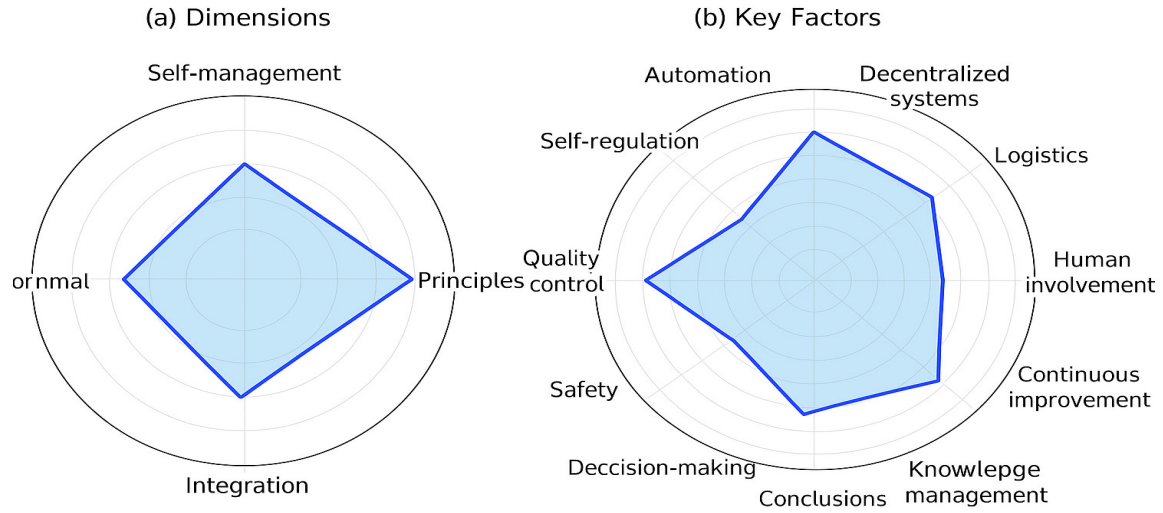

Figure 4 – The obtained radial diagrams: (a) measurements and (b) key factors based on the results of the evaluation questionnaire for the production department
Note – Compiled by the author, according to Ávila-Gutiérrez et al. (2025)

The results obtained demonstrate that the combination of a diagnostic questionnaire and a level matrix of methods provides a comprehensive analysis of the production system, as well as allows you to build a realistic modernization trajectory. This integration contributes to the informed choice of improvement tools, the selection of Industry 4.0 technologies in accordance with the current capabilities of the enterprise and the consistent achievement of digital maturity stages.

In general, the study highlights that the proposed Lean 4.0 model is able not only to identify problem areas, but also to guide the enterprise along the path of structured improvements based on Lean and Six Sigma methodologies. The application of the model has shown its potential as a practical tool for managing the modernization of SMEs, which is especially important in conditions of limited resources and high variability of production processes.

The results of the study open up opportunities for further scientific developments. In the future, the model can be expanded by (Fig. 5).:

- enabling predictive analytics and artificial intelligence tools;
- development of industry modules for enterprises with different production specifics;
- integration of ESG and sustainable development indicators into the assessment system;
- testing the model on a sample of enterprises in different regions and countries.

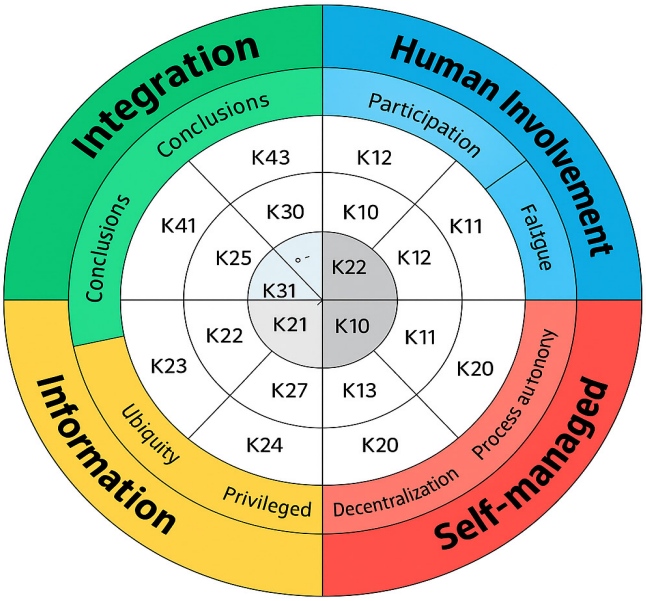

Figure 5 – Updated measurement map for the production department of the audited company
Note – Compiled by the author, according to Ávila-Gutiérrez et al (2025)

Thus, the proposed Lean 4.0 model demonstrates high practical significance and is a flexible tool to support the digital transformation of SMEs, providing a systematic and step-by-step increase in their technological maturity.

This study presents an innovative Lean audit model specifically designed to meet the modernization needs and transition to Industry 4.0 of small and medium-sized enterprises (SMEs) in the manufacturing sector, especially those that rely on traditional or artisanal production systems. The main purpose of the work was to create a structured tool that allows SMEs to assess their current state, identify key areas for improvement and identify priorities for effective digital transformation. The proposed approach is based on the basic principles of Lean Manufacturing, Lean Thinking, and Lean management, taking into account limited resources (Table 3).

Table 3 – Matrix of methods with levels for the key factor: Continuous improvement (Measurement: Integration)

Levels	Readiness	Maturity: the initial stage (Start-Up)	Maturity: In-Transition	Maturity: Advanced level
1 (0.0)	Traditional Lean tools are not used.	Traditional Lean tools are not used.	Modern Lean tools are not used.	Modern Lean tools are not used.
2 (0.3)	A separate traditional management tool is used that is not related to Lean.	Several traditional management tools that are not related to Lean are used.	A separate traditional management tool is used that is not related to Lean.	Several traditional management tools that are not related to Lean are used.
3 (0.7)	The traditional Lean tool is used sporadically in individual departments.	Several traditional Lean tools are used sporadically in individual departments.	The modern Lean tool is used sporadically in individual departments.	Several modern Lean tools are used sporadically in individual departments.
4 (1.0)	A separate traditional Lean tool is used regularly in most departments; there is an expert staff.	Several traditional Lean tools are used regularly in most departments; there is an expert staff.	A separate modern Lean tool is used regularly in most departments; there is an expert staff.	Several modern Lean tools are used regularly in most departments; there is an expert staff.
Note – Compiled by the authors on the basis of, with the use of COSO (2013)				

The main contribution of this study is to develop an integrated audit model specifically focused on the challenges and resource constraints faced by small and medium-sized enterprises (SMEs) on their way to implementing Industry 4.0. Unlike numerous existing models, mainly designed for large companies, the proposed model combines detailed diagnostics, strategic recommendations and a prioritization mechanism. based on the principles of Lean Manufacturing and the Six Sigma methodology. Highlighting four consecutive strategic stages – "Readiness", "Initial stage", "Transitional stage" and "Advanced level" – forms a clear and logically structured roadmap for continuous improvement.

In addition, the study adapts and develops existing concepts such as the Carter and Baker Factors Balance Method for parallel engineering, applying them to the specific context of modernization of production systems within the framework of the Lean Six Sigma paradigm and Industry 4.0. The integration of the Likert scale into the assessment questionnaire represents an improvement over dichotomous models, providing a more comprehensive and nuanced data collection.

Thus, the proposed Lean 4.0 audit model is a valuable and practical tool for SMEs seeking to modernize their production processes and effectively integrate digital technologies in accordance with their capabilities. The use of the model as part of a case study confirms its potential to identify critical areas of improvement, form strategic priorities, and develop concrete actions based on Lean principles. These actions ensure a gradual, optimized and sustainable transition to Industry 4.0.

Focusing the model on the specific needs and limitations of SMEs eliminates a significant gap in the existing scientific literature and forms a reliable basis for future modernization initiatives in this key segment of the economy.

Of particular importance is the use of artificial intelligence and machine learning technologies that can not only detect violations after the fact, but also predict their likelihood at an early stage. Intelligent algorithms for risk analysis and modeling create the basis for proactive control and prevent violations even before they occur.

A promising area is also the development of the analytical infrastructure of internal audit – data visualization systems, interactive dashboards and risk maps that ensure transparency and efficiency of management decision-making. The introduction of such tools will increase confidence in audit results and ensure more efficient use of budgetary resources.

In general, the transition to a comprehensive ecosystem of digital internal audit is expected, combining technologies, competencies and regulatory mechanisms into a single intelligent risk and efficiency management system.

The implementation of the proposed measures will lead to a qualitative transformation of Kazakhstan's internal audit, which will transform from a mechanical verification tool into an intelligent risk and efficiency management system based on digital technologies, transparency and a scientific approach.

This will ensure the sustainable development of the country, increase public confidence and integrate Kazakhstan into the international digital financial control space.

Conclusion

Thus, the development and transformation of the internal audit system in Kazakhstan is not only a requirement of the digital age, but also a strategic necessity for building a sustainable, transparent and efficient economy.

A key element of the new audit model is a preliminary examination of the audit objects using digital technologies and artificial intelligence. This provides predictive control, helps to prevent violations, increase public confidence, and ensure sustainable development.

In the future, internal audit should become an intelligent risk management center that combines science, digital technologies and public responsibility. To achieve this goal, it is advisable to implement the following practical recommendations:

1. Creation of a national digital internal audit platform.

It should combine data from government information systems (e-Gov, e-Kargy, e-Licensing, public procurement portal) in order to automate monitoring and risk analysis in real time.

2. Implementation of artificial intelligence and Big Data tools in control procedures. The use of machine learning algorithms will make it possible to identify patterns and predict anomalies in financial flows, increasing the accuracy and efficiency of the auditor's decisions.

3. Development of the Digital Maturity Model of internal audit. It is necessary to identify key performance indicators (KPIs) of digital processes, the level of automation and analytical integration in public sector organizations.

4. Improving the digital competencies of auditors. It is necessary to introduce specialized educational programs based on leading universities in Kazakhstan (in particular, al-Farabi Kazakh National University), including courses on data analytics, RPA, IT audit and digital risk management.

5. Harmonization of national standards with international ones (IIA, ISACA, INTOSAI). This will ensure that Kazakhstan's internal audit system meets global requirements for transparency, efficiency, and cybersecurity.

6. Development of scientific and practical cooperation between universities and internal audit bodies. The creation of digital audit research laboratories at universities will make it possible to integrate scientific developments into the practice of state and corporate control.

7. Formation of a unified ethical and legal framework for digital audit. It is necessary to provide for regulatory regulation of the use of artificial intelligence, data protection and responsibility for automated solutions in the field of financial control.

The implementation of these measures will allow Kazakhstan to move from a traditional audit model to an intelligent control ecosystem based on transparency, predictive analysis and digital interaction. The implementation of these approaches will strengthen trust in government institutions, improve the quality of financial management, and ensure the sustainability of the economy in the face of digital transformation.

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АГРОӨНЕРКӘСІП КЕШЕНІНДЕГІ ESG-СТРАТЕГИЯСЫН ҚАЛЫПТАСТЫРУДА БАСҚАРУ ЕСЕБІН ҚОЛДАНУ

ESG-қағидаттары ұйымдардың экологиялық, әлеуметтік және басқарушылық міндеттерін шешуге көмектесетін бизнестің тұрақты дамуының моделіне айналды. ESG (Environmental, Social, Governance) қағидалары бизнестің әртүрлі салаларында бағыттаушы және беделді әсерге ие болып отыр. Осы орайда агроөнеркәсіп кешені құрамында бизнес-үдерістердің көптігі мен күрделілігі ESG-стратегиясын қалыптастыруды талап етеді. Бұл өз кезегінде сапалы басқару есебі жүйесі арқылы жүзеге асырылады.

Мақаланы жазудағы басты мақсат агроөнеркәсіп кешенінде ESG-стратегиясын қалыптастырудағы басқару есебінің атқаратын рөлі мен маңыздылығын нақты ұйым мысалында қарастыра отырып негіздеу. Зерттеу объектісі ретінде басқару есебі ESG стратегиясын жүзеге асыру үшін қажетті деректерді жинауды, жүйелеуді, талдауды және түсіндіруді қамтамасыз етеді, ал ESG басқару есебінің мазмұнына, әдістері мен құралдарына жаңа талаптар қояды.

Зерттеу барысында теориялық-әдіснамалық, қатынастарды модельдеу мен визуализациялау әдістемелері қолданылды. Жүйелік тәсіл басқарушылық есеп пен ESG стратегиясын жалпы корпоративтік басқару жүйесінің өзара байланысты элементтері ретінде қарастыруға мүмкіндік береді. Мазмұнды талдау халықаралық және ұлттық есеп беру стандарттарын, корпоративтік ESG есептерін және компаниялардың ішкі ережелерін зерттеу үшін қолданылады. Салыстырмалы талдау жасау арқылы басқару есебінің қаржылық есеппен салыстырғандағы артықшылықтары айқындалды. ESG стратегиялық картасы арқылы есеп жүйесінің қандай элементтері тұрақты даму мақсаттарының орындалуын қамтамасыз ететіндігі көрсетілді. ESG-қағидаларына сәйкес ұйымның құрастыратын қаржылық емес ақпаратқа негізделген есептілік нысанын қарастыру үшін Aitasagro холдингінің мәліметтеріне талдау жасалынды.

Мақаланың теориялық маңыздылығы – Басқару есебі мен ESG-тұжырымдамасының өзара байланысын теориялық тұрғыда негіздеу және ESG-көрсеткіштерін басқару есебінің объектілері ретінде жүйелеу.

Мақаланың практикалық маңыздылығы ESG-есептілік пен басқарушылық есептің үйлесімділігін сипаттауы арқылы құнды деп есептеледі.

Зерттеу қорытындысында ESG-қағидалары іске асырудағы қаржылық есеппен салыстырғандағы басқару есебінің артықшылықтарына салыстырмалы сипаттама берілді. ESG көрсеткіштерін басқару есебі жүйесімен байланыстыру қаржылық және қаржылық емес ақпараттарды талдаудың бірыңғай ақпараттық базасын қалыптастыру мүмкіндігін береді.

Түйін сөздер: ESG-стратегия, басқару есебі, агроөнеркәсіп кешені, тұрақты даму.

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The use of management accounting in the formation of an ESG strategy in the agro-industrial complex

ESG principles have become a model for sustainable business development, helping organizations solve environmental, social, and management challenges. The principles of ESG (Environmental, Social, Governance) have a guiding and authoritative influence in various business areas. In this regard, the large number and complexity of business processes in the agro-industrial complex require the formation of an ESG strategy. This, in turn, is carried out through a quality management accounting system.

The main purpose of this article is to substantiate the role and importance of management accounting in the formation of an ESG strategy in the agro-industrial complex using the example of a specific organization. Management accounting as an object of research provides the collection, systematization,

analysis and interpretation of data necessary for the implementation of the ESG strategy, and ESG imposes new requirements on the content, methods and tools of management accounting.

In the course of the research, theoretical and methodological methods, methods of modeling and visualizing relationships were used. A systematic approach allows us to consider Management Accounting and ESG strategy as interrelated elements of a common corporate governance system. Content analysis is used to study international and national reporting standards, corporate ESG reports, and companies' internal rules. Comparative analysis revealed the advantages of managerial accounting over financial accounting. Using the ESG strategic map, it was shown which elements of the accounting system ensure the achievement of the Sustainable Development Goals. In order to review the reporting form based on non-financial information compiled by the organization in accordance with ESG principles, the data of Aitasagro holding was analyzed.

The theoretical significance of the article lies in the theoretical substantiation of the relationship between management accounting and the ESG concept and the systematization of ESG indicators as objects of management accounting.

The practical significance of the article is considered valuable due to its description of the compatibility of ESG reporting and management accounting.

In conclusion, the study provides a comparative description of the advantages of management accounting in comparison with the financial report in the implementation of ESG principles. Linking ESG indicators with the management accounting system makes it possible to form a unified information base for the analysis of financial and non-financial information.

Keywords: ESG strategy, Management accounting, agro-industrial complex, sustainable development.

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Применение управленческого учета в формировании ESG-стратегии в агропромышленном комплексе

ESG-принципы стали моделью устойчивого развития бизнеса, помогающей организациям решать экологические, социальные и управленческие задачи. Принципы ESG (Environmental, Social, Governance) оказывают направляющее и авторитетное влияние в различных сферах бизнеса. В этой связи большое количество и сложность бизнес-процессов в составе агропромышленного комплекса требуют формирования ESG-стратегии. Это, в свою очередь, осуществляется через систему качественного управленческого учета.

Основная цель написания статьи – обосновать роль и значение управленческого учета в формировании ESG-стратегии в агропромышленном комплексе на примере конкретной организации. Управленческий учет как объект исследования обеспечивает сбор, систематизацию, анализ и интерпретацию данных, необходимых для реализации стратегии ESG, а ESG предъявляет новые требования к содержанию, методам и инструментам управленческого учета.

В ходе исследования были использованы теоретико-методологические методики, методики моделирования и визуализации отношений. Системный подход позволяет рассматривать Управленческий учет и стратегию ESG как взаимосвязанные элементы общей системы корпоративного управления. Контент-анализ используется для изучения международных и национальных стандартов отчетности, корпоративных отчетов ESG и внутренних правил компаний. Путем сравнительного анализа были выявлены преимущества управленческого учета по сравнению с финансовым. С помощью стратегической карты ESG было показано, какие элементы системы учета обеспечивают выполнение Целей устойчивого развития. Для рассмотрения формы отчетности, основанной на нефинансовой информации, составляемой организацией в соответствии с ESG-принципами, был проведен анализ данных холдинга Aitasagro.

Теоретическая значимость статьи состоит в теоретическом обосновании взаимосвязи управленческого учета и ESG-концепции и систематизации ESG-показателей как объектов управленческого учета.

Практическая значимость статьи считается ценной благодаря ее описанию совместимости ESG-отчетности и управленческого учета.

В заключении исследования дана сравнительная характеристика преимуществ управленческого учета по сравнению с финансовым отчетом в реализации ESG-принципов. Увязка показателей ESG с системой управленческого учета дает возможность формирования единой информационной базы анализа финансовой и нефинансовой информации.

Ключевые слова: ESG-стратегия, управленческий учет, агропромышленный комплекс, устойчивое развитие.

Кіріспе

Бүгін күнде бизнес өте тұрақсыз сыртқы орта жағдайында өмір сүруде, ол жаһандық сипаттағы әлеуметтік және экологиялық, сонымен қатар экономикалық себептермен түсіндіріледі. Соңғы жылдар үшін сыртқы ортаның ұйымның ішкі бизнес-үрдістеріне теріс ықпалы артып келеді, ұйымдар тұрақты даму стратегиясын қалыптастыру арқылы сол ықпалды азайту мүмкіндіктеріне ие болуда. Қызметін тұрақты дамудың ESG қағидаларына сәйкестендіруді ұйымның ішкі ортасында жұмыс істейтін механизмдерді қоршаған орта факторларының көп бағытты әсеріне бейімдеу деп түсінуге болады.

Қазақстан экономикасының стратегиялық саласы болып табылатын агроөнеркәсіп кешені үшін ESG-қағидаларын енгізу корпоративті мәдениеттің элементі ғана емес, сонымен бірге ұзақ мерзімді бәсекеге қабілеттілік факторы болып табылады. Агроөнеркәсіп кешенінің құрылымы сараланған және көп салалы болып келеді. Агроөнеркәсіп кешені ұйымдарының тұрақты даму қағидаларын стратификациялау және оалрдың бизнес-үрдістерін жүзеге асыру жағдайларын анықтау міндеті қойылады, бұл олардың ұйымдастырушылық, өнеркәсіптік, қаржылық және әлеуметтік қызметін ESG-қағидаларына сәйкестендіру үшін басқару үрдісін қайта құруды талап етеді.

ESG-қағидаларын енгізу мүмкіндіктерін бағалау, яғни олардың ұйым қызметіне әсер ету дәржесін талдау, қолданыстағы мүмкіндіктері мен өсу резервтерін анықтау, салдарынан туындайтын тәуекелдерді бағалауға жағдай жасайды, яғни агроөнеркәсіп кешені ұйымдарының бизнес-үрдістерін жетілдіру мүмкіндігін береді. Сәйкесінше, агроөнеркәсіптегі бизнес-үрдістерді тұрақты даму қағидаларына сәйкестендіру бағытында өзгерту жалпы кешен үшін жаңа стратегиялық мақсаттарды қалыптастырудағы басымдылықтарды айқындауды, қалыптасқан өндірістік және ұйымдастырушылық құрылымды қайта құруды көздейді.

Осы орайда, басқару есебі дәстүрлі шығындарды бақылау функциясы шеңберінен шығып, ұйымның ESG-стратегиясын жүзеге асыруды қамтамасыз ететін талдамалық жүйеге айналады. Басқару есебі ұйымның экологиялық тұрақтылығына, әлеуметтік дамуына, корпоративті басқару сапасына ықпал ететін қаржылық және қаржылық емес ақпаратты қамтитын интерграцияланған ақпарат жиынтығын қалыптастырады. Сол себепті басқару есебінің орны мен рөлін, маңыздылығын ашып көрсету, беретін мүмкіндіктерін сараптамалық бағалау бүгінгі күннің өзекті мәселесі деп танылады. Яғни, агроөнеркәсіп кешеніндегі басқару есебінің ESG-қағидаларын жүзеге асырудың негізгі құралы ретінде маңыздылығын және атқаратын рөлін ашып көрсету арнайы зерттеу жұмыстарын қажет етеді. Сол арқылы басқару есебінің беретін мүмкіндіктері бағаланады. Агроөнеркәсіп кешеніндегі басқару есебі жүйесі зерттеу объектісі болса, ESG-стратегияға арналған басқару есебі құралдары, әдістері, ESG-тиімділік жүйесі және есептеу модельдері зерттеу пәні болып табылады.

Зерттеу жұмысының басты гипотезасы – басқару есебі агроөнеркісіп кешеніндегі ESG-стратегиясын қалыптастырудың негізгі құралыдеп тануға болады.

ESG қағидаттары ұйымның экономикалық мүддесі мен оның қоғам және қоршаған орта алдындағы жауапкершілігі арасында тепе-теңдекті қамтамасыз етуге бағытталған. Агроөнеркәсіп ұйымдары үшін ESG-әдістемесі ерекше маңызға ие болады, себебі олардың қызметтері табиғи ресурстарды пайдаланумен, экожүйелердің жағдайы және ауылшаруашылық аймақтардың дамуымен тікелей байланысты.

ESG шеңберінде басқару есебі келесі үш негізгі қызметтерді атқарады:

1) Ақпараттық қызметі – өндірістік үрдістердің қоршаған орта және қоғамға ықпалы жөніндегі деректерді ұсынады;

2) Бақылау қызметі – ESG-қағидаларына қол жеткізу мүмкіндігін қадағалайды;

3) Талдамалық – тұрақты дамуды стратегиялық басқарудың негізін қалыптастырады.

Осылайша, басқару есебі ұйым қызметінің экономикалық, экологиялық және әлеуметтік түрғыда байланыстырушы құралға айналады.

Агроөнеркәсіп кешені ұйымдарында ESG-қағидаларына бағытталған басқару есебін жүргізу келесі бағыттарда жүзеге асырылады:

1. Тұрақты жобаларды жоспарлау және бюджеттеу. Басқару есебі жүйесі көміртегі іздерін азайту, су мен энергияны үнемді пайдалану, қалдықтарды кәдеге жарату, «жасыл» технологияларды енгізу шараларының бюджетін қалыптастыруға мүмкіндік береді.

2. Экологиялық және әлеуметтік шығындарды бағалау. Басқару есебі жүйесіне ұйымның қоршаған ортаға ықпалы жөнінлегі ақпаратты қосу экологиялық тәуекелдермен байланысты

қаржылық және қаржылық емес жоғалтуларды есепке алуға жағдай жасайды.

3. ESG-көрсеткіштерін қалыптастыру. Агроөнеркәсіп ұйымдары басқару есебі жүйесіне қаржылық емес KPI-көрсеткіштерін қоса алады, оның ішінде шығарылымдар деңгейі, қайта өңделген қалдықтар көлемі, энергияны үнемдеу коэффициенті, жұмысшылардың әлеуметтік әлауқатының индексін қосса болады.

4. Халықаралық қаржылық есептілік стандарттарымен үйлестірілуі. GRI, ISSB және IFRS S1/S2 стандарттарын басшылыққа ала отырып ұсынылатын қаржылық есептілік басқарушылық ақпараттың ашықтығын қамтамасыз етеді, инвесторлар мен партнерлердің сенімін нығайтады.

Яғни, басқару есебін ESG-басқарудың ажыратылмас бөлігі деп тануға болады, себебі ол ұйымның тұрақты дамуына қатысты шешім қабылдаудың ақпараттық негізін қамтамасыз етеді.

ESG-әдістемесінің артықшылықтары көп болғанына қарамастан оны енгізуде Қазақстанның агроөнеркәсіп ұйымдарында келесідей мәселелер туындайды:

- қаржылық емес ақпаратты есепке алудың әдістемелік негіздерінің жеткіліксіздігі;
- басқарушылық үрдістерді цифрландыру деңгейінің төмендігі;
- ESG- ақпараттарды ашып көрсетуге ынталандырудың жоқтығы;
- Тұрақты басқару есебін жүргізе алатын мамандардың тапшылығы.

Осы кемшіліктердің орнын толтыру мақсатында ESG-жобаларын қолдауды институционалдық тұрғыда дамыту, цифрлық құралдарды енгізу, айталық ESG Data Hub платформасын пайдалану, халықаралық қаржылық есептілік стандарттарын Қазақстанның аграрлық секторының ерекшеліктеріне сай бейімдеу қажет.

Әдебиеттерге шолу

Ғасырлар бойы туындайтын көптеген өзгерістер мен маңызды оқиғалар ұйымдардың стратегиясын қайта қарауды, тіпті ұйым қызметін қайта жобалауды талап етіп отырады. Әсіресе, соңғы кездердегі экологиялық, әлеуметтік, басқарушылық көрсеткіштерге көңіл бөлу қажеттігі ұйымдар үшін жаңа міндеттерді анықтады. ESG ақпараттың қосымша құрылымының болуы мен оны ашып көрсетудің қатаң талаптарын айқындайды, яғни корпоративтік әлеуметтік жауапкершілікке негізделген есептілік көрсеткіштеріне сүйенеді. Бұл жердегі қиындықтар ESG тұжырымдаларымен байланысты емес, керісінше, мүдделі тараптардың есептілікте ұсынылған ақпаратты қабылдауы мен мақұлдауына қатысты пайда болады (Jean, Grant, 2022). Мүдделі тараптар, яғни, институционалдық инвесторлар мен реттеуші органдардың, жалпы қоғамның ақпаратты алуы АӨК ұйымдары үшін инвестиция тарту деңгейіне, қарыздармен байланысты шығыстары мен сақтандыру шығыстарының үлғаюына ықпал ететін болады. ESG мен есептілікті жетілдіру мүмкіндігін беретін механизмдер ретінде есептілік бойынша жаһандық бастамаларды (GRI), тұрақты даму саласындағы бухгалтерлік есеп стандарттары бойынша Кеңесті (SASB), ауа-райының өзгерістерімен байланысты қаржылық ақпаратты ашып көрсету бойынша мақсатты топты (TCFD), тұрақты даму бойынша БҰҰ мақсаттарын атап өтуге болады. Механизмдердің құрамы жаңа құрылымдардың пайда болуына сәйкес тұрақты түрде жаңартылып отыр. Көп болғанына қарамастан олардың басты мақсаты ESG бір немесе бірнеше бағыттары бойынша өнімділікті арттыру болып табылады. ESG-бағдарлану – бұл күрт өзгеріс емес, уақыт өте келе тұрақты түрде жетілдіру дегенді анықтайды. ESG және есептілікті жетілдіру жолдары өте көп, дегенмен ESG бойынша жоғары өнімділікке қол жеткізу тек тиімді басқару жүйесі арқылы ғана жүзеге асырылады. ESG талаптарына сәйкестігін растау үшін ұйымдар тұрақты түрде жақсартулардың орын алғанын көрсетуі керек, олар келесі негіздерге сүйенеді:

- айқын ESG-стратегиясының болуы;
- бекітілген үрдістердің және прогрессивті тәжірибенің болуы;
- есептілік және оны басшылық тарапынан бағалау және қадағалау;
- ақпаратты ашып көрсету деңгейі.

Жалпы ESG бойынша экологиялық, әлеуметтік жағдай, басқарумен байланысты мәселелердің қарастырылу деңгейіне қатысты жасалынған зерттеулер (Mishra және т.б., 2025) 2008 жылдан бастап 2024 жылды қоса алғандағы көшбасшы ғылыми басылымдардағы 884 жарияланымдар бойынша жүзеге асырылды. Библиометрикалық талдаулар нәтижесінде, авторлар келесідей маңызды мәселелерді анықтаған болатын: ESG және корпоративтік есептілік; ESG-инвестициялandыру және тұрақты қаржыландыру; ESG –

тәуекелдер және қаржылық тұрақтылық, ESG және тұрақты даму мақсаттары; ESG негізінде бизнесті және инновацияларды трансформациялау. ESG тенденцияларын жете түйсіну арқылы ұйымдар тұрақты дамуға бағытталған шешімдерді қабылдай бастайды, тәуекелдерді басқару және қаржылық көрсеткіштерді жақсарту мүмкіндіктеріне ие болады.

Басқару жүйесінің «Жоспарла – іске асыр – қадағала – әрекет ет» әдістемесіне сәйкес ESG бастамалары тиімді жоспарланып орындалуы, талдау жасалып, есептілікте ұсынылуы мүмкін. Осы пікірді жалғастыра отырып, келесі авторлар тұрақты даму жөніндегі есептілікте ұйымдардан корпоративті жауапкершілік талап етілетінін нақтылады (Rubio және т.б., 2024). Есептілік бухгалтерлік ақпарат шегінен шығып, ұйымдардың шаруашылық қызметімен байланысты тәуекелдерін анықтауды, корпоративті әлеуметтік жауапкершілігін растауды, өз ресурстарын тиімді пайдалануын талап етеді.

Дәстүрлі бухгалтерлік есеп жүйесінің әдіснамалық, субъектілік, объектілік және инструменталдық негіздерінің толыққанды жетілдірілмегендігі АӨК ұйымдарының тұрақты дамуын ESG-стратегиясы негізінде басқару мүмкіндігін қамтамасыз ете алмайды. Басқарудың ашық сипатта жүзеге асырылуы, қоршаған орта және адамдарға қамқорлық жасау үшін оларды дамыту қажет (Velikanov және т.б., 2023). ESG-есептілігін құрастыруда маңызды орын алатын сапалы бухгалтерлік ақпараттың болуы және оның озық басқарушылық технологияларға негізделуі басқару есебі жүйесіне деген жаңа көзқарасты қалыптастыратын болады.

ESG шеңберіндегі экологиялық компоненттердің ұйымдардың инновациялық дамуына ықпалын бағалау мақсатында Bloomberg ақпараттық база деректері негізінде Қытайдың корпоративтік секторына қатысты жасалған зерттеулерінде авторлар (Kenneth және т.б., 2024) келесідей қорытынды жасады: ESG стратегиясы аумағында экологиялық міндеттемелерін қатаң орындайтын ұйымдар жоғары инновациялы және тұрақты дамудың жаһандық критерийлеріне сәйкес болып келеді. Сонымен бірге, зерттеу нәтижелері инновацияларға ынталандырудағы басқару үрдістерінің ашықтығын айқын көрсетті. Авторлардың пікірінше, стратегиялық әртараптандыру мен инновация арасындағы синергия, яғни, әртараптандыру стратегияларындағы оңтайлы тепе-теңдік ұйымның инновациялық әлеуетін арттырады. Ол үшін дәстүрлі бухгалтерлік ақпаратты озық деректер аналитикасымен біріктіру қажет. Яғни, осы авторлар дәстүрлі бухгалтерлік есеп және қаржылық есептілік ақпаратын терең және жүйелі талдау жасауға мүмкіндік беретін басқару есебінің рөлін айқын көрсетті.

Тұрақсыздық жағдайында ESG негізінде корпоративті басқаруды жүзеге асырудың макро және микро деңгейінде зерттеулер жасаған келесі авторлар (Aleksin, Dyba, 2024) Украинадағы дағдарыстық жағдайлар мен халықаралық стандарттарға негізделген басқару жүйесіндегі жасалған реформалардың әсерін бағалады. Авторлардың пікірінше, бұл реформалар есептілік ақпаратының ашықтығын, тәуекелді басқару, құрылымдық қағадалау жасау мүмкіндігін береді, сол арқылы ұйымдарда шетелдік тұрақты инвестициялар үшін қажетті стратегиялық негіз қалыптасады. ESG-қағидаттарына сәйкес ұйым басшылығының экологиялық, әлеуметтік және басқару мақсаттары өзара байланыста қарастырылады, есептілікке халықты әлеуметтік тұрғыда қамтамасыз ету, қоршаған ортаны қалпына келтіру, басқару этикасын ұстану жөніндегі ақпарат қосымша ұсынылады.

ESG-қағидаттарын ауыл шаруашылығы өнімдерінің өндірісімен айналысатын ұйымдарға енгізу арқылы Ресейлік агробизнестің тұрақты даму мақсатында трансформациялануы мәселелерін зерттеуге бағытталған авторлардың (Kusakina және т.б., 2026) мақаласына сәйкес агробизнестің ESG-қағидаттарына бағдарлануы қоршаған ортаны қорғауға, әлеуметтік әділдікке, тиімді корпоративтік басқаруға қол жеткізуге жағдай жасайды. Яғни, ESG-қағидаттарына сәйкес тұрақты дамуы ұйымдардың стратегиялық мақсаттары негізінде жүзеге асырылуы керек, қағидалар мен нұсқаулықтарды, рейтингтерді бизнестің тұрақты дамуының әдістемелік құралдары ретінде басшылыққа алу мүмкіндігі туындайды.

Отандық авторлар тарапынан жасалынған зерттеулер мен сәйкес жарияланымдар жалпы агроөнеркәсіп кешеніндегі тұрақты даму бағыттарын айқындауға бағытталған.

Агроөнеркәсіп кешеніндегі тұрақты дамуды цифрландыру арқылы жүзеге асыру мүмкіндіктері келесі авторлардың (Даулиева және т.б., 2024) зерттеулеріне негіз болды. Цифрландыру процесінің маңыздылығын және экономикалық тұрғыда қажеттілігін негіздей отырып, цифр-

ландыруды ауыл шаруашылығының тұрақты дамуының, инновациялық және инвестициялық өсуінің басты факторы ретінде қарастырады. Зерттеу нәтижесінде авторлар АӨК жоғары өнімділік пен инновациялық белсенділікке қол жеткізудің негізгі бағыттары ретінде ресурстарды үнемдеудің нанотехнологияларын, генетикалық ресурстарды оңтайландыруды, селекциялық әдістерді жетілдіруді және ақпараттық-коммуникациялық жүйелерді игеруді ұсынады.

Агроөнеркәсіптегі шағын және орта бизнестің үлесінің 14,8% болуы олардың материалдық мүмкіндіктерінің шектеулі екендігін көрсетеді (Кошербек және т.б., 2025), яғни, ауыл шаруашылығы құрылымдарының белсенділігін арттыру заман талабы, себебі бүкіл әлем бойынша нарықтық өзгерістер орын алуда. Бұндай мүмкіндік шағын және орта бизнес кәсіпкерлерінің ресурстарын жақсарту, инновациялық әзірлемелерді пайдалану, тұрақтылықты нығайту арқылы іске асрылады.

Тұрақты өсудің басты шарты (Керимова, Zhao, 2025) тұрақсыздықты тудыратын жағдайларды азайту қажет, яғни ауыл тұрғындарының жұмыспен қамтылуы, инженерлік коммуникациялардың жұмысын жақсарту, жер, сур ресурстарын тиімді пайдалану, өмір сапасын арттыру сияқты шараларды көбейту керек.

ESG қағидаларын енгізу компаниялардың ұзақ мерзімді бәсекеге қабілеттілігін арттырып, халықаралық әріптестік орнатуға және бедел тәуекелін азайтуға мүмкіндік береді, яғни ESG қағидаттарының дамушы елдердегі әлеуметтік-экономикалық даму үшін қаржылық емес ақпараттың маңызын айқындай отырып, компанияларға қолайлы стратегияларды әзірлеуге негіз бола алады (Мазбаева және т.б., 2025)

Ауыл шаруашылығындағы цифрлық мүмкіндіктерді зерттеу барысында авторлар (Амирханов және т.б., 2025) оларды енгізу өнімділік пен тұрақтылықты арттыруға мүмкіндік беретінін нақты жобалау технологиялары арқылы бизнес үрдістерін автоматтандыру мүмкіндіктеріне салыстырмалы сипаттама келтіреді.

АӨК ұйымдарының орнықты өсуін қамтамасыз ететін, ESG-қағидаларының іске асырылуын сипаттайтын қаржылық емес ақпарат келітірілетін есептілік нысаны үлгісі мен ұсынылатын ақпараттың мазмұны мен мәніне қатысты, осы есептілікті құрастырудағы басқару есебінің орны мен атқаратын рөлі туралы көп деректер табылмағандықтан бұл мәселені нақты ұйым мысалында бағалау қажеттігі айқын болды.

Әдіснама

Басқару есебі мен ESG стратегиясы арасындағы байланысты зерттеу теориялық аспектілерді, практикалық құралдарды және эмпирикалық тәуелділіктерді бір уақытта бағалауға мүмкіндік беретін әдістердің кешенді жиынтығын қолдануды талап етеді. ESG принциптерін басқарушылық есепке алу жүйесіне интеграциялау пәнаралық сипатта болады, сондықтан әдістемелік тәсіл талдаудың сапалық және сандық әдістерін де қамтуы тиіс.

1. Теориялық -әдіснамалық әдістер.

1.1 Жүйелік тәсіл

Басқару есебі ESG бастамаларына ақпараттық қолдау көрсететін Ішкі жүйе ретінде әрекет етеді, ал ESG деректерге, процестерге және басқару есептілігіне қойылатын талаптарды анықтайтын стратегиялық қондырма механизмі ретінде қызмет етеді. Жүйелік талдау шеңберінде экологиялық, әлеуметтік және басқару көрсеткіштері мен олардың бизнес-процестерге әсері арасындағы байланыстар анықталады.

1.2. Мазмұнды талдау

Бұл әдіс басқарушылық есепке интеграциялауды қажет ететін ESG көрсеткіштерінің тізімін анықтауға, қаржылық емес Есептіліктің құрылымын анықтауға және тұрақты дамудың әсерінен бухгалтерлік процестердің өзгеруін анықтауға мүмкіндік береді.

1.3. Салыстырмалы талдау

Салыстырмалы талдау арқылы дәстүрлі басқару есебі негізінде тұрақты даму есебін құрастыру мүмкіндіктеріне қаржылық есеппен салыстырмалы сипаттама беріледі, сондай-ақ ESG стратегиясын енгізген ұйымдағы есептілік ақпаратының артықшылықтары көрсетіледі. Бұл деректер басқару құрылымындағы, бақылау құралдарындағы, бюджеттеудегі айырмашылықтарды анықтауға және ESG стратегиясының басқару процестеріне әсерін бағалауға мүмкіндік береді.

2.1. ESG стратегиялық карталары

ESG стратегиялық картасын құру Басқару есебі процестері, операциялық қызмет және ESG мақсаттарына қол жеткізу арасындағы себеп-салдарлық байланыстарды визуализациялауға мүмкіндік береді. ESG көрсеткіштерін есептеу үшін басқарушылық есеп деректері қолданылатын процестерді көрнекі түрде көрсетуге және ESG стратегиясының бухгалтерлік есеп процедураларына қандай кезеңдерде әсер ететінін анықтауға мүмкіндік береді, ақпараттық ағын-

дардың, көрсеткіштердің және басқару шешімдерінің байланысын ашады.

Агроөнеркәсіп кешені сияқты күрделі құрылымдық байланыстары бар ұйымның ESG-қағидаларын іске асыру мүмкіндіктері бағаланып, ESG-стратегиясын қалыптастыру қажеттігі ашып көрсетілді. Стратегиялық мақсаттар мен оларға қол жеткізудегі басқару есебінің орны мен қызметі сараланып көрсетілді. Нәтижесінде, Aitasagro холдингінің 2023 жыл қорытындысы бойынша жарияланған қаржылық емес ақпарат көрсетілген есептілігін құрастырудағы басқару есебінің маңызыдылығы ашып көрсетілді. Жалпы ESG-қағидаларын іске асырудағы басқару есебінің қаржылық есеппен салыстырғандағы артықшылықтары сараланды.

Нәтижелер мен талқылау

Агроөнеркәсіп кешені – экономиканың стратегиялық маңызды секторы болып табылады, себебі ол азық-түлік қауіпсіздігін қамтамасыз етеді, жұмыс орындарын құруға және ауылдық аймақтардың дамуына ықпал етеді (World Bank, 2021). ESG-стратегиясын енгізу қазіргі заманда-ғы халықаралық және ұлттық талаптарға сәйкес тұрақты дамуды қамтамасыз етудің негізгі құралдарының бірі болып табылады (OECD, 2020).

Басқару есебі – кәсіпорынның қаржылық, өндірістік, әлеуметтік және экологиялық ақпаратын жинау, өңдеу және талдау процесі. ESG-стратегиясын енгізу барысында басқару есебі шешім қабылдауды ақпараттық қамтамасыз ету, шығындарды оңтайландыру және компанияның тұрақтылық көрсеткіштерін арттыру мүмкіндіктерін береді (IFAC, 2020; Мұстафин & Сейтханова, 2021).

ESG-стратегия келесі компоненттерден тұрады:

1. Environmental (Экологиялық) – табиғи ресурстарды сақтау, парниктік газдар шығарындыларын азайту, қалдықтарды басқару (SASB, 2022).

2. Social (Әлеуметтік) – еңбек қауіпсіздігі, қызметкерлердің дамуы, жергілікті қоғаммен өзара қатынас.

3. Governance (Басқару) – корпоративтік басқару стандарттары, ашықтық және есеп беру мәдениеті.

АӨК кәсіпорындары үшін ESG-стратегия қамтиды:

- Өнімділік пен тұрақтылықты арттыру;
- Қаржылық және экологиялық тәуекелдерді азайту;
- Халықаралық стандарттарға сәйкестік;
- Инвесторлар мен қоғам сенімін арттыру (Қазақстан Республикасының Үкіметі, 2021).

Басқару есебі ESG-стратегияны жүзеге асыруда келесі мүмкіндіктерді қамтамасыз етеді (Münch және т.б., 2025):

1. Қаржылық және экологиялық көрсеткіштерді талдау – шығындарды, энергия және су ресурстарын пайдалану тиімділігін бақылау.

2. Әлеуметтік көрсеткіштерді бақылау – қызметкерлердің еңбек өнімділігі, қауіпсіздік деңгейі, әлеуметтік жобаларға қатысу.

3. Шешім қабылдауды қолдау – стратегиялық жоспарлау және ұзақ мерзімді мақсаттарды белгілеу.

4. Тәуекелдерді басқару – экологиялық және әлеуметтік тәуекелдерді дер кезінде анықтау және азайту.

Осы орайда басқару есебі көмегімен АӨК бизнес-үрдістерді оңтайландыру алгортмі қажет, оның мүмкін болатын үлгісі 1-суретте келтірілді.

1-суретте келтірілгендей, ұйымның бизнес моделін ESG-қағидаларына сәйкес трансформациялау алдымен корпоративті басқару моделдерін өзгертуді, содан кейін ұйым қызметін бағалау жүйесін де қайта құруды талап етеді. Бизнес модельді трансформациялау басқарушылық бизнес-модельдерден басталады, себебі бұл басқару есебінің жсопарлау және ұйымдастыру функцияларына сәйкес келеді, яғни, ұйым мақсаттарына сәйкес жоспар жасап, оны іске асыру үшін нақты әрекеттерді анықтайды. Басқару есебінің ұйымдастырушылық функциясы персоналды басқарудан бастау алады, себебі олардың міндеттерін анықтау, өзара байланыстарын белгілеу, есеп беру тәртібін қалыптастырады. Содан кейін басқа ресурстармен қамтамасыз ету жүзеге асырылады. Жоспарлау және ұйымдастыру функциялары сәтті жүзеге асырылғанан кейін ғана негізгі бизнес-үрдістеріндегі сапаны басқару мүмкін болады. Есепті кезең соңында бақылау және ауытқуларды талдау жүзеге асырылады. Бұл өз кезегінде келесі кезеңнің тәуекелдерін мүмкіндігінше азайтады. Алынған қаржылық және қаржылық емес деректерге сүйене отырып есептіліктер құрастырылады.

1-сурет – Басқару есебі негізінде бизнес-үрдістерін оңтайландыру алгоритмі
Ескерту – авторлармен (Münch және т.б., 2025) негізінде құрастырылған

ESG-қағидаларына сәйкестендіру ұйым қызметін бағалау жүйесін де қайта құруды талап етеді, себебі жалпы бухгалтерлік есеп және қаржылық есептілік жүйесіне қойылатын талаптар бойынша қаржылық есептілікте пайдаланушыларға ұсынылатын ақпарат жалпылама ақшалай өлшемде жинақталып, негізгі қаржылық көрсеткіштер түрінде беріледі. Ал, ESG-қағидаларын орындау қаншалықты жүзеге асырылғандығын сипаттайтын есептілік қаржылық емес ақпаратқа сүйенеді.

1-суретте басқару есебі жүйесінде қалыптасқан ақпаратқа сүйене отырып ESG-критерийлері арқылы тұрақты даму мүмкіндіктері бағаланатындығы көрсетілді. Мұндай баға ұйымның болашақ стратегиялық шешімдеріне тікелей ықпал етеді, себебі мүмкіндіктерді саралап, мықты тұстарды айқындап қана қоймайды, сонымен қатар, әлсіз тұстарын ажыратып алуға, кемшіліктерді анықтауға мүмкіндік тудырады.

Осы орайда қаржылық емес ақпараттың алдымен басқару есебі жүйесінде қалыптасатындығын және ұйымның шешім қабылдауға өкілетті мамандарының еншісінде қалатындығын атап өту керек. Есептілік құрамында қаржылық емес ақпаратты қоса ұсыну ұйым мүмкіндіктерін барынша арттырады (Дегтярев, 2023) себебі инвестициялық тартымдылығын ұлғайтады деген авторлардың пікірімен келісетіндігімізді атап өту керек.

Aitasagro Ақмола, Шығыс Қазақстан және Алматы облыстары аумағында 35 мың гектардан астам жерде ауылшаруашылығы өндірісімен айналысатын ірі аграрлық ұйым болып табылады. Ұйым 2023 жыл қорытындысы бойынша алғаш рет ESG-қағидаларына негізделген қаржылық емес есептілік тапсырған болатын. Стратегиялық даму бағыттары ретінде тұрақты 1) қоршаған орта, 2) тұрақты қоғам, 3) тұрақты бизнес алынған. Aitasagro БҰҰ ұсынған тұрақты даму мақсаттарын жүзеге асыруда белсенді атсалысуда (1-кесте) («Aitasagro.kz» ресми сайты).

1-кестеде көрсетілгендей, Aitasagro холдингтің миссиясы тұрақты даму мақсатттарына толықтай сәйкес келеді, себебі холдинг қызметінің басты мақсаты қолжетімді, сапалы, қауіпсіз азық-түлікпен тұтынушыларды қамтамасыз ету. Жалпы агроөнеркісіптің үлесіне жалпы өндірістің 43% тиесілі (Ұлттық статистика бюросы, 2025). Сәйкесінше тұрақты дамудың лайықты, әрі қауіпсіз жұмыс орындарымен қамту талаптарын да қанағаттандырады. Арнайы қалыптас-

тырылған қор есебінен білім мен ғылымды қолдау бағытында да 86-астам мектептермен өзара бірлесе отырып жұмыс жасауда. Индустрияландыру мен инновацияларды жүзеге асыруда да ауқымды шараларды іске асыруда. Ауылдық жердлердің өміршеңдігі мен экономикалық тұрақтылығын қамтамасыз ету бағытында жобаларды жүзеге асырушы боылп табылады.

Қазақстандағы ТОП-5 құрамына кіретін Аграрлық сала туралы пікірді өзгертуді мақсат еткен ұйымға қатысты қаржылық емес көрсеткіштер келесідей түрде анықталды (2-кесте).

1-кесте – Aitasagro холдингінің БҰҰ тұрақты даму мақсаттарының жүзеге асыруда қосқан үлесі

Тұрақты даму мақсаттары		Aitasagro холдингтің қосқан үлесі
	Аштықты жою, азық-түлік қауіпсіздігін қамтамасыз ету, тамақтануды жақсарту, ауыл шаруашылығының тұрақты дамуына атсалысу	Тұтынушыларды сапалы, қолжетімді бағадағы азық-түлікпен қамту, азық-түліктің қауіпсіздігін қамтамасыз ету (Қазақстандағы жалпы өндірістің 43% құрайды)
	Жан-жақсы және сапалы біліммен қаматмасыз ету, білім алу мүмкіндіктерін ынталандыру	Тұрақты даму қоры есебінен білім беру саласында әртүрлі жобаларды жүзеге асырады, ауылдар мен моноқалалардың 86-дан астам мектептерімен бірлесе жұмыс жүргізуде
	Үдемелі, толық қамтылған және орнықты экономикалық өсуге, нәтижелі және лайықты жұмыспен қамтуға атсалысу	Мақсат, миссия және құндылықтарға негізделген басқару жүйесі техникалық жаңғырту және инновациялық қызметі арқылы лайықты, әрі қауіпсіз жұмыс орындарын қамтамасыз етеді (4363 жұмыс орны)
	Тұрақты инфрақұрылым қалыптастыру, жан-жақты және тұрақты индустрияландыру мен инновацияларға атсалысу	АӨК жоғары технологияларды енгіздегі лидер, Data Driven әдістемесі қолданыста, Халықаралық ШЕ-марапаты «Бөлшек саудада CRM жүйелерін енгізу»
	Қалалар мен елді мекендердің ашықтығын, қауіпсіздігін, өміршеңдігін және экономикалық тұрақтылығын қамтамасыз ету	Тұрақты даму қоры есебінен ауылды жерлерде 40-тан астам жобаларды жүзеге асыруға 190 млн теңгеден астам қаражат бағытталған
Ескерту – Aitasagro холдингінің деректері негізінде авторлармен құрастырылды		

2-кесте – Aitasagro БҰҰ тұрақты даму мақсаттарының жүзеге асыруда қосқан үлесі

Көрсеткіштер	2021 жыл	2022 жыл	2023 жыл
Өндіріс көлемі, тонна	91143	102442	143614
Сату көлемі, тонна	89456	98864	140077
Инвестициялар, млн тг	30624	41619	8360
Оның ішінде стратегиялық инвестициялар, млн тг	29019	35918	4557
Ескерту – Aitasagro холдингінің ESG есептілігі негізінде авторлармен құрастырылды			

2-кестеде көрсетілгендей натуралды өлшемдердегі ақпарат әдетте басқару есебі жүйесінде қалыптасады, ESG-қағидаларына негізделген есептілікті құрастыруда пайдаланылады. Кестеде келтірілген көрсеткіштердің есептілік құрастырылған 2023 жыл деректерін оған дейінгі 2 жылмен салыстырғанда арту жағдайында екендігі анық көрінеді. Ал жалпы инвестициялар мен стратегиялық мақсаттарға сай инвестициялар көлеміне қатысты керісінше жағдайды көруге болады, себебі алғашқы жылдары салынған инвестициялар мөлшерінің басымдылығын, кейінгі жылдары олардың мөлшерінің азайғанын сипаттайды.

Aitasagro холдингінің тұрақты қоғам стратегиясының басты мақсаты елдің әл-ауқатын жақсартуға білім беру жүйесі мен жергілікті қоғамдастықтардың дамуы арқылы қол жеткізу. Тұрақты қоршаған орта стратегиясы ARR бизнес-бағытында қалдықсыз өндірісті (zero waste – full recycling) қамтамасыз ету. Тұрақты бизнес атқарушы және басқарушы органдар арқылы жүзеге асырылады, оның ішінде атқарушы органдар бақылайды, тәуекелдерді біледі және басқарады, ал басқару органы тәуекелдерді қадағалайды, ішкі бақылауды, комплаенс, қаіпсіздікті қамтамасыз етеді, ішкі адуит арқылы тәуелсіз баға береді.

Aitasagro қаржылық емес есептілігі GRI (with reference) стандартының талаптарына сәйкестендіріліп құрастырлған, бұл есептілікте «Aitasagro» холдингінің елдің экономикалық және әлеуметтік дамуына, жұмысшылар және қоғамның әл-ауқатын жақсартуға, қоршаған ортаны қорғауға қосқан үлестері жөніндегі қаржылық емес ақпарат ашылып келтірілген. Осындай деректер базасы ұйымның басқару есебі жүйесінде қалыптастырылады, себебі ол тек басқару шешімдерінің тиімділігін бағалау үшін ғана емес, ұйымның салықтық міндеттемелері бойынша есеп айырысу үшін де маңызды. Деректер 3-кестеде жинақталып келтірілді.

3-кесте – Aitasagro холдингінің ESG-қағидаларына негізделген есептілігі бойынша негізгі индикаторлары

GRI	*Экологиялық индикаторлар*	2021 жыл	2022 жыл	2023 жыл
306-3	Қалдықтардың жалпы көлемі, тонна	107780,2	132764,2	181026,7
303-5	Суды тұтыну көлемі, м3	1178486,3	1535621	1979503,5
305-7	Ауаны ластаушы шығарылымдар мөлшері, тонна	2120	2381	2827
302-1	Электр энергиясын тұтыну, кВт	60644353	64206771	80051475
302-1	Энергия тұтыну (көмір), тонна	41374,6	40641,9	50164,5
302-1	Энергия тұтыну (табиғи газ), тонна	10943,4	13656,9	19890,6
302-1	Энергия тұтыну (дизель отыны), л	621779,5	785605	873598,6
GRI	*Әлеуметтік индикаторлар*			
2-7	Орташа тізімдік жұмысшылар саны, адам	2742	3299	4333
401-1	Кадрлар ағымдылығы, %	56	49	44
401-1	Жыл бойы жұмысқа қабылданғандар саны, адам	2004	3825	2321
202-1	Орташа еңбек ақы, мың теңге	211	262	316
403-9	Өлімге әкелетін жазатайым оқиғалар, штук	0	0	1
403-9	Жазатайым оқиғалардың жалпы саны, штук	7	7	9
Ескерту – Aitasagro холдингінің ESG есептілігі негізінде авторлармен құрастырылды				

3-кестеде келтірілген экологиялық индикаторларға жеке талдау жасап, негізінде көрсеткіштердің мәндерінің жыл сайын төмендегені өте қолайлы болар еді, бірақ олардың үлғаюы ұйымның өндіріс көлемінің артуымен байланысты орын алып отыр.

Әлеуметтік индикаторлар құрамындағы кадрлар ағымдылығы коэффциенті ғана кему жағдайында, бұл ұйым үшін қолайлы ауытқу, себебі 2021 жылмен салыстырғанда 56 пайыздан 49 пайызға дейін, яғни 7 пайызға төмендеген, ал 2022 жылмен салыстырғанда 2023 жылы 5 па-

йызға төмендеген, бұл кадрлар құрамының тұрақтанғандығын көрсетеді. Тұрақтана бастауына орташа еңбек ақы мөлшерінің жыл сайын арта бастауы тікелей себеп болады. Дегенмен, бұл коэффицентті әлі де мүмкіндігінше төмендету қажет, өйткені осы коэффициент ұйымның нарықтағы бәсекеге қабілеттілігін азайта түседі, сәйкесінше қаржылық тұрақтылығы да төмендей бастайды.

ESG есептілігі соңғы жылдары ESG бағытында айтарлықтай жетістіктерге қол жеткізді.

Компанияда келесі көрсеткіштер жақсарған:

- CO_2 эмиссиясы 2021–2023 жылдары 21% төмендеді;
- Су тұтыну 34% қысқарды;
- Қалдықтарды қайта өңдеу үлесі артты;
- Еңбек өнімділігі 12% өсті.

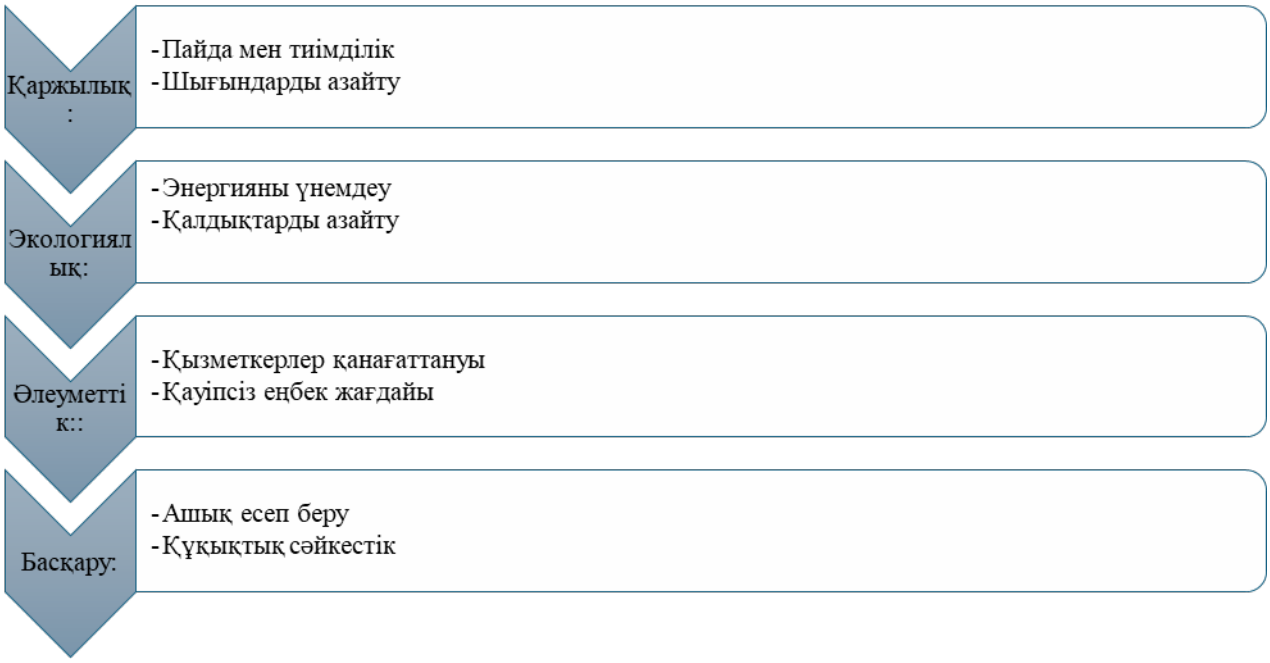
Бұл нәтижелер басқару есебі жүйесіне ESG-KPI енгізудің тиімділігін дәлелдейді.

Көріп отырғанымыздай, негізгі өндіріс пен сату көлеміне қатысты ақпарат, инвестициялар мөлшеріне қатысты мәліметтер, экологиялық және әлеуметтік басты көрсеткіштер толықтай басқару есебінің ақпаратына негізделеді. Өз кезегінде қаржылық есеп ақпараты негізінде қаржылық есептілік құрастырылады, ол сатудан алынған түсім, барлық сатылған өнімнің өзіндік құны, жалпы пайда, жалпы активтер, жалпы міндеттемелер мен капитал мөлшері туралы ақпаратты ұсынады. Яғни, қаржылық есептілікке қарағанда басқару есебінде қалыптасатын ақпараттар кешені ESG-қағидаларын жүзеге асыру деңгейін бағалауда пайдалануға әлдеқайда икемді.

Әсіресе, АПК кәсіпорындары үшін ESG қағидаларын тиімді іске асыруда басқару есебі негізгі құралға айналады. Ол:

- экологиялық әсерді азайту,
- ресурстық тиімділікті арттыру,
- әлеуметтік тұрақтылықты қамтамасыз ету,
- ESG инвестицияларын дәлелді жоспарлау,
- тәуекелдерді кешенді бағалау мүмкіндіктерін береді.

Aitasagro холдингінің ESG-қағидаларын іске асыру жөніндегі қаржылық емес ақпаратқа негізделген есептілігі бойынша талдау қорытындыларына сүйене отырып, ұйым келесідей стратегиялық бағыттарды тереңірек қарастыру қажет (сурет 2).



2-сурет – ESG-стратегиясының негізгі бағыттары
Ескерту – (Kusakina және т.б., 2026) негізінде авторлармен құрастырылды

Басқару есебі агроөнеркәсіп кешені үйымдарының ESG- стратегиясын жүзеге асыруда басты рөлді атқарады. Себебі басқару есебі қаржылық және қаржылық емес көрсеткіштерді таалдау әдістемесінің жүйесін қалыптастырады, ресурстардың үнемді пайдаланылуына жағдай жасайды, корпоративті басқарудың ашықтығын және әлеуметтік тұрақтылықты арттырады.

ESG қағидаларын іске асырудағы басқару есебінің артықшылықтары

1) Экологиялық тиімділік. Басқару есебі су, энергия және химиялық құралдар бойынша шығындарды есептеп, тұрақты өндірісті қамтамасыз етеді (IFRS Foundation, 2023).

2) Әлеуметтік көрсеткіштерді бағалау. Әлеуметтік шығындарды басқару еңбек өнімділігін арттыруға ықпал етеді.

3) Корпоративтік басқаруды жетілдіру. Корпоративтік басқару тәуекелдерді басқаруды және ашық есептілікті қамтиды.

Бұл бағыттарда жүргізілген жұмыстар басқару шешімдерінің тиімділігін арттырады, экологиялық тәуекелдерді қысқартады және бизнестің әлеуметтік жауапкершілігін нығайтады.

ESG қағидаларын іске асырудағы қаржылық есеп пен басқару есебінің салыстырмалы талдауы олардың артықшылықтары мен кемшіліктерін айқындауға және сәйкесінше қажетті ақпараттық базаны қалыптасаруға мүмкіндік береді. Қаржылық есеп қорытындысында құрастырылатын қаржылық есептілік нысандарын түсініктеме жазбаларда басқару есебіінң деректерімен толықтыру мүмкіндігі бар. Осы салыстырмалы талдау жүргізу қорытындысы келесі кестеде ұсынылды (4-кесте).

4-кесте – ESG қағидаларын іске асырудағы қаржылық есеп пен басқару есебін салыстырмалы талдау

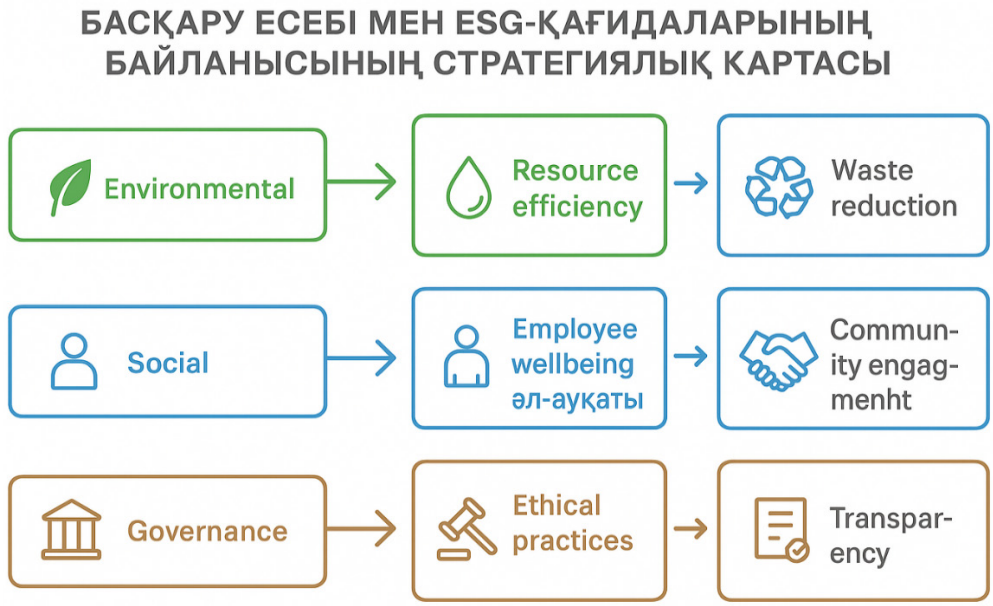
Көрсеткіштер	Басқару есебі	Қаржылық есеп
Негізгі мақсаты	ESG стратегиясын жоспарлау, тәуекелдерді бағалау	Қаржылық жағдай туралы объективті ақпарат беру
Фокус және мазмұны	Экологиялық, әлеуметтік, басқарушылық көрсеткіштер	Активтер, міндеттемелер, табыс, шығындар
Уақыттық көкжиек	Болашаққа бағытталған	Өткен нәтижелерге бағытталған
Ақпарат түрі	Сандық және сапалық	Негізінен сандық
ESG көрсеткіштері	KPI тікелей енгізіледі	Қосымша ақпарат ретінде ғана
Реттелуі	Ішкі регламенттер	IFRS және ұлттық стандарттар
Пайдаланушылар	Менеджмент, ESG комитеті	Инвесторлар, реттеушілер
Деректер жеделдігі	Жедел	Белгіленген мерзімдер
ESG тәуекелдерін бағалау	Жоғары деңгей	Төмен деңгей
АПК үшін рөлі	Экожүйеге әсерді азайту, ресурс үнемдеу	Қаржылық нәтижелер мен субсидиялар
ESG инвестицияларын негіздеу	Жасыл жобалар тиімділігін есептеу	Қаржылық қайтарымды есептеу
Икемділік	Жоғары	Төмен
Шешім қабылдауға әсері	Стратегиялық деңгейде	Қаржылық шешімдер
Ескерту – (Мазбаева және т.б., 2025) негізінде авторлармен құрастырылды		

Басқару есебі ақпараты заманауи жүйелері дәстүрлі қаржылық көрсеткіштерден асып компанияның тұрақты дамуын өлшеу, бақылау және дамытудың негізгі құралына айналды. Басқару есебі ESG-ді кәсіпорынның стратегиясы мен операциялық процестеріне біріктіру үшін әлдеқайда негізді болып табылатын әдістемелік базаны, құралдарды және деректерді қамтамасыз етеді.

Қазақстанның АӨК үйымдарында ESG-бағдарланған басқару есебін енгізу экономиканың жаһандық ESG-трансформациясы жағдайында олардың бәсекеге қабілеттілігі мен инвестициялық тартымдылығын арттырудың басты шарты болып табылады.

Басқару есебі мен ESG-қағидаларының өщара байланысы мен тәуелділігі келесідей стратегиялық карта арқылы айқын көрінеді (3-сурет).

Ұсынылған стратегиялық карта басқару есебі мен ESG-қағидалары арасындағы өзара байланысты жүйелі түрде көрсетеді. Карта үш негізгі блоктан тұрады және әр блок басқару есебінде қолданылатын нақты көрсеткіштермен, құралдармен және басқару шешімдерімен байланыстырылған.



3-сурет – Басқару есебі мен ESG-қағидалары байланысының стратегиялық картасы
Ескерту – (Münch және т.б., 2025) негізінде авторлармен құрастырылды
Суретте келтірілген бірінші блок – Environmental (E) – Экологиялық өлшем.

Негізгі фокус: Resource Efficiency (ресурстар тиімділігі). Экологиялық бағыттың негізгі мақсаты – табиғи ресурстарды ұтымды пайдалану және экологиялық ізді азайту. Басқару есебі бұл салада келесі функцияларды атқарады:

- ресурстардың шығынын (су, энергия, жанармай) өлшеу;
- шығындарды ABC немесе Lean жүйелері арқылы талдау;
- экологиялық шығындар есебін жүргізу (environmental costing);
- қалдықтарды басқару тиімділігін бағалау.

ESG нәтижесі: Waste Reduction (қалдықтарды азайту). Басқару есебінің дұрыс ұйымдастырылуы агроөнеркісіп кешенінің қалдықтарды азайту бойынша стратегиялық шешімдер қабылдауына ықпал етеді. Нақты деректер негізінде ресурстарды үнемдеу бағдарламалары жасалып, өндірістің экологиялық тиімділігі артады.

Екінші блок – Social (S) – Әлеуметтік өлшем.

Негізгі фокус: Employee Wellbeing (қызметкерлер әл-ауқаты). Әлеуметтік бағытта басқару есебі еңбек ресурстарын басқару, персоналға инвестициялар және әлеуметтік бағдарламаларды бағалауға мүмкіндік береді:

- кадрлардың айналымын және оқыту шығындарын есептеу;
- еңбек өнімділігін бағалау;
- қызметкерлердің әлеуметтік пакеттерінің құнын талдау;
- HR-көрсеткіштерді Balanced Scorecard арқылы бақылау.

ESG нәтижесі: Community Engagement (қоғаммен байланыс). Қызметкерлер әл-ауқаты жақсарған сайын кәсіпорынның репутациясы өседі, корпоративтік мәдениет нығаяды және қоғаммен өзара іс-қимыл тиімділігі артады. Басқару есебі әлеуметтік инвестициялардың қайтарымын (SROI – social return on investment) өлшеуге көмектеседі.

Үшінші блок – Governance (G) – Корпоративтік басқару.

Негізгі фокус: Ethical Practices (этикалық тәжірибелер). Корпоративтік басқаруда басқару есебі келесі міндеттерді атқарады:

- шешім қабылдау үдерістерінің ашықтығын қамтамасыз ету;
- қаржылық және бейқаржылық KPI-лардың дұрыстығын бақылау;
- тәуекелдерді басқару жүйесін қолдау;

- ішкі аудиттің тиімділігін арттыру.

ESG нәтижесі: Transparency (ашықтық). Этикалық нормаларды ұстанатын және таза деректерге сүйенетін компания инвесторлар сеніміне ие болады. Басқару есебі корпоративтік есептіліктің ашықтығын қамтамасыз етеді: ESG-есеп, интеграцияланған есеп, тұрақты даму туралы есеп.

Стратегиялық карта көрсеткендей, басқару есебі ESG стратегиясының барлық деңгейінде орталық рөл атқарады. Ол экологиялық, әлеуметтік және корпоративтік басқару көрсеткіштерін өлшеу, талдау және мониторинг жасау арқылы кәсіпорынның тұрақты дамуына, тиімді стратегиялық шешімдер қабылдауына негіз болады.

Қорытынды

Агроөнеркәсіп кешенінде ESG-стратегиясын қалыптастыру қазіргі кезеңде кәсіпорындардың ұзақ мерзімді бәсекеге қабілеттілігін, қаржылық тұрақтылығын және әлеуметтік-экологиялық жауапкершілігін қамтамасыз етудің негізгі тетігіне айналып отыр. Бұл үдерісте басқару есебі стратегиялық шешім қабылдаудың ақпараттық-талдамалық базасы ретінде ерекше маңызға ие.

Зерттеу нәтижелері көрсеткендей, басқару есебі ESG қағидаттарын агроөнеркәсіп кәсіпорындарының бизнес-үдерістеріне интеграциялауға мүмкіндік береді. Экологиялық компонент аясында ресурстарды пайдалану тиімділігін, көміртек ізін, энергия және су тұтыну шығындарын есепке алу және талдау жүзеге асырылады. Әлеуметтік өлшемде персоналдың еңбек жағдайы, қауіпсіздік деңгейі, адами капиталға инвестициялар мен жергілікті қауымдастықтармен өзара іс-қимыл көрсеткіштері жүйеленеді. Басқарушылық (governance) аспект шеңберінде ішкі бақылау, тәуекел-менеджмент, ашықтық пен есептілік деңгейін арттыруға бағытталған көрсеткіштер қалыптастырылады.

ESG және басқару есебінің бірігуінің перспективалық бағыттары төмендегі қадамдарды қамтиды:

- Агроөнеркәсіп үшін ESG-стандарттарының ұлттық жүйесін дамыту;
- Қаржылық және қаржылық емес көрсеткіштерден тұратын біріктірілген есептілікке көшу;
- Стратегиялық талдау үшін ESG-контроллинг жүйесін қалыптастыру;
- Деректерді жинау және талдауды автоматтандыруды қамтамасыз ететін басқару есебінің цифрлық платформаларын енгізу.

Егер, дәстүрлі басқару есебі шығындарды оңтайландыруға, рентабельділікке және тиімділікке бағытталған болса, ESG тәсілі ұзақ мерзімді тұрақтылық пен материалдық емес құндылықтарға (бедел, стейкхолдерлердің сенімі, экологиялық тәуекелдер) бағытталған.

Басқару есебі мен ESG-қағидаларының синергиясы келесідей көрініс береді:

- Басқару есебі ESG тәуекелдері мен мүмкіндіктерін бағалау үшін қажетті деректер мен талдауды қамтамасыз етеді;
- ESG қаржылық емес аспектілермен кеңейте отырып, ішкі тиімділік көрсеткіштері жүйесіне жаңа талаптарды анықтайды.

ESG-стратегияны енгізу АӨК кәсіпорындарына тұрақтылықты арттыруға, ресурстық тиімділікті көтеруге, тәуекелдерді азайтуға және инвесторларға тартымдылықты күшейтуге мүмкіндік береді.

Басқару есебі ESG деректерінің бірыңғай ақпараттық орталығына айналып, стратегиялық басқарудың маңызды элементіне айналады.

ESG-мен интеграцияланған басқару есебі бизнес-процестерді жақсартады, шығындарды төмендетеді, тәуекелдерді азайтады және компанияның ұзақ мерзімді құндылығын арттырады.

Әдебиеттер

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CURRENT TRENDS AND PROSPECTS FOR THE DEVELOPMENT OF FOOD PRODUCTION IN THE REGIONS OF KAZAKHSTAN

In developed countries, supporting agricultural producers is considered a key goal of government policy. Support for the agricultural industry is focused on subsidies, modernizing production technologies, purchasing fertilizers, increasing the competitiveness of agricultural products, supporting industry research through regulatory and methodological support, and implementing tax, budgetary, and customs tariff measures.

The research purpose was to analyze the significance of potato cultivation by examining key metrics such as cultivation area, total yield, productivity, and fertilizer usage. It utilized methods like descriptive statistics, quartile analysis, and regression analysis to derive insights from the available data.

Originality/value of the research lies in its comprehensive evaluation of how potato production impacts Kazakhstan's food security. By providing detailed statistics, such as Pavlodar region's cultivation area of 24,033.5 hectares and its yield of 6,616,240.6 centners, the study offers a nuanced understanding of the sector's contribution to the national food supply.

Findings reveal that potato production is crucial for Kazakhstan's food security. Regions like Pavlodar and Ulytau, with high yields and productivity levels (e.g., 293.6 centners per hectare in Ulytau region), underscore the efficiency of potato farming. The study also highlights the role of effective fertilizer management in enhancing productivity,vital for maintaining a stable food supply and ensuring nutritional security.

Keywords: potato production efficiency, agriculture of Kazakhstan, food security, economic regions of Kazakhstan.

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Қазақстан өңірлерінде азық-түлік өндірісі дамуының қазіргі тенденциялары мен болашағы

Дамыған елдерде ауыл шаруашылығы тауарын өндірушілерді қолдау мемлекеттік саясаттың негізгі мақсаты болып саналады. Аграрлық саланы қолдау субсидиялауға, өндіріс технологияларын жаңғыртуға, тыңайтқыштар сатып алуға, ауыл шаруашылығы өнімдерінің бәсекеге қабілеттілігін арттыруға, нормативтік және әдістемелік қамтамасыз ету арқылы салалық зерттеулерді қолдауға, салықтық, бюджеттік және кедендік тарифтік шараларды іске асыруға бағытталған.

Зерттеудің мақсаты картоп өсірудің маңыздылығын өсіру алаңы, жалпы өнім, өнімділік және тыңайтқышты пайдалану сияқты негізгі көрсеткіштерді зерделеу арқылы талдау болды. Ол қол жетімді деректерден түсінік алу үшін сипаттамалық статистика, квартильді талдау және регрессиялық талдау сияқты әдістерді пайдаланды.

Зерттеудің түпнұсқалығы/құндылығы оның картоп өндірісінің Қазақстанның азық-түлік қауіпсіздігіне қалай әсер ететінін жан-жақты бағалауында жатыр. Павлодар облысының егістік көлемі 24 033,5 гектар және оның өнімділігі 6 616 240,6 центнер сияқты егжей-тегжейлі статистикалық мәліметтерді бере отырып, зерттеу сектордың ұлттық азық-түлікпен қамтамасыз етудегі үлесі туралы нақты түсінік береді.

Зерттеу нәтижелері картоп өндірісінің Қазақстанның азық-түлік қауіпсіздігі үшін маңызды екенін көрсетеді. Өнімділік деңгейі жоғары Павлодар және Ұлытау сияқты облыстар (мысалы, Ұлытау облысында гектарына 293,6 центнер) картоп өсірудің тиімділігін көрсетеді. Зерттеу

нымен қатар тұрақты азық-түлікпен қамтамасыз ету және тағамдық қауіпсіздікті қамтамасыз ету үшін маңызды өнімділікті арттырудағы тыңайтқыштарды тиімді басқарудың рөлін көрсетеді.

Түйін сөздер: азық-түлік қауіпсіздігі, картоп өндірісі тиімділігі, Қазақстанның ауыл шаруашылығы, Қазақстанның экономикалық аудандары.

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Современные тенденции и перспективы развития производства продовольствия в регионах Казахстана

В развитых странах поддержка сельскохозяйственных товаропроизводителей считается одной из ключевых целей государственной политики. Поддержка аграрной отрасли направлена на субсидирование, модернизацию технологий производства, закупку удобрений, повышение конкурентоспособности сельскохозяйственной продукции, поддержку отраслевых исследований посредством нормативно-правового и методического обеспечения, а также реализацию налоговых, бюджетных и таможенно-тарифных мер.

Целью исследования было проанализировать значимость выращивания картофеля путем изучения ключевых показателей, таких как площадь возделывания, общая урожайность, продуктивность и использование удобрений. Для получения информации на основе имеющихся данных использовались такие методы, как описательная статистика, квартильный анализ и регрессионный анализ.

Оригинальность/ценность исследования заключается в его всесторонней оценке того, как производство картофеля влияет на продовольственную безопасность Казахстана. Предоставляя подробные статистические данные, такие как площадь посевных площадей Павлодарской области в 24 033,5 га и урожайность в 6 616 240,6 центнеров, исследование дает детальное понимание вклада этого сектора в национальное продовольственное снабжение.

Результаты показывают, что производство картофеля имеет решающее значение для продовольственной безопасности Казахстана. Такие области, как Павлодар и Улытау, с высокими уровнями урожайности и продуктивности (например, 293,6 ц/га в Улытауской области), подчеркивают эффективность выращивания картофеля. В исследовании также подчеркивается роль эффективного управления удобрениями в повышении производительности, что жизненно важно для поддержания стабильных поставок продовольствия и обеспечения продовольственной безопасности.

Ключевые слова: эффективность производства картофеля, сельское хозяйство Казахстана, продовольственная безопасность, экономические регионы Казахстана.

Introduction

The production of potatoes is an important strategic element in the agricultural sector and the country's food security system. Potatoes are a staple food that has a considerably high contribution to the diet and the employment of the rural population in Kazakhstan. The fact that there are large areas of agricultural land and varying climate conditions in Kazakhstan gives a positive indication regarding the prospects for growing potatoes. However, the efficiency of production and production levels are quite diverse due to the regional disparities.

Despite the economic and nutritional significance of potatoes in the country, detailed analyses concerning the area wherein potatoes are grown, total production, production per unit area, and the application of fertilizers in the Kazakhstan region appear to be limited in studies conducted in the past. The challenge of this gap in current research will be especially important in view of the challenges the country experiences because of climate variability and the need to improve its self-sufficiency in basic food products. The purpose of the investigation will be to evaluate the present level and regional specifics of potato growing in Kazakhstan based on the four central indicators: cultivation area, total yield, productivity (centners/ha), mineral fertilizer usage.

To accomplish this, the study utilizes the tools of descriptive statistics, quartile comparison, and linear regression analysis, thus enabling the comparison of distributions and the relationship assessment of utilization and production outputs. The combination of the tools gives a systematic and objective approach to understanding production trends and the determi-

nants that cause variability in the results across the respective regions.

The study focuses on the following inquiries:

1. How do the area, production, and productivity of potatoes vary in the respective regions of Kazakhstan?

2. Listing the basic factors associated with higher and lower levels of productivity:

3. To what extent does the application of fertilizers explain the variation in the yields for potatoes?

4. What are the implications of the trends noted above concerning food security and agricultural policies?

The significance of the study is in its contribution to the formulation of the country's food security policy and sustainable agricultural development strategies because the study offers an interdisciplinary assessment of the scale of production and efficiency in order to make informed decisions concerning the improvement of farming practices in the region and the utilization of fertilizers.

The results show a large difference in the levels of development of the potato industry in the regions of Kazakhstan. The top region in terms of the area (24,033.5 ha) and the total production (6.6 million centners) is the Pavlodar region, and the highest production capacity is recorded in the Ulytau. While regression analysis demonstrates that the use of fertilizers has a moderate explanatory value regarding the variation in the productivity levels to the tune of approximately 29.5%, other important determinants include climate and soil quality, amongst other variables. The above results highlight the importance of having a well-balanced and region-specific approach that encompasses the efficiency of fertilizers and agricultural and land practices.

Overall, this report offers a full and fact-based review of potato production in the various regions of Kazakhstan. By highlighting trends, pointing out constraints, and estimating the critical relationships, the study provides a basis for policymakers to make effective interventions to improve efficiency and food security.

Methodology

In order to achieve a better understanding of the Kasakh farming of potatoes, the research uses various research methods to analyze the trends in farming as well as the utilization of lands. The research methods complement each other to present foremost information–such as cultivated lands, overall potato production, farm productivity, as well as the use of fertilizers.

A substantial portion of the analysis dedicates to descriptive statistics. They reduce intricate data to easily interpretable and communicable levels. By employing the help of charts, tables, along with simple figures such as averages, medians, and ranges, the research provides a preliminary look at the data. This way, repeating patterns as well as one-time anomalies that could easily be overlooked can be made prominent.

Another way to get a better picture of how the data is spread around is the quartile analysis. This emphasizes center values and shows how the data points are bunched together by splitting the data into four even parts. This, in research on agriculture, can be used to compare regions since it can be used to display discrepancies in the use of the terrain as well as farm output. This can also detect oddities, where some places are doing significantly better or poorer than the rest, possibly requiring special attention.

The research meanwhile uses regression analysis to analyze the relationship between different farming factors to each other with particular interest given to the relationship between the yield of potatoes as well as the use of mineral fertilizers. Regression analysis is a powerful statistical tool used to model how one main factor is affected by one or more other factors (Postiglione, 2021, pp. 6-7, 64-87, 108-121). It helps in showing how the main variable changes when one of the other factors is adjusted. In this context, the regression model is used to quantify the impact of fertilizer usage on potato productivity, providing insights into the effectiveness and influence of fertilizers on crop yields.

The use of R-squared and adjusted R-squared values in regression analysis offers an understanding of the model's explanatory power (Postiglione, 2021, pp. 6-7, 64-87, 108-121). The R-squared value shows how much of the change in the main variable can be explained by the other factors in the model. The adjusted R-squared value gives a clearer picture by taking into account the number of variables and the size of the data set. This makes it a more accurate measure of how well the model works (Postiglione, 2021, pp. 6-7, 64-87, 108-121).

In Kazakhstan, understanding the pattern of potato cultivation requires more than one analytical prism. By combining various methodological instruments, the research retains significant regional variations, describes current practices, and identi-

fies factors that govern the outcome of crops. This wider overview acts as a basis for decision-taking both in agriculture management as well as policy, with the pragmatic advice given to enhance yields, promote the conservation of ecological material, as well as ensure economic sustainability. Using descriptive measures, quartile division, and regression analysis, the study builds a multi-faceted picture of the variables that dictate the production of potatoes throughout the nation.

Understanding the nuance of the cultivation of potatoes in Kazakhstan requires analysis of the set of principal agronomic measures (Stark et al., 2020, pp. 35-64, 87-100).The factors of potato cultivation area, total potato yield, potato productivity measured in centners per hectare, and usage of mineral fertilizers for potato, each play a pivotal role in painting a comprehensive picture of the state of potato farming. Therefore, these factors were shown below in Table 1.

Table 1 – 2023 potato cultivation and production statistics by regions of Kazakhstan

Regions of Kazakhstan	Potato cultivation area, in hectares	Total potato yield, in centners	Potato productivity, measured in centners per hectare	Usage of mineral fertilizers for potato, calculated as 100% nutrient content, in centners
Abai	8056.9	1766939.0	219.3	5404.0
Akmola	12603.0	2304891.7	182.9	22645.4
Aktobe	5777.0	979862.9	169.6	1234.2
Almaty	23955.0	4583044.6	191.3	400.4
Atyrau	1901.1	291564.0	153.4	88.4
West Kazakhstan	4246.1	688494.1	162.1	6556.4
Zhambyl	11359.3	2852172.4	251.1	815.7
Zhetysu	11867.7	2524198.8	212.7	-
Karaganda	15703.5	3641827.9	231.9	28,385.6
Kostanay	8286.4	1604784.1	193.7	11887.6
Kyzylorda	4156.8	616202.8	148.2	184.6
Pavlodar	24033.5	6616240.6	275.3	43352.6
North Kazakhstan	26456.9	3770637.4	142.5	5419.8
Turkestan	14391.8	2867377.8	199.2	6079.4
Ulytau	515.0	151206.9	293.6	-
East Kazakhstan	10809.1	2589167.8	239.5	388.7
City of Astana	51.3	6621.1	129.1	27.1
City of Almaty	82.5	15211.5	184.3	-
City of Shymkent	53.2	10733.0	201.7	-
Total for Kazakhstan	184306.3	37881178.3	205.5	132869.9

Note – compiled by the author based on Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan (2024a; 2024b; 2024c)

The potato cultivation area in hectares is fundamental in understanding the scale of potato production. It indicates the geographical extent to which potato farming is spread across Kazakhstan. This information is key to understanding how important the crop is to Kazakhstani farming industry. A larger cultivation area not only points to the significance of potatoes as a staple food but also influences economic policies, food security considerations, and land use planning. Observing changes in the cultivation area over time can also reveal trends and shifts in agricultural practices and market dynamics (Khatri et al., 2024, pp. 71-82, 243-278; (Postiglione, 2021, pp. 6-7, 64-87, 108-121; Stark et al., 2020, pp. 35-64, 547-572).

Total potato yield in centners is another critical factor. This number shows how much potatoes are being produced in Kazakhstan. By looking at the to-

tal amount grown, people involved in farming can see how well potato farming is doing each year. It helps them understand if there's enough to meet the country's needs, if there's extra to export, and how it supports the economy. Comparing this data across regions and years also shows which areas have better farming methods or better conditions for growing potatoes.

Potato productivity, expressed as the number of centners per hectare, is a prominent indicator of proper farming. The indicator delivers what the farm ground is capable of doing as well as the farming techniques itself. Where the productiveness is high, the techniques, climate, and measures to control pests are standing strong. Where the productiveness is low, there could be problems such as wrong farming techniques, inferior soil, or harsh climate. The figure is significant to planning within each region to determine the area to inject funds, technologies, as well as training to promote farming.

Finally, considering how much mineral fertilizer is applied to potatoes, measured in terms of full nutritional value, can be used to gain some understanding of what is required to produce the crop. Application of the fertilizer is a crucial function of contemporary agriculture because it significantly influences how much is actually produced as nutrition as well as the quality. Knowing the amount applied can be used to gain some idea of the long-term sustainability of Kazakhstan potato farming. Over-application can cause soil to be lost in quality as it becomes polluted with waters, whereas too meager use could lead to smaller crops as the quality is spoiled. This information is crucial to developing farming practices that stay productive as well as environmentally friendly over the long term.

In summary, the combined components present a balanced account of the farmings of the area. Current conditions are defined, principal challenges are highlighted, and potential avenues of future development are indicated. Such analytical acuity assists decision makers, be they growers, administrators, or industry planners, to improve operation, to save natural resources, and to enhance economic paybacks.

In this detailed analysis of Kazakhstani potato farming, the focus is on two main points: the area used for growing potatoes (in hectares) and the total amount harvested (in centners), along with how these figures are spread across different levels.

The potato cultivation area differsacross Kazakhstan. The smallest area, observed in the City of Astana, only 51.3 hectares, showing that farming is very limited in this city area. On the other hand, the Pavlodar region has the biggest potato-growing area at 24,033.5 hectares, highlighting its key role in national potato production (Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan, 2024a). The quartile distribution for the cultivation area reveals that the first quartile (25th percentile) is 3,028.95 hectares, the median (50th percentile) is 8,286.4 hectares, and the third quartile (75th percentile) is 13,497.4 hectares. This data suggests a significant variation in cultivation sizes, with a substantial number of regions engaging in potato farming on a larger scale.

Looking at total potato yield, the highest amount comes from areas with the most land used for farming, especially the Pavlodar region, which produced an impressive 6,616,240.6 centners (Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan, 2024b). On the other hand, the City of Astana had the lowest yield at just 6,621.1 centners, which matches its small farming area. The quartile data helps show how potato production is spread out across the country: the first quartile is 453,883.4 centners, the median is 1,766,939.0 centners, and the third quartile is 2,859,775.1 centners. These numbers show clear differences in how much each region produces and also hint at differences in how well resources and farming methods are being used.

Overall, this analysis highlights how potato farming varies across different parts of Kazakhstan. It definesuseful insight on how different farm sizes and crop sizes across Kazakhstani regions are, which allows to make decisions on planning, where resources are recommended to be invested, and how to expand potato farming in the sustainable way. This data is also essential for shaping policies that can help to strengthen farming sector of Kazakhstan through defining how to increase crop production and ensure food supply and safety.

Understanding how mineral fertilizers impact potato yields in Kazakhstan is possible throughapplying the regression analysis. This method looks at how closely these two factors are connected and how strong that connection is, using R-squared and adjusted R-squared values to measure it (Postiglione, 2021, pp. 6-7, 64-87, 108-121).

The data shows a range of productivity levels across different regions of Kazakhstan, from as low as 142.5 centners per hectare in North Kazakhstan region to as high as 293.6 centners per hectare in Ulytau region (Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the

Republic of Kazakhstan, 2024c). Similarly, the usage of mineral fertilizers varies, with the lowest being 27.1 centners in the City of Astana and the highest at 43,352.6 centners in Pavlodar. To understand how these variables interact, we performed a linear regression analysis.

The regression model yielded an R-squared value of 0.295, indicating that approximately 29.5% of the variability in potato productivity is explained by the usage of mineral fertilizers. While this indicates some level of correlation, it also suggests that other factors are at play in determining productivity. The adjusted R-squared value, which takes into account the number of factors in the model and the size of the data set, is a bit lower at 0.240 (Postiglione, 2021, pp. 6-7, 64-87, 108-121). This gives a more reliable picture of the relationship based on the data and variables included.

The R-squared and adjusted R-squared values play an important role in understanding potato farming in Kazakhstan. An R-squared value of 0.295, though not very high, shows a moderate positive link between fertilizer use and potato productivity. This means that regions using more mineral fertilizers often see better yields. However, since the value isn't closer to 1, it also shows that other important factors affect productivity – such as climate, soil quality, farming techniques, and how pests are controlled.

The adjusted R-squared value of 0.240 is a more conservative estimate that adjusts for the number of variables in the model relative to the number of data points (Postiglione, 2021, pp. 6-7, 64-87, 108-121). In practical terms, this means that while fertilizer usage does impact productivity, it is not the only factor, and its effect is not overwhelmingly strong.

For policymakers and agricultural stakeholders in Kazakhstan, these findings emphasize the importance of a balanced approach to improving potato productivity. While the use of mineral fertilizers is indeed a contributing factor, it's clear that other aspects of agricultural practice and environmental conditions also play significant roles (Stark et al., 2020, pp. 87-100, 135-154, 203-257).This shows that increasing potato yields shouldn't depend just on using more fertilizer. A wider approach is needed, e.g. using better farming techniques, taking care of the soil, and managing pests and diseases effectively. It could also be helpful to study and grow potato varieties that are better suited to local conditions.

In summary, the analysis shows a somewhat positive connection between potato productivity and fertilizer use in Kazakhstan. But since the R-squared values aren't very strong, it's clear that boosting yields will take more than just using more fertilizer. Looking into and improving other key factors can help develop better farming practices and guidelines to support potato farming throughout the country.

Building on the analysis of potato farming in Kazakhstan, using specific data gives solid proof to back up the study's results. This in-depth approach looks at several important factors, e.g. the amount of land used, total harvest, productivity, and fertilizer use – each playing a key role in showing how the farming sector works.

For example, the study found that potato farming areas differ a lot across Kazakhstan. Quartile analysis showed that 25% of regions have less than 3,028.95 hectares, the middle value is 8,286.4 hectares, and 75% have less than 13,497.4 hectares. This shows clear differences in how much land is used for growing potatoes. Some areas, like the City of Astana, farm on a very small scale with just 51.3 hectares, while others, like Pavlodar, use much larger areas – up to 24,033.5 hectares.

In the same way, the total potato yield across regions also highlights the differences in how effectively resources are used and how productive farming is in each area. The first quartile for yield is 453,883.4 centners, the median is 1,766,939.0 centners, and the third quartile is 2,859,775.1 centners. Pavlodar region, with its large cultivation area, aligns with the highest yield, producing a staggering 6,616,240.6 centners, contrasting sharply with the City of Astana, which, due to its limited cultivation area, amounts to just 6,621.1 centners.

The regression analysis looked at how potato productivity is related to the use of mineral fertilizers. The R-squared value was 0.295, meaning around 29.5% of the changes in productivity can be linked to fertilizer use. While this shows some connection, it also suggests that many other factors play a role. The adjusted R-squared value, which is slightly lower at 0.240, gives a more accurate view by considering the number of variables and the size of the data set (Postiglione, 2021, pp. 6-7, 64-87, 108-121).

These findings are important for people who make farming decisions in Kazakhstan. Although they are not the only factor involved, mineral fertilizers can lead to increased potato yields. Hence, the well-rounded approach taking into account other key elements is necessary. There are conditions such as climate, soil condition, cultivation techniques, and pest control which also carry considerable weight. This suggests that boosting potato production isn't

simply about increasing fertilizer use. A broader plan is required. This could include better farming practices, maintaining soil quality, and managing pests and diseases effectively. It may also be useful to examine which potato varieties are best suited to local conditions.

In conclusion, this analysis uses the real-world data to examine the state of Kazakhstani potato cultivation. It reveals that cultivating potatoes entails various difficulties and is shaped by multiple conditions. Through examining and refining these aspects, agricultural guidelines and practices may be adjusted to support growers across the nation. The research is a useful tool for creating plans that can boost harvests, protect the environment, and increase profits – helping both the farming sector and the country's food supply.

In the current analysis, the model of regression employs the ordinary least square method in a univariate analysis where potato productivity is dependent on the use of mineral fertilizer at the regional level. The model deployed can thus be considered as exploratory or preliminary. The intention in such calculations is to make an initial quantitative assessment of the link between fertilizer use and productivity, rather than attempting to estimate a complete production function or make claims about causation.

One of the main drawbacks of the univariate model based on OLS analysis is the issue of omitted variable bias. The productivity in potato output is proxied by many variables such as climate factors (rain and temperature) or irrigation facilities. It should be noted that many other factors affect potato productivity collectively; such factors include climate factors like rainfall and temperature. These factors are not included in the model because of data constraints at the regional level. If any of these factors are correlated with fertilizer use, then the estimated coefficient on "fertilizer" will measure not only the impacts of using fertilizer but will also measure the impacts of any of these factors that are not included in the model. It can therefore be said that the regression parameter needs to be considered as a partial association rather than an unbiased estimate of the causal link between fertilizer and productivity.

The model is further restricted by the fact that it is a cross-sectional model and there are few data points per region. Being based on data from a single year, it is not feasible to check for fixed region characteristics or dynamic relationships such as the reaction of yields to fertilizer or weather. In addition, the sample size means that it is not feasible to consider complex models without risking the danger of overfitting. Subsequently, the power of the test has remained low, and the data obtained from the analysis can basically help in pointing out rather than in predicting.

Further, the OLS model has standard assumptions such as linearity, homoskedasticity, and independence of the error terms. In comparison to the linear functional form, where the marginal treatment effect of fertilizer always remains constant regardless of the quantity applied, the actual relationship between yields and fertilizer can result in diminishing returns or thresholds. Possible measurement error in the use of fertilizer and agricultural produce in the region can equally have an influence on the estimates. By taking the aggregate level in the analysis, the result might not apply to farms and households (ecological fallacy).

These factors combined mean that the result from the regression analysis can be considered as exploratory or suggestive analysis in addition to the descriptive analysis and comparison of quartiles. It must be considered that the analysis was done at an aggregate level. Although the model helps in structuring and synthesizing data regarding differences in the use of fertilizer and productivity in different regions, the model fails to generate data regarding complex agricultural factors and socio-economic considerations related to potato farming. In future studies, a multivariate model framework and more detailed data regarding climate, soil, irrigation, varieties, and technology would all be helpful. Also, longitudinal data would strengthen the analysis of causal relationships.

Literature review

In a comprehensive literature review focusing on potato cultivation, particularly in regions like Kazakhstan, scholars typically explore a wide range of topics that are crucial for understanding and improving agricultural productivity. Such reviews delve into the effectiveness of different farming techniques on potato yields, often emphasizing the importance of practices like crop rotation and soil management (Khatri et al, 2024, pp. 123-146, 374-432). The resilience of these methods in maintaining soil health and increasing yield, along with the adaptation of local and indigenous farming practices, forms a significant part of this discourse (Khatri et

al, 2024, pp. 123-146, 374-432; Stark et al., 2020, pp. 417-446).

Climate and environmental impact on potato cultivation is another area that receives considerable attention. Studies in this domain assess how fluctuating weather patterns, including increased temperatures and irregular rainfall, influence potato growth. In this context, research into climate-resilient potato varieties and early-warning systems for climate-related threats is prevalent (Reddy, 2015, pp. 223-272, 280-320; Stark et al., 2020, pp. 135-154, 417-446).

Additionally, the role of technological advancements in agriculture, particularly precision agriculture, is a key theme (Khatri et al., 2024, pp. 341-462; Stafford, 2023, pp. 415-421, 443-449). These advancements encompass the use of data analytics, GPS-guided equipment, drones for crop health monitoring, and automated systems for efficient irrigation and pest control. Such technologies are seen as pivotal in optimizing farming practices and enhancing potato productivity (Khatri et al., 2024, pp. 99-240, 341-462; Stafford, 2023, pp. 635-642, 715-721, 909-916).

The relationship between fertilizer usage and potato yield is also a crucial research topic (Stark et al., 2020, pp. 135-154). Optimal fertilization strategies are explored extensively, considering their economic and environmental impacts. The development of sustainable fertilizer alternatives, like organic or slow-release fertilizers, forms a part of this discussion, highlighting the need for balance between enhancing productivity and preserving environmental health (Stark et al., 2020, pp. 135-154; Campos & Ortiz, 2020, pp. 163-217, 451-473; Stafford, 2023, pp. 415-421, 715-721).

Socio-economic factors, including government policies, market dynamics, and the economic aspects of potato farming, are also analyzed (Campos & Ortiz, 2020, pp. 163-217, 451-473; Stafford, 2023, pp. 415-421, 715-721; Stark et al., 2020, pp. 135-154). Research in this area evaluates how agricultural subsidies, trade policies, and infrastructure development boost potato yields and enhance the productivity and viability of potato farming (Stark et al., 2020, pp. 135-154; Campos & Ortiz, 2020, pp. 163-217, 451-473; Stafford, 2023, pp. 415-421, 715-721; Struik & Wiersema, 2012, pp. 315-342).

Land use planning, closely tied to sustainable agriculture and food security, is another significant subject. Research here often involves examining land allocation strategies for potato cultivation and the need to balance agricultural demands with urban development (Campos &Ortiz, 2020, pp. 75-106, 163-217). This aspect of research is intertwined with national and regional objectives for food security.

Moreover, sustainability and environmental practices in farming receive considerable attention (Londhe, 2017, pp. 17-49, 133-151). Sustainable irrigation practices, reduction of the carbon footprint through improved farm management, and the conservation of biodiversity in potato farming ecosystems are critical areas of focus (Londhe, 2017, pp. 50-86, 105-132, 247-269).

In summary, the literature review encapsulates an integrated approach to potato farming, combining traditional and modern techniques, state-of-the-art technologies, and supportive policies. This approach underscores the need for ongoing innovation in potato cultivation to meet global challenges like food security and environmental sustainability (Campos & Ortiz, 2020, pp. 163-217, 451-473; Stafford, 2023, pp. 415-421, 715-721; Khatri et al., 2024, pp. 99-240, 341-462). Particularly in Kazakhstan, where agriculture is a cornerstone of the economy and essential for the populace's well-being, such research is invaluable (Food and Agriculture Organization of the United Nations, 2023, pp. 47-57). It serves not only to guide current practices but also to shape future strategies in agricultural development, ensuring that potato cultivation remains both a sustainable and productive venture (Caliskan et al., 2022, pp. 317-329, 457-470; Food and Agriculture Organization of the United Nations & Organisation for Economic Co-operation and Development, 2021, pp. 21-39, 225-230).

Although prior research provides valuable insights into agronomy, climate impacts, fertilizer management, and technological progress in potato cultivation, much of the existing literature remains descriptive and fragmented when applied to Kazakhstan's regional context. Studies tend to focus on global and country levels in terms of challenges and fail to take into account discrepancies in the areas where the growth and production are taking place in the respective Kazakhstani regions. Consequently, the current results fail to provide an answer to why some Kazakhstani regions, such as Pavlodar and Ulytau, are performing better than others and fail to establish the contribution of specific input indicators, namely mineral fertilizers, to the production discrepancies. Nonetheless, the absence of an assessment based on indicators for the regions creates a significant empirical gap, and this is even more important in the case of a country where the agri-

cultural environment, quality of soil, climate, and availability of fertilizers vary considerably across the territories.

Building on the studies reviewed above, the current study adopts an agricultural production function perspective wherein potato output and productivity may be expressed in terms of a function of the key inputs and relevant management conditions: Potato output/productivity = f(land, fertilizers, climate, technology, management). In this view, land area, soil and climatic conditions, and mineral fertilizer availability are the key inputs into production, while farming practices, pest management, mechanization, and regional policy support are the means by which these inputs are transformed into agricultural output in the form of yield and productivity. These, in turn, feed into the broader outcomes related to food security and rural development that link farm-level decisions to national goals of sustainable agriculture and nutritional security (Food and Agriculture Organization of the United Nations & Organisation for Economic Co-operation and Development, 2021, pp. 21-39, 225-230; Khatri et al., 2024, pp. 3-98).

In accordance with the «inputs–processes–results–sustainability» scheme, this paper places the variables analyzed within a broader framework of sustainability. The area under potato cultivation and the amount of fertilizer used point toward scale and intensity of resource use, whereas yield and productivity describe efficiency in conversion into agricultural produce under given conditions of climate and soil. These production results directly affect the capability of Kazakhstan to offer a stable supply of potatoes and reduce inequalities in the food supply at a regional level. At the same time, policies about land use planning, support to modern technologies and precision agriculture, and promoting balanced fertilizer management shape the long-term sustainability of the potato production systems by encouraging efficient resource use, protection of environmental quality, and resilient regional development (Campos & Ortiz, 2020, pp. 163-217, 451-473; Stafford, 2023, pp. 415-421, 715-721).

Despite the shortcoming, this current study incorporates the use of descriptive statistics, comparative quartiles, and regression analysis to consistently analyze the production of potatoes in the regions of Kazakhstan. For instance, unlike the current study and its focus on the production of potatoes in the various regions in Kazakhstan based on the data collected in 2023, previous studies tend to focus broadly on the issues of sustainability and precision farming. Through the quantification of the link between the utilization of fertilizers and the levels of productivity ($R^2 = 0.295$), the study offers a better insight into the structural levels that regulate the production of potatoes. The combination of the insights derived from literature and the current empirical realities enhances the theoretical basis for conducting an investigation into the indicators and their significance.

Results and discussion

A Directed Acyclic Graph (DAG) is a conceptual tool used in various fields, including epidemiology, genetics, and social sciences, to visually depict assumptions about relationships and causal pathways between variables (Bang-Jensen&Gutin, 2009, pp. 1-20, 643-694; Digitale, 2022). In the context of potato cultivation in Kazakhstan, constructing a comprehensive DAG involves identifying and connecting various factors that influence potato productivity. This graphical representation aids in understanding the complexity of agricultural systems and the interplay of multiple factors.

The DAG for potato productivity in Kazakhstan would start with the primary node: potato productivity measured in centners per hectare. This variable is the outcome of interest, influenced by multiple factors, each represented as nodes in the graph. For instance, Figure 1 demonstrates the Directed Acyclic Graph (DAG) that visually represents the factors influencing potato productivity in Kazakhstan, as described earlier.

In our research, the Directed Acyclic Graph or DAG can be viewed as a conceptual framework which encapsulates our conjectures regarding the relationships between important inputs like land, fertilizers, climate and soil characteristics, and farming methods, and the intermediate data related to farming, and, ultimately, the output of interest, which in our case is potato productivity in the regions of Kazakhstan. The analysis of the DAG framework relies on agricultural production theory and sustainability-minded conceptualizations because in these, productivity arises based on the interactions of biophysical factors, management actions, and policy considerations.

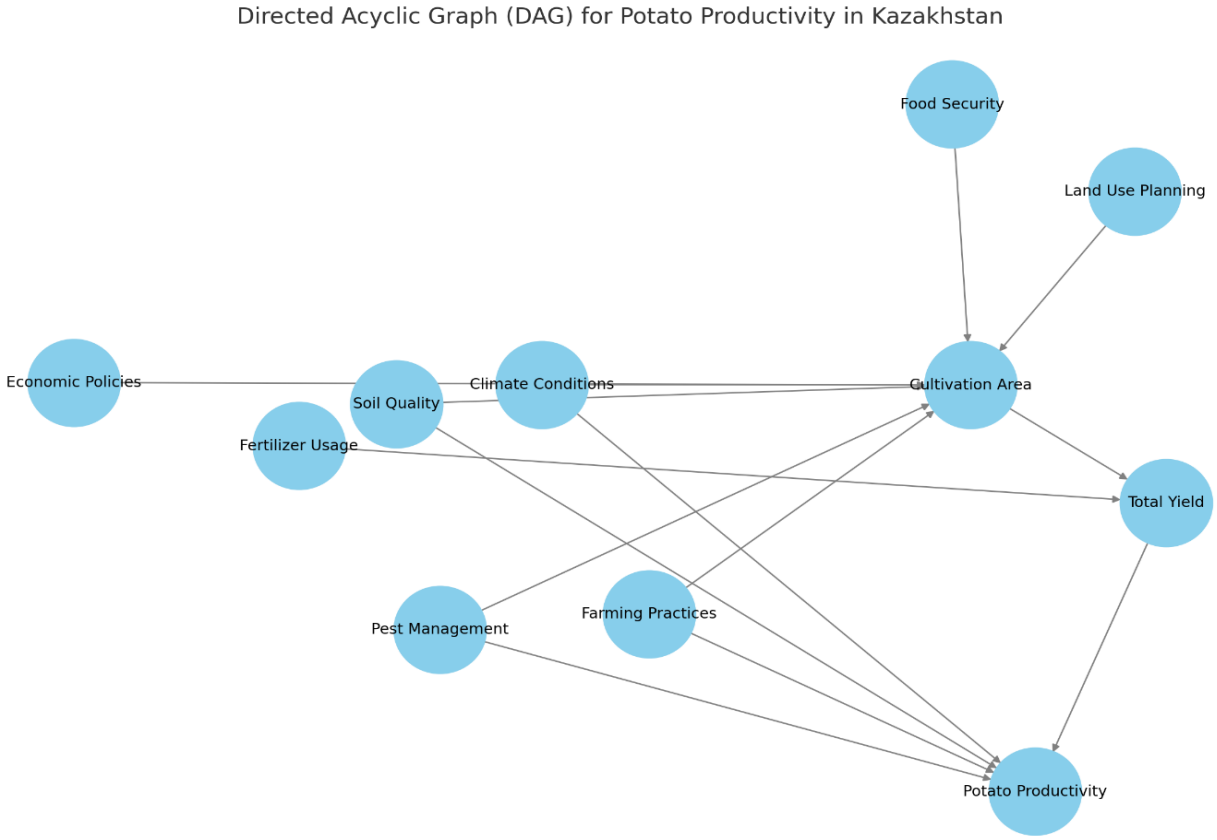

Figure 1 – Directed Acyclic Graph (DAG) for potato productivity in Kazakhstan.
Note: The figure illustrates hypothesized causal relationships among factors influencing potato productivity in Kazakhstan. Arrows indicate the assumed direction of influence between variables. Source: compiled by the authors.

The DAG shows the directional influences among various factors:

- "cultivation area" is a starting point, influencing "total yield";
- "potato productivity" and cultivation area" are affected by "pest management", "soil quality," "farming practices" and "climate conditions";
- "fertilizer usage" also influences "total yield";
- "potato productivity" is strongly influenced by "total yield";
- "economic policies," "food security," and "land use planning" are linked to "cultivation area."

Each arrow indicates the direction of influence, demonstrating the complex network of factors contributing to the overall productivity of potato farming in Kazakhstan. This DAG provides a clear visual framework for understanding the intricate relationships and dependencies within the agricultural sector (Bang-Jensen&Gutin, 2009, pp. 1-20, 643-694; Digitale, 2022).

The DAG for potato productivity in Kazakhstan would start with the primary node: potato productivity measured in centners per hectare. This variable is the outcome of interest, influenced by multiple factors, each represented as nodes in the graph.

One major influencing factor is the cultivation area in hectares. As shown in the research, the size of the cultivation area varies significantly across regions, ranging from as small as 51.3 hectares in the City of Astana to as extensive as 24,033.5 hectares in Pavlodar. This variability directly impacts the total potato yield, which is another crucial node in the DAG. Yield data reveals disparities in agricultural efficiency and resource utilization, with first and third quartiles being 453,883.4 centners and 2,859,775.1 centners, respectively.

Another critical factor is the usage of mineral fertilizers, quantified as 100% nutrient content in centners. The regression analysis conducted in the study indicated that approximately 29.5% of the variability in potato productivity is explained by fertilizer usage, as reflected by an R-squared value of 0.295. This relationship suggests a moderate positive correlation, positioning fertilizer usage as

an important node in the DAG, influencing potato productivity.

Climate conditions, soil quality, farming practices, and pest management strategies are additional nodes that significantly impact potato productivity. These factors are not as directly quantifiable as the others but are essential components of the overall agricultural environment. They interact with both the cultivation area and the use of fertilizers. This affects how much is harvested and how efficient the farming is.

The DAG would also take into account economic strategies, concerns about stable food supply, and how land is managed as underlying influences. These wider background elements shape choices about how much land is used for farming and which methods are applied, which can then have an indirect effect on crop output.

In the DAG, arrows would show how different elements affect each other. For instance, lines would go from land size and fertilizer use toward total harvest, and then continue toward potato output. Individual indicators would extend from weather patterns, land fertility, and agricultural methods toward both the planted area and crop output, illustrating their multifaceted influence.

Creating this DAG provides a visual framework to understand the interdependencies and causal pathways in potato cultivation. It highlights that while some factors have a more direct impact on productivity, others exert their influence through a web of interrelated agricultural practices and environmental conditions. This graphical representation is invaluable for policymakers and stakeholders in Kazakhstan's agricultural sector, providing a clear overview of the factors that need to be addressed to enhance productivity, sustainability, and profitability in potato farming. It serves as a roadmap for developing targeted interventions and policies that address the specific needs and challenges of the potato cultivation sector in Kazakhstan.

Using the Directed Acyclic Graph (DAG) for potato productivity in Kazakhstan, along with the research findings, here are three simple and clear suggestions to help increase potato yields in the country:

1. Optimize fertilizer use: while the regression analysis shows that fertilizer usage does influence potato productivity, the R-squared value of 0.295 indicates that there are additional factors at play (Postiglione, 2021, pp. 6-7, 64-87, 108-121; Mueller et al., 2021, pp. 349-372, 513-525). It is recommended that Kazakhstan develop a precision agriculture strategy. This strategy should focus on optimizing fertilizer use to ensure that each region applies the right type and amount of fertilizers based on specific soil quality and climate conditions (Campos & Ortiz, 2020, pp. 163-217, 451-473; Mueller et al., 2021, pp. 513-525, 661-677;). This could involve soil testing programs to tailor fertilizer types and quantities to the needs of different areas, potentially enhancing productivity more efficiently.

2. Improve farming methods: since agricultural techniques play an important role in shaping both the amount of land used and the level of crop output, it's important to focus on raising the quality of these methods. A nationwide effort should be made to upgrade how farming is done. This could involve applying modern agricultural methods like rotating crops, managing pests in a combined way, and planting potato types that produce larger harvests (Khatri et al., 2024, pp. 37-98, 182-188).Moreover, funding farmer education initiatives can provide them with the skills needed to apply up-to-date and effective cultivation techniques, which could help raise the average yield of 205.5 centners per hectare, as observed in the analysis.

3. Introduce well-managed land allocation practices: the notable variation in potato growing areas, from the lower quartile at 3,028.95 hectares to the upper quartile at 13,497.4 hectares, demonstrates that there is the need for better coordination in land use. To guide this, the government authorities should create policies that encourage responsible expansion of cultivated zones suited to potato farming (Caliskan et al., 2022, pp. 317-329, 457-470; Londhe, 2017, pp. 152-168, 189-204). These measures may include land-use zoning laws that safeguard farming areas, along with support for restoring degraded or underutilized lands (Caliskan et al., 2022, pp. 317-329, 457-470; Londhe, 2017, pp. 1-16, 247-270). Careful planning of both location and cultivation methods can help Kazakhstan to use its land resources more effectively in order to align food supply and safety with broader economic strategies (Food and Agriculture Organization of the United Nations, 2023, pp. 47-57; Londhe, 2017, pp. 1-16, 246-271).

Hence, the Kazakhstani government can adopt the holistic approach to increasing potato yield productivity by addressing the above mentioned three areas. This involves not only direct interventions in agricultural practice but also broader policy and infrastructural changes that create a supportive environment for efficient and sustainable potato farming (Caliskan et al., 2022, pp. 317-329, 457-470).

Drawing from the study findings on potato farming in Kazakhstan, the following region-specific suggestions are provided. They consider weather patterns, soil health, and available farmland to help boost potato yields:

1. The Southern economic region of Kazakhstan:

- Almaty region has one of the largest cultivation areas at 23,955 hectares. The region should focus on advanced pest management and disease control strategies to maintain its high yield of 4,583,044.6 centners. The introduction of climate-resilient potato varieties would be beneficial due to variable weather patterns;

- Kyzylorda region: with a smaller area of 4,156.8 hectares and yield of 616,202.8 centners, the priority should be on diversifying farming practices. Introducing high-yield potato varieties could help increase its relatively low productivity (148.2 centners per hectare);

- Turkestan region can benefit from enhanced water management and irrigation practices, considering its cultivation area of 14,391.8 hectares and yield of 2,867,377.8 centners. The region's moderate fertilizer usage (6,079.4 centners) suggests an opportunity to optimize fertilizer application methods for better yield;

- Zhambyl region: with a notable productivity of 251.1 centners per hectare, should focus on expanding its cultivation area from the current 11,359.3 hectares to boost overall yield. The usage of fertilizers (815.7 centners) should be optimized with precision agriculture techniques to enhance efficiency;

- in Zhetysu region land rehabilitation programs can help expand the current cultivation area of 11,867.7 hectares. Developing more efficient water management systems would also be beneficial for this region.

2. The Western economic region of Kazakhstan:

- Aktobe region: with a smaller area of 5,777 hectares and yield of 979,862.9 centners, Aktobe can benefit from improved irrigation techniques, considering the region's semi-arid climate. Fertilizer usage is relatively low (1,234.2 centners); thus, tailored fertilizer programs based on soil testing can enhance productivity;

- Atyrau region: with a modest area of 1,901.1 hectares and a yield of 291,564 centners, Atyrau can improve yields by adopting modern farming techniques and equipment. Training programs for farmers on efficient farming practices would be valuable given the region's lower productivity (153.4 centners per hectare);

- West Kazakhstan region's cultivation area of 4,246.1 hectares and yield of 688,494.1 centners suggest room for improvement in farming efficiency. Initiatives to enhance soil quality and farming practices can be implemented, supported by a moderate level of fertilizer usage (6,556.4 centners).

3. The Northern economic region of Kazakhstan:

- Akmola region: with a larger cultivation area of 12,603 hectares and a yield of 2,304,891.7 centners, should invest in precision farming technologies. This would help optimize the use of its considerable fertilizer application (22,645.4 centners). Water conservation strategies are also critical here, considering the region's climate conditions;

- Kostanay region: with an area of 8,286.4 hectares and a yield of 1,604,784.1 centners, can benefit from advanced soil health management strategies. The region should also focus on enhancing crop rotation techniques to maintain soil fertility;

- North Kazakhstan region: with a vast cultivation area of 26,456.9 hectares but lower productivity (142.5 centners per hectare), North Kazakhstan needs to address soil quality and introduce advanced farming methods. The emphasis on training programs for farmers and the adoption of innovative agricultural practices could significantly boost productivity;

- Pavlodar region: with the largest cultivation area of 24,033.5 hectares, should leverage its high yield (6,616,240.6 centners) by adopting state-of-the-art agricultural technologies. The region's significant fertilizer usage (43,352.6 centners) calls for a focus on precision agriculture to enhance yield efficiency and environmental sustainability.

4. The Eastern economic region of Kazakhstan:

- Abai region: with a cultivation area of 8,056.9 hectares and a yield of 1,766,939 centners, the focus in Abai should be on enhancing soil fertility. Implementing crop rotation practices and organic farming could boost productivity, currently at 219.3 centners per hectare. Given the moderate usage of fertilizers (5,404 centners), a shift towards more organic and sustainable fertilizers could benefit both yield and environmental health;

- in East Kazakhstan region, improving crop varieties and implementing integrated pest management can enhance the current yield from its 10,809.1 hectares of cultivated land. Given its low fertilizer usage (388.7 centners), there's an opportunity to explore more efficient and sustainable fertilizer options.

5. KazakhstaniCentral economic region:

- the region of Karaganda: with high area of sowing of 15,703.5 ha and high yield, the region should introduce technological solutions such as auto-maidan machinery to preserve the existing levels of productivity as high as possible (231.9 centners per ha). As the high utilization of fertilizers reaches 28,385.6 centners, one should encourage the use of balanced and highly efficient fertilizers;

- the region of Ulytau: though the region demonstrates the best productivity of 293.6 centners per ha, the limited area of sowing of 515 ha implies potential growth. The introduction of the use of the lands on the sustainable basis can expand the region's agrarian produce to the maximum.

These area-specific recommendations seek to promote the high-cascade irrigation farming of potatoes in Kazakhstan through the alignment of each region's climate, soil, and land use with enhanced technologies, climate-resilient farming practices, and favorable policies to achieve long-term success and profit sustainability.

Conclusion

The objective of this research was to analyze the condition of potato cultivation in Kazakhstan. The study concerned the role played by potato cultivation in ensuring that there is sufficient food supply through examining the extent of area coverage, the quantity of potatoes produced, the intensity of farming, and the use of fertilizer. The research ran various techniques – e.g. simple data summaries, quartile analysis, and regression – to grasp the variation in farming as well as farming productivity across regions. The research also utilized a Directed Acyclic Graph (DAG) to present the relationship between these various factors as they are interrelated as influencing overall potato production.

The data revealed significant variations in the cultivation of potatoes between regions. Pavlador, for example, had the highest area of territory devoted to cultivating potatoes – 24,033.5 ha – as well as the highest yield, with 6,616,240.6 centners, to demonstrate the significance of this region as a source of the republic's general potato yield.

In terms of productivity per hectare, Ulytau region stood out with the highest value at 293.6 centners per hectare, signaling efficient farming practices and optimal resource use. Other regions, while showing lower productivity, indicate potential for targeted improvements through enhanced agricultural practices and resource management.

Quartile analysis provided a deeper look into the distribution of cultivation sizes and yields. The first quartile for cultivation area was 3,028.95 hectares, while the third quartile reached 13,497.4 hectares. This spread highlighted the differences between smaller-scale operations and larger, more intensive cultivation efforts. Likewise, the data showed that regions with lower harvests could do better by improving soil health, using modern farming equipment, and finding better ways to deal with pests and plant diseases.

A regression analysis was done to see how fertilizer use affects potato productivity, showing an R-squared value of 0.295. This means about 29.5% of the changes in productivity can be linked to how much mineral fertilizer is used. The adjusted R-squared value was 0.240, which gives a more accurate picture by considering the number of variables and the size of the data. Although fertilizers contributed positively, the findings also revealed that additional factors such as climate, soil condition, and cultivation practices hold substantial influence. This modest connection points to the importance of a balanced strategy that considers more than just fertilizer application.

The additional layer of depth to the study was added by the DAG, which showed that different factors work together by affecting the potato productivity in Kazakhstan. For instance, weather, farming methods, and government policies. Among the key diagram components of diagram were the area planted, and the amount of fertilizer used, where both were directly associated with harvest volume and farming efficiency. There are other factors, e.g. climate and soil quality, which had an indirect impact by shaping how farmers work and how well crops grow. Hence, the DAG helped to illustrate how everything connects, making it easier for farmers and decision-makers to find ways to improve results and increase efficiency.

These results not only confirm that fertilizer usage impacts potato yields in Kazakhstan, but also show that land use, applied technology, and the ability to manage weather changes are important factors in potato production. For example, average to high productivity yield areas, e. g. Karaganda and East Kazakhstan, could work on wiser fertilizer usage. For instance, switching to precision-based or organic agricultural methods that are better for the environmental sustainability. On the other hand, lower yield regions, e. g. North Kazakhstan, could move forward by paying more attention on the soil care. For instance, more efficient water usage or growing

only those potato types that match the local climate.

The research findings also demonstrated that improving farming practices in Kazakhstan requires a well-rounded approach that includes promoting sustainable methods, introducing new technology, and offering training programs to help farmers learn better techniques, rather than focusing solely on increased fertilizer use. This approach is necessary to secure Kazakhstani food security and supply through strengthening its farming economy by allowing better resource handling and increasing crop yields.

Further studies might explore how emerging farm technologies, including precision equipment and intelligent irrigation systems, impact long-term potato yields, as well as how climate change impacts plant health and how farmers might adapt their strategies accordingly. Additionally, what new policies and tools actually achieve across seasons might be uncovered with long-term studies to help better address what fosters long-term sustainability in farming. In summary, this research provides valuable information about the different factors that relate to Kazakhstan potato farming, including what motivates productivity and how those factors relate to each other to help guide decision-making and planning narrowed to desired long-term environmental and economic wellness globally. Hence, Kazakhstan by following these suggestions can make potato farming more efficient and stable in the long term, strengthening its agricultural sector and boosting the national food supply.

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АВТОРЛАРҒА АРНАЛҒАН АҚПАРАТ

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Мақаланы жариялау үшін ақы төлеу тәртібі мен құнын «Қазақ университеті» баспасы белгілейді және оны рецензенттер мен ғылыми редактор мақұлдағаннан кейін автор жасайды.

Мақала құрылымы: Бірінші бет: Бірінші жол – ҒТАХР нөмірі, мәтін беттің сол жақ шетімен тегістеледі, қаралау шрифт. Мақала автор(лар)ы – аты-жөнінің бірінші әріптері және тегі, жұмыс істейтін орны (аффилиация), қала, мемлекет, e-mail, ORCID ID – орыс, қазақ және ағылшын тілдерінде жазылады. Авторлар туралы ақпарат қалыпты шрифтті кіші әріптермен жазылып, беттің ортасында тегістеледі.

Мақала атауы (Тақырып) мақаланың мәні мен мазмұнын көрсетіп, оқырманның назарын аудару керек. Тақырып қысқа әрі ақпараттық, жаргондар мен аббревиатурасыз жазылуы тиіс. Тақырыптың орташа ұзындығы 5-7 сөз (кей жағдайда 10-12 сөз). Мақаланың тақырыбы орыс, қазақ және ағылшын тілдерінде берілуі керек. Тақырып қаралау шрифтті кіші әріптермен, беттің ортасымен тегістеледі. Аңдатпа көлемі – 150 сөзден кем емес, 300 сөзден артық емес орыс, қазақ, ағылшын тілдерінде жазылады.

Аңдатпа құрылымында келесі ақпарат міндетті түрде болуы керек: Зерттеу тақырыбы бойынша кіріспе сөз; Ғылыми зерттеудің мақсаты, негізгі бағыттары мен идеялары; Жұмыстың ғылыми және практикалық маңыздылығы бойынша қысқа ақпарат; Зерттеу әдістемесі бойынша қысқа ақпарат; Ғылыми зерттеудің негізгі нәтижелері, талдау және түжырымдама; Жүргізілген зерттеу жұмысының маңыздылығы (аталған жұмыстың ғылымның сәйкес саласына енгізген үлесі); Жұмыс қорытындысының практикалық маңыздылығы.

Түйін сөздер/сөз тіркестері – орыс, қазақ, ағылшын тілдерінде 3-5 сөз аралығында.

Кіріспе келесіде берілген негізгі элементтерден тұрады: Таңдалған тақырыптың негіздемесі; тақырып өзектілігі мен зерттеу проблемалары. Таңдалған тақырыптың негіздемесінде алдыңғы зерттеушілердің тәжірибелері негізінде проблемалық жағдайдың (зерттеу жұмыстарының жоқтығы, жаңа зерттеу нысанының пайда болғаны және т.б.). бар екендігі айтылады. Тақырыптың өзектілігі аталған зерттеу нысанының қойылған сұрақтарға толық жауаптардың болмаған жағдайда, тақырыптың теориялық және практикалық маңыздылығы арқылы дәлелденіп жалпыға ортақ мүдде арқылы анықталады. Жұмыстың нысанын, пәнін, мақсаттарын, міндеттерін, тәсілдерін, әдістер, гипотезасын анықтау. Зерттеудің мақсаты тезисті дәлелдеумен, яғни зерттеу тақырыбын автор таңдаған аспектімен көрсетумен байланысты.

Әдебиеттерге шолу бөлімінде – зерттеу тақырыбы бойынша ағылшын тілінде шетелдік авторлардың іргелі және жаңа еңбектер (кемінде 15 жұмыс), оларды ғылыми үлесі түрғысынан талдау, сондай-ақ сіздің мақалаңызда толықтырылған зерттеу кемшіліктері беріледі.

Әдістеме – материалдар мен жұмыс барысының сипаттамасынан, сондай-ақ қолданылатын әдістердің толық сипаттамасынан тұруы керек.

Нәтижелер мен Талқылау бөлімінде сіздің зерттеу нәтижелеріңізді талдауы және талқылауы беріледі. Зерттеу барысында алынған нәтижелер туралы қорытынды беру арқылы негізгі мәні айқындалады. Бұл мақаланың маңызды бөлімдерінің бірі болып саналады. Онда жұмысыңыздың нәтижелерінің талдауы және алдыңғы жұмыстармен, талдаулармен және түжырымдамаларымен салыстыру арқылы сәйкес нәтижелерді талқылау беріледі.

Қорытынды – жұмыстың осы кезеңдегі нәтижелерін жалпылау және қорытындылау; автор алға қойған түжырымның растығын және алынған нәтижелерді ескере отырып, ғылыми білімнің өзгеруі туралы автордың қорытындысын растау. Қорытынды абстрактілі болмауы керек, оларды ұсыныстарды немесе одан әрі жасалатын жұмысты сипаттай отырып белгілі бір ғылыми саладағы зерттеу нәтижелерін жалпылау үшін қолдану керек.

Пайдаланылған әдебиеттер тізімі немесе библиографиялық тізім жаратылыстану және техникалық бағыттарға кем дегенде 15 атаулардан тұрады, ал ағылшын тіліндегі жалпы атаулар саны 50%-дан кем болмауы керек. Егер сілтемелер тізімінде кириллицада берілген еңбектер болса, сілтемелер тізімін екі нұсқада ұсыну қажет: біріншісі – түпнұсқада, екіншісі – романизацияланған алфавитте (транслитерация – translit-online.ru).

Әлеуметтік және гуманитарлы бағыттағы мәтіндерде дәйексөз келтірілген сілтемелер жұмыстың бірінші авторы, шыққан жылы: бет нөмір(лер)і жақша ішінде көрсетіліп беріледі. Мысалы, (Залесский, 1991: 25). Әдебиеттер тізімінде бір автордың бір жылда жарық көрген бірнеше жұмысы келтірілген жағдайда, шыққан жылдың түсына «а», «б» және т.б. әріптерді қосып жазу керек. Мысалы, (Садуова, 2001а: 15), (Садуова, 2001б, 22). Мақала жариялау құны – 2000 теңге / бет

ИНФОРМАЦИЯ ДЛЯ АВТОРОВ

Авторами могут быть:

- докторанты, совместно с руководителем;
- лица, имеющие ученую степень;
- лица, занимающиеся научно-педагогической деятельностью.

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Порядок оплаты и стоимость за публикацию статьи устанавливается издательским домом «Қазақ университеті» и производится автором после одобрения рецензентами и научным редактором.

Структура статьи Первая страница: Первая строка – номер МРНТИ, выравнивание – по левому краю, шрифт – полужирный; Автор(ы) статьи – Инициалы и фамилия, ученая степень, звание, место работы (аффилиация), город, страна, e-mail, ORCID ID – на русском, казахском и английском языках. Сведения об авторах представляются обычным шрифтом строчными буквами, выравнивание – по центру;

Название статьи (Заголовок) должно отражать суть и содержание статьи и привлекать внимание читателя. Название должно быть кратким, информативным и не содержать жаргонизмов или аббревиатур. Оптимальная длина заголовка – 5–7 слов (в некоторых случаях 10–12 слов). Название статьи должно быть представлено на русском, казахском и английском языках. Название статьи представляется полужирным шрифтом строчными буквами, выравнивание – по центру.

Аннотация объемом не менее 150 и не более 300 слов на русском, казахском и английском языках. Структура аннотации включает в себя следующие обязательные пункты: Вступительное слово о теме исследования; Цель, основные направления и идеи научного исследования; Краткое описание научной и практической значимости работы; Краткое описание методологии исследования; Основные результаты и анализ, выводы исследовательской работы.

Ключевые слова/словосочетания – количеством 3–5 на русском, казахском и английском языках;

Введение состоит из следующих основных элементов: Обоснование выбора темы; актуальность темы или проблемы. В обосновании выбора темы на основе описания опыта предшественников сообщается о наличии проблемной ситуации (отсутствие каких-либо исследований, появление нового объекта и т.д.).

Актуальность темы определяется общим интересом к изученности данного объекта, но отсутствием исчерпывающих ответов на имеющиеся вопросы, она доказывается теоретической или практической значимостью темы.

Определение объекта, предмета, целей, задач, методов, подходов, гипотезы и значения вашей работы. Цель исследования связана с доказательством тезиса, то есть представлением предмета исследования в избранном автором аспекте.

В секции обзор литературы – должны быть охвачены фундаментальные и новые труды по исследуемой тематике зарубежных авторов на английском языке, анализ данных трудов с точки зрения их научного вклада, а также пробелы в исследовании, которые Вы дополняете в своей статье.

Методология – должны состоять из описания материалов и хода работы, а также полного описания использованных методов.

В разделе Результаты и Обсуждение – приводится анализ и обсуждение полученных вами результатов исследования. Приводятся выводы по полученным в ходе исследования результатам, раскрывается основная суть. И это один из самых важных разделов статьи. В нем необходимо провести анализ результатов своей работы и обсуждение соответствующих результатов в сравнении с предыдущими работами, анализами и выводами.

Заключение – обобщение и подведение итогов работы на данном этапе; подтверждение истинности выдвигаемого утверждения, высказанного автором, и заключение автора об изменении научного знания с учетом полученных результатов. Выводы не должны быть абстрактными, они должны быть использованы для обобщения результатов исследования в той или иной научной области, с описанием предложений или возможностей дальнейшей работы.

Список используемой литературы, или Библиографический список состоит из не менее 15 наименований, и из общего числа наименований на английском языке должно быть не менее 50%. В случае наличия в списке литературы работ, представленных на кириллице, необходимо представить список литературы в двух вариантах: первый – в оригинале, второй – романизированным алфавитом (транслитерация – translit-online.ru).

Ссылки на цитируемые работы в тексте даются в скобках, с указанием первого автора работы, год издания: номер страниц(-ы). Например, (Залесский, 1991: 25). Стоимость публикации – 2000 тенге/страница.

INFORMATION FOR AUTHORS

The authors can be:

- doctoral students, together with the supervisor;
- persons with an academic degree;
- persons engaged in scientific and pedagogical activities.

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Structure of the article: First page: First line – IRSTI number (international rubricator of scientific and technical information), alignment – left, font – bold. Author(s) of the article – Initials and surname, place of work (affiliation), city, country, e-mail, ORCID ID. Information about authors is represented in ordinary type in lowercase letters, alignment in the center. The title of the article should reflect the essence and content of the article and attract the reader's attention. The title should be short, informative and not contain jargons or abbreviations. The optimal length of the title is 5-7 words (in some cases 10-12 words). The title of the article is shown in bold in lowercase letters, alignment – in the center. Abstract – at least 150-300 words.

The structure of the annotation includes the following obligatory items: Opening remarks about the research topic, purpose, main directions and ideas of scientific research, brief description of the scientific and practical significance of the work, brief description of the research methodology, main results and analysis, conclusions of research work, the value of the research carried out (contribution of this work to the relevant field of knowledge).

Keywords – 3-5 words.

Introduction consists of the following main elements: Justification of the choice of topic; relevance of the topic or problem. In substantiation of the choice of topic based on the description of the experience of predecessors, the presence of a problem situation (the absence of any research, the emergence of a new object, etc.) is reported.

The relevance of the topic is determined by the general interest in the knowledge of this object, but the lack of comprehensive answers to the questions, it is proved by the theoretical or practical significance of the topic.

In the literature review section, fundamental and new works on the subject matter of foreign authors in English should be covered (at least 15 works), analysis of the given works in terms of their scientific contribution, as well as research gaps that you supplement in your article.

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Conclusion – synthesis and summarizing the work at this stage; confirmation of the truth of the statement put forward by the author, and the author's conclusion on the change of scientific knowledge, taking into account the results obtained. Conclusions should not be abstract, they should be used to summarize the results of research in a particular scientific field, with a description of the proposals or opportunities for further work.

References consists of at least 15 titles, and from the total number of titles in English must be at least 50%. style of the list of references – American Psychological Association (http://www.apastyle.org/). The list of references is presented in alphabetical order, and ONLY those works that are cited in the text. References to cited works in the text are given in brackets, indicating the first author of the work, year of publication: the number of pages. For example, (Zalessky, 1991: 25). Publication cost – 2000 tenge/page

МАЗМҰНЫ – CONTENTS – СОДЕРЖАНИЕ