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Enhancing human capital for national economic competitiveness: Assessment of international experience

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Abstract. The innovation component, one of the most important parts of which is human capital, is beginning to play a leading role in the modern conditions of economic development. This determines the research relevance of assessing its condition and opportunities for its development in different countries. The study aimed to analyse human capital in developed countries and to find opportunities for using their experience in Kazakhstan. Within the framework of the research, the possibilities of the Republic of Kazakhstan to increase its competitiveness in the international arena were assessed. The state of certain components of human capital in the country was also described, namely in the context of education and health care, and positive trends in these areas were noted. By analysing the experience of developed countries, ways to increase the level of human capital in the country were shown. Reforms should be aimed at improving the quality of education and making it more selective: in other words, it should become less accessible to increase its value. Concerning health care, the country should undertake reforms that would be aimed at developing insurance in the field to enable the provision of health care services to citizens. The study also showed that by implementing such reforms, the country can achieve significant positive results in human capital development in the long run. The work brings new knowledge for assessing the innovativeness of economic development, as well as finding new solutions and opportunities to improve the state of human capital in Kazakhstan

Keywords: public policy; international relations; innovation; education; health care

Introduction

Innovative economic development is a key factor determining competitiveness and sustainability in competition with other countries. It refers to the creation, adoption and scaling up of new ideas, technologies and approaches that increase productivity, reduce costs, and improve quality of life. The latest technologies drive economic growth by creating new markets, jobs, and development opportunities. They also play a significant role in addressing global challenges related to health or the environment. In turn, one of the most important components of innovative development is human capital. It is the totality of knowledge, skills, experience, and abilities that a country's citizens possess. It includes both the level of education of the population and the innovations they propose and develop. It can also include the entrepreneurship of the local population, which is a special personality trait that, among other things, allows the introduction of the latest technologies. Considering all the above information, it remains relevant to research the assessment of human capital in different countries.

Many scientists studied the assessment of the development of innovativeness in Kazakhstan. G.K. Issayeva *et al.* (2020) assessed the scientific and innovative development of Kazakhstan. They showed that science and innovation in Kazakhstan suffer from underfunding, and state funding of innovation activities is inefficient. In addition, the scientists formed certain recommendations for the formation of state policy in this direction, but without assessing foreign experience. Nevertheless, little attention was paid to the human capital component. A. Kazhmuratova *et al.* (2020) assessed the innovative development of Kazakhstan in the context of solving environmental problems. Scientists noted the importance of introducing new technologies in the country to operate enterprises and reduce their emissions into the environment more efficiently. Researches also noted tips for the formation of public policy in this direction, but primarily in terms of legislation, ignoring other areas.

R.E. Janshanlo *et al.* (2019) described the existing trends in the context of human capital management in the country. The scholars highlighted the role of increasing life expectancy, reducing poverty and providing quality education for the development of human capital in the country. However, the study did not provide a detailed analysis of the factors influencing the effectiveness of these policies. D. Toimbek (2022) described the formation of human capital in Kazakhstan, but he did it rather superficially, without a deep analysis of cause-and-effect relationships. Moreover, the study lacked empirical data to support its conclusions.

S.S. Baktymbet *et al.* (2023) analysed human capital as a driving force of economic growth, emphasising investments in research and development (R&D) and higher education as key factors for improving human capital. The study identified both the strengths and weaknesses of Kazakhstan in this regard, and advocated for increased enrolment in higher education to align with global trends. Furthermore, they stressed that improving the quality of university education and aligning it with international standards is essential for enhancing the competitiveness of the Kazakhstani workforce. Another study by K. Bokenchin *et al.* (2024) examined the impact of technological innovations in Kazakhstan's mechanical engineering sector, demonstrating that increased R&D investment and accelerated technology adoption could significantly improve production efficiency. Despite the focus on the industrial sector, the findings underscore the broader significance of innovation policies for human capital development. However, the research did not sufficiently explore the role of vocational education and training in preparing the workforce for these technological transformations.

R.E. Janshanlo *et al.* (2020) provided a comprehensive analysis of human capital composition in Kazakhstan, underscoring the need for continuous investments in education, skills, and health to enhance economic performance. The authors emphasised the role of human capital in fostering economic growth and global competitiveness. Nonetheless, the study was largely descriptive and lacked comparative insights from other countries with similar

economic structures. In a similar vein, I. Bumane *et al.* (2024) examined the role of human capital in Kazakhstan's manufacturing industry, demonstrating how workforce education, skill development, and professional training contribute to innovation and productivity. They highlighted the necessity of industry-academia collaboration to ensure that educational institutions produce graduates with the skills required by the labour market. However, further research is needed to quantify the specific impact of various educational initiatives on industrial growth.

The study aimed to assess the state of human capital in Kazakhstan, as well as in selected developed countries, and to find opportunities to apply their experience in the country's conditions.

Materials and Methods

The study utilised a diverse range of sources for data analysis. Data from H. Ritchie *et al.* (2023) were employed to assess the Human Capital Index, which quantifies human capital development on a scale from 0 to 1. The index data, provided by the World Bank (2020), were limited for Kazakhstan, covering only 2010, 2017, 2018, and 2020. Despite these limitations, the index remained relevant for examining human capital trends. Additionally, data from the Bureau of National statistics Agency for Strategic planning and reforms of the Republic of Kazakhstan (2023; 2024a; 2024b) were analysed to evaluate education and healthcare in the country. Although the dataset was somewhat constrained, it allowed for conclusions regarding the development of human capital in Kazakhstan. All calculations and visualisations were performed using Microsoft Excel. The study covered the period from 2010 to 2024, ensuring a more comprehensive analysis of trends in human capital development.

A systematic approach was applied to construct a unified model incorporating various factors influencing human capital. This approach facilitated a more precise assessment and ensured that the study's conclusions could be effectively applied in real-world conditions. A comparative analysis enabled the identification of similarities and differences in human capital development between Kazakhstan and selected developed countries, namely the United States, Germany, France, the United Kingdom, Japan, Canada, and Australia. The historical analysis allowed for the identification of long-term trends in human capital development, particularly in education and healthcare. Forecasting was used to estimate the potential future state of human capital in Kazakhstan based on past and current trends. Abstraction facilitated the selection of key factors influencing human capital while limiting extraneous variables. A graphical method was utilised to visualise analysed data, and statistical research methods were applied for quantitative data processing and evaluation.

The analysis of education considered key indicators such as primary school enrolment rates, higher education accessibility, and public spending on education as a share of GDP. The healthcare sector was assessed based on the number of medical institutions, healthcare expenditures, and physician density. By incorporating comparative data from developed countries, the study aimed to identify best practices and potential policy recommendations for enhancing human capital in Kazakhstan.

Results

In modern conditions, one of the main long-term development goals of Kazakhstan is innovativeness. There are many reasons for this. Some of them are quite general: for example, innovativeness in general allows to bring great benefits in the long term by improving the country's competitiveness in the international arena (Sadyrova *et al.*, 2021). It can also generate large revenues for companies, and thus replenish the state budget, improving the country's economic and social prospects. Nevertheless, in the context of Kazakhstan, there are other reasons for this. In particular, one of the main positions of the country's foreign trade is oil, due to which the country's well-being largely depends on its sales. Although, on the one hand, the ability to have and sell to foreign markets large volumes of such resources brings significant dividends for the country, however, it has its risks associated primarily with the dependence on its sales and prices in the international market. As a result, it is impossible to predict future budget revenues accurately enough; this significantly complicates the country's forecasting capabilities and prevents it from thinking through its long-term policy. Thus, the diversification of the country's economy remains an important component, and the development of innovations is an important way to achieve this. In addition, since the country's foreign trade consists primarily of oil, this leads to long-term risks that may arise when the reserves of this product expire or when countries switch to renewable energy sources in the long term (Tjia, 2022). The sale of oil itself also does not create any added value, which does not create a significant advantage in its sale. All these factors allow us to better understand the motivation for increasing the role of innovative development in Kazakhstan. Certain steps have been taken in Kazakhstan to develop human capital in the country. Thus, the quality of education in higher education institutions has been improved in the country, although primarily in large cities, while in small towns the situation remains at approximately the same level. Certain steps have also been taken in the context of healthcare reform.

In general, human capital in a country consists of several indicators. They can be divided into two main ones: education (school, higher and formal education) and health (both physical and mental). Separately, it is possible mention the experience, innovativeness, and competencies of citizens, but they somehow depend on the level of education in the country (Ponomarenko & Pysarchuk, 2024). Thus, research in the context of human capital should be primarily aimed at assessing these components. The most straightforward method of assessing human capital development is the Human Capital Index (World Bank, 2020; Ritchie *et al.*, 2023). Data for this index are known only in

2010, 2017, 2018 and 2020 for Kazakhstan; although such volumes of information do not allow making any conclusions about the state of human capital, they do provide some information. Thus, in 2010 its value was 0.59, in 2017 – 0.75, in 2018 – 0.78, in 2020 – 0.63. The decrease in 2020 may have been caused by the beginning of the COVID-19 pandemic, but in general, before that, there was an increase in this indicator, which indicates an improvement in the situation in terms of human capital. It is worth noting that Our World in Data also conducted a study on how the level of human capital development interacts with gross domestic product (GDP) per capita. The data shows that both indicators are significantly correlated, which means that there may be a significant relationship between them.

As previously described, one of the components of human capital development is education. There are various indicators for assessing the level of education: for this paper, it was decided to analyse only a few of them, which could show the main trends that exist in Kazakhstan. They are shown in Figure 1.

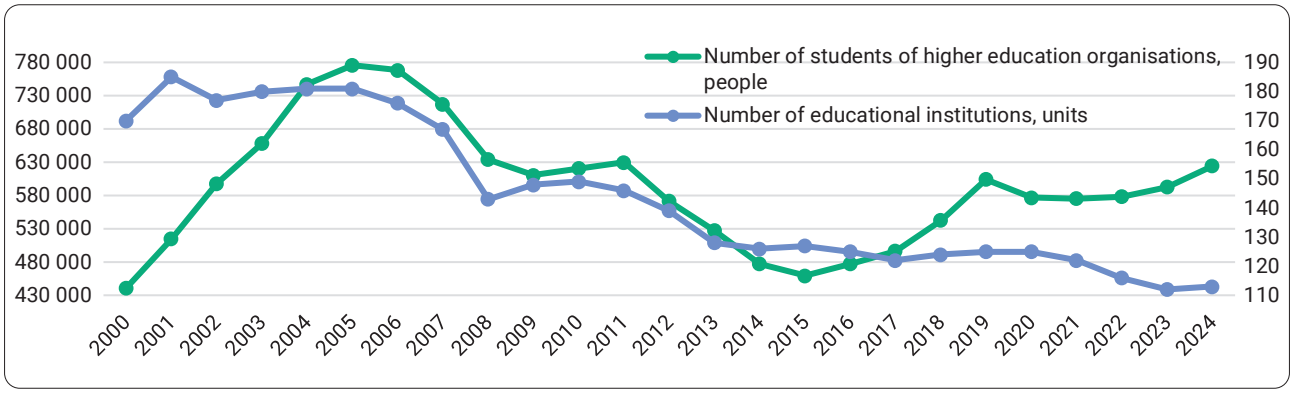

Figure 1. Data on the number of students in higher education organisations and the number of institutions in Kazakhstan from 2000 to 2024

Source: compiled by the authors based on Bureau of National Statistics Agency for Strategic Planning and Reforms of the Republic of Kazakhstan (2023; 2024a)

As can be seen from Figure 1, the number of educational institutions in the country is gradually decreasing. Nevertheless, this is not a negative sign: in fact, this trend is associated with the closure of inefficient and uncompetitive HEIs, which has generally had a positive impact on the ability to provide education-related services in the country. However, in 2024, the number of educational institutions began to increase. The situation with the number of students is not so unambiguous. The number of students gradually increased until 2005, but gradually started to decline until 2015, after which it started to recover. The number of students continued to grow in 2023 and 2024, indicating a steady upward trend. The number of students as of 2022 is higher than in 2020, but the record numbers were much higher in 2004. Thus, it is possible to state the existing difficulties in the context of education development in Kazakhstan. It is also worth considering data characterising the health sector. Official statistics do not provide them in large quantities, but some data can be emphasised from them as well. Information in this context is shown in Figure 2.

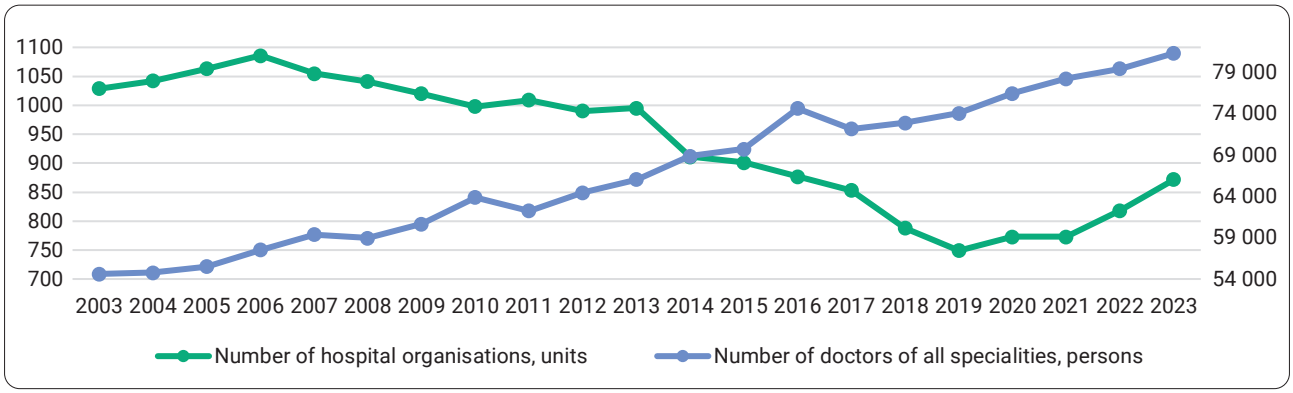

Figure 2. Data on the number of hospital organisations and the number of doctors of all specialties in Kazakhstan from 2003 to 2023

Source: compiled by the authors based on Bureau of National Statistics Agency for Strategic Planning and Reforms of the Republic of Kazakhstan (2024b)

As can be seen from Figure 2, there are two opposite trends in Kazakhstan in terms of healthcare development. Thus, the number of hospital organisations in the country increased until 2007, after which it gradually declined until 2019. However, from 2020 to 2023, the number of hospitals began to grow again, reversing the previous downward trend. At the same time, the number of doctors has been steadily increasing. The increase in the number of doctors can be directly linked to improvements in human capital. However, the data in the context of the number of hospital organisations is rather ambiguous. A decrease in their number should indicate a deterioration in the healthcare sector as a whole, but this is not the case: the trend is related to the liquidation or consolidation of inefficient medical institutions, which leads to better functioning of the sector. This indicates that the human capital development situation is also improving in the healthcare sector.

To better understand the current state of human capital development in Kazakhstan, a comparison with some other countries is appropriate. The comparison for one of these indicators is shown in Table 1.

Table 1 shows the number of populations per 1 university in selected countries. Accordingly, the lower this indicator is, the better the level of education in the country and human capital should be. As can be seen, in Kazakhstan this indicator is at a fairly good level, although the large number of universities is also due to their general inefficiency. Other variables can be seen in Table 2.

Table 1. Estimated population per university in selected countries

Index	Number of universities	Population (millions)	Population per 1 university, thousand
India	5349	1408	263.2
Indonesia	3277	273.8	83.6
USA	3180	331.9	104.4
China	2495	1412	565.9
Brazil	1264	214.3	169.5
Mexico	1139	126.7	111.2
Japan	992	125.7	126.7
France	625	67.75	108.4
Germany	461	83.2	180.5
Poland	408	37.75	92.5
South Korea	401	51.74	129
Canada	383	38.25	99.9
Philippines	366	113.9	311.2
Pakistan	359	231.4	644.6
United Kingdom	337	67.33	199.8
Italy	289	59.11	204.5
Spain	276	47.42	171.8
Turkey	209	84.78	405.6
Kazakhstan	116	19	163.8

Source: compiled by the authors based on S. Galan (n.d.)

Table 2. Selected indicators characterising educational development in selected countries

Index	Share of children of primary school age who are in school, in 2019	Population having attained at least some formal education	Average learning outcomes*	Public spending on education as a share of GDP, %
Kazakhstan	86.9	99.9	416.2	4.45
United States of America	94.6	99.7	511.8	6.05
Australia	96.4	99.1	515.7	6.1
Japan	100	99.8	537.7	3.42
Germany	90.1	98.4	517.3	4.66
France	98.9	98.9	510.3	5.5
United Kingdom	99.5	99.9	520.4	5.53

Note: * – average learning outcomes correspond to harmonised test scores across standardised, psychometrically robust international and regional student achievement tests

Source: compiled by the authors based on H. Ritchie *et al.* (2023)

As can be seen in Table 2, Kazakhstan has indicators that lag behind those of developed countries. For example, not all children still attend primary school, budget expenditures are not high enough in this area, and the level of education remains very low. To find methods to improve the state of human capital in Kazakhstan, it is worth

evaluating the experience of developed countries. For this purpose, it is possible to consider the history of the development of this component in European countries. In the 19th and 20th centuries, there was a clear core-periphery structure in education across Europe: the industrialised core countries, such as Germany, Northern France, and Scandinavia, had high levels of numeracy and literacy, while the periphery in Western, Southern and Eastern Europe had lower levels of education (Huang *et al.*, 2021; Deming, 2022). Similar effects were observed in terms of urbanisation: people in urban areas were more literate than those in rural areas. Nevertheless, educational attainment in the countries improved over time. This was primarily influenced by government policy, which at the time was aimed at building new educational institutions to stimulate junior and secondary education among the population. Subsequently, support for education also increased among entrepreneurs who needed specialists (Attanasio *et al.*, 2022; Zhang *et al.*, 2023; Butenko *et al.*, 2023). Thus, actions towards the formation of a more accessible higher education system began to be applied. The current model of education in developed countries, in contrast to post-Soviet countries, is characterised mainly by tuition fees. However, there are still opportunities for grants or free places (the number of which is lower than in transition countries).

Thus, the state authorities of Kazakhstan should think about reforming the existing education system to increase the efficiency of services provided by educational institutions. The main problem in the country is that higher education remains accessible to a fairly wide range of the population, and it remains much easier to obtain than in developed countries. As a result, specialists educated in the country are valued much less, which in turn reduces the motivation to study among students, which lowers the level of education and so on. The reform should not only improve the quality of teaching (which may require significant investments from the state budget) but also make it more difficult to get an education and strengthen the selection process to increase its value. This will improve the quality of human capital in the country in the long term. In terms of healthcare systems, they also differ significantly from those implemented in developing countries, particularly those in transition (Yarovaya *et al.*, 2021; Kuzior *et al.*, 2022). In Canada, for example, the government finances the bulk (about 70%) of health insurance, while the private sector provides the services. Insurance is provided at the provincial level, and many Canadians have additional private insurance for drugs and dental care. In the UK, health services are also socialised and financed by the National Health Service (80% of the sphere is financed by the state). That said, most services in the country are free. Private insurance exists, but it is only used by about 10% of the population (Angrist *et al.*, 2021; Wang *et al.*, 2023; Khan *et al.*, 2023). Both countries spend about 10% of their GDP on health care, and the quality of care is generally good. However, they do not exceed international averages.

The other is the health care system in the United States. Their system is largely dominated by private companies. Healthcare services are provided by private medical facilities and doctors. They are provided through both private and public systems such as Medicare. Despite the variety of insurance programmes, there are still a significant number of people in the US without health insurance. Given that the provision of health services in the country is generally quite expensive due to the current system, it is often problematic for such people to get proper medical care (Ng *et al.*, 2024). Singapore has a different approach: primary health care in public hospitals is available at low cost and often free of charge. Private hospitals, on the other hand, charge a fee for services. In the country, citizens contribute part of their income to compulsory savings accounts used for health, education, and social welfare projects, which are then managed and channelled by the state (Ng *et al.*, 2024). In France, health insurance is sold by small non-profit organisations and financed by taxes. Public insurance covers 70%-80% of costs, while voluntary health insurance covers the remaining costs (Benoît & Coron, 2019). In Australia, inpatient care in public hospitals is free and includes medical services and prescription drugs. Private health insurance provides access to private hospitals and services not covered by the public system (Ng *et al.*, 2024). Such a list could go on for quite some time. The systems that exist in public countries, although there are some differences, are generally characterised by some common features. For example, they all have well-developed health insurance systems, which, in contrast, are not common in transition countries and Kazakhstan in particular. Thus, state authorities should pay more attention to the opportunities for reforms in this area for the development of human capital.

Discussion

Thus, based on the experience of developed countries, the authorities of Kazakhstan can use some components related to education and health care reforms. Hence, it is effective to improve the quality of education in general to international standards, which can be achieved by closing uncompetitive universities, restructuring the higher education system to make access more selective, introducing merit-based scholarship programmes, and applying public-private partnerships to bring education in line with labour market needs. Concerning health care, it is important to introduce a comprehensive health insurance system that combines elements of public and private financing (Pētersone *et al.*, 2021). In this context, it would be effective to increase the role of non-state funds in the country. State authorities should also allocate a larger share of the budget to ensure that quality services are available to all citizens (Ketners, 2024). Despite all this, the country should develop its health insurance programmes to meet the needs of different population groups. Only by doing so will it be possible to make significant progress in terms of improving the efficiency of the healthcare system and increasing the quality of human capital.

Human capital formation in the European region was assessed by R. Hippe (2020). In it, the scientist emphasised the regional distribution of human capital: the main industrialised countries have a higher level of human capital, while the peripheral regions have a lower level. The scholar believes that this can be influenced by many factors such as geography, economic development, and government policies. The importance of individual incentives to invest in human capital, especially in peripheral regions, was also emphasised. The role of education in these processes was also emphasised. Thus, given the increasing role of human capital in improving the competitiveness of countries in the world, the scholar writes about the need to give this component much more attention than it has at the moment. The work above also formed a conclusion about the high role of human capital in countries. It is worth noting, however, that this component plays a particularly large role for developing countries since their main goal is to obtain a higher level of competitiveness in the international arena. For Kazakhstan, this is also important due to certain peculiarities of the country's development, in particular, its dependence on the export of resources and their price in international markets.

V. Sima *et al.* (2020) studied the impact of the Industry 4.0 revolution on human capital development and consumer behaviour. Researchers noted that new technologies, especially digitalisation and information technology, are changing the way businesses operate. Changes are also taking place within the concept of innovation capital: it is becoming a more creative innovation resource, as well as significantly more valuable. Researchers have also pointed out that traditional jobs in sectors such as manufacturing and agriculture may soon be automated, which in turn may lead to the creation of new jobs in areas such as health and education. To adapt to these changes, employees need to acquire new skills, especially digital skills, as well as continually undertake specialised courses related to retraining (Alishli *et al.*, 2024). When analysing the drivers that contribute to the emergence and development of human capital, scholars pay particular attention to education, describing its role in providing the population with the right knowledge and skills to be useful citizens to society in today's harsh fast-changing environment. Thus, the scholars write about the need for the state to pay much more attention to the development of human capital; they recommend devoting more resources to supporting such activities, which could secure the steady improvement of this component of innovation capital. They also note the need to pay attention to the development of such components of human capital development as health care and education. In Kazakhstan, improving the quality of higher education, with a possible transition to the model of developed countries, remains particularly important. In the long term, this should lead to significant positive results in the context of the quality of human capital.

S.A. Sarkodie *et al.* (2020) analysed the impact of individual components on China's economic development, one of which was human capital. The scholars observed that the growth of human capital and fossil fuel energy consumption in China leads to increased environmental degradation and emissions. At the same time, human capital was seen as a critical component of knowledge and skills that contribute to economic development. In addition, scholars have noted the importance of continuous education and skills development to maintain and increase human capital due to its gradual depreciation over time (diminishing relevance of past knowledge). This remains relevant for Kazakhstan, which in general has certain difficulties in terms of the quality of education provided (Khamzina *et al.*, 2020). Thus, public policy in this context should focus not only on improving the current efficiency of services provided but also on creating a flexible system that allows for rapid changes in programmes to keep students' education up to date.

T. Sultana *et al.* (2022) examined the relationship between human capital and economic growth in their study. The scholars observed that in both developed and developing countries during the selected period (1980 to 2008), there was a positive interdependence between human capital and economic growth in developing countries. In turn, a different scenario was observed in developed countries. In particular, increasing life expectancy hurt economic growth, probably due to population ageing. Only if life expectancy is excluded, is expenditure on health care and other educational aspects of human capital contribute to sustainable growth (Kichurchak, 2024). The study emphasises the importance of considering both educational and health indicators of human capital simultaneously to assess their impact more accurately on economic growth. Since Kazakhstan is essentially a developing country (with an economy in transition), the development of human capital in the country will lead to a significant economic and social breakthrough, as noted above.

R. Khan & I.S. Chaudhry (2019) examined the impact of human capital on employment and economic growth in developing countries as part of their study. The scholars observed that, for human capital development, governments in developing countries should allocate more resources to education. This includes improving the quality of education in rural areas, strengthening primary school systems, ensuring that every child has access to education, improving school infrastructure, and monitoring the punctuality and regularity of teachers. In addition, providing not only primary education but also secondary and tertiary education is important. Researchers also recommend paying attention to the health sector to increase the life expectancy of citizens. This includes providing basic health centres, free medicines for the less privileged, child and maternal health centres, clean water, and better sanitation.

Conclusions

Thus, the development of innovation and human capital is critical to Kazakhstan's long-term prosperity and economic stability. As a country heavily dependent on oil exports, Kazakhstan faces inherent risks associated with volatile oil

prices and changing global energy trends. To mitigate these risks and ensure sustainable economic growth, the country must diversify its economy and invest in innovation, education, and healthcare. Innovative development can enhance Kazakhstan's international competitiveness, generate revenue for both business and government and pave the way for economic and social progress.

The research findings highlight key trends in human capital development. The Human Capital Index for Kazakhstan increased from 0.59 in 2010 to 0.78 in 2018, followed by a decline to 0.63 in 2020, likely influenced by the COVID-19 pandemic. Despite the decrease, the long-term trend demonstrates an improvement in human capital before 2020. In the education sector, the number of higher education institutions declined over time due to the closure of inefficient universities, while student enrolment showed fluctuations: an increase until 2005, a decline until 2015, and a steady recovery thereafter, with growth continuing into 2023 and 2024. In 2022, the number of students exceeded 2020 levels but remained below the record highs of 2004. These findings indicate existing challenges in the educational system despite ongoing reforms.

The healthcare sector also experienced contrasting trends. The number of hospital organisations increased until 2007, declined until 2019, and began growing again from 2020 to 2023. Simultaneously, the number of doctors per capita has steadily increased, contributing to human capital growth. However, the consolidation of healthcare institutions, while improving efficiency, raises concerns regarding accessibility to medical services in some regions. To enhance human capital, the study proposes reforms in education and healthcare. Educational reforms should focus on improving quality and selectivity, ensuring that university graduates meet international standards. The introduction of merit-based scholarships and stricter selection criteria will enhance the value of higher education. In healthcare, Kazakhstan should develop a comprehensive insurance system combining public and private funding, similar to developed nations. Expanding state insurance coverage and increasing healthcare spending beyond the current 4.45% of GDP would improve accessibility and service quality.

Kazakhstan's commitment to innovative development and human capital improvement is crucial for long-term prosperity. By diversifying the economy, strengthening education and healthcare systems, and adopting best practices from developed countries, Kazakhstan can enhance its competitiveness, reduce its dependence on oil revenues, and secure sustainable growth. However, achieving these goals requires long-term investment, strategic planning, and continuous policy reform. Further research should assess additional components of Kazakhstan's innovative development, including technological advancements and competitiveness in new technology production on the international stage.

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Conflict of Interest

None.

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Посилення людського капіталу для національної економічної конкурентоспроможності: оцінка міжнародного досвіду

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Анотація. Інноваційний компонент, одним із найважливіших складників якого є людський капітал, починає відігравати провідну роль у сучасних умовах економічного розвитку. Це зумовлює актуальність дослідження оцінки його стану та можливостей розвитку в різних країнах. Метою дослідження був аналіз людського капіталу в розвинених країнах та пошук можливостей використання їхнього досвіду в Казахстані. У межах дослідження було оцінено можливості Республіки Казахстан щодо підвищення її конкурентоспроможності на міжнародній арені. Також було охарактеризовано стан окремих компонентів людського капіталу в країні, а саме в контексті освіти та охорони здоров'я, і відзначено позитивні тенденції в цих сферах. На основі аналізу досвіду розвинених країн було визначено шляхи підвищення рівня людського капіталу в країні. Реформи мають бути спрямовані на підвищення якості освіти та її селективність: іншими словами, вона має стати менш доступною, щоб підвищити її цінність. Щодо охорони здоров'я, країні слід провести реформи, спрямовані на розвиток страхування у цій сфері, що дозволить забезпечити громадян необхідними медичними послугами. Дослідження також показало, що впровадження таких реформ може призвести до значних позитивних результатів у розвитку людського капіталу в довгостроковій перспективі. Робота містить нові знання для оцінки інноваційності економічного розвитку, а також пошуку нових рішень і можливостей для покращення стану людського капіталу в Казахстані

Ключові слова: державна політика; міжнародні відносини; інновації; освіта; охорона здоров'я

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Environmental challenges and the impact of human capital on Azerbaijan's foreign economic activity

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Abstract. The aim of this study was to analyse the main environmental challenges of Azerbaijan, their impact on the economy and international trade, and to assess the role of the quality of human capital in the country's adaptation to these challenges and the development of innovative solutions to reduce the negative impact on the environment. The study used an analytical approach that included the analysis of atmospheric emissions, such as CO_2, methane and nitrogen oxides, the assessment of their economic impact, as well as the analysis of the Human Development Index (HDI) indicators, which covered the level of education, health and standard of living of the population. The study analysed Azerbaijan's environmental challenges, including air pollution, land degradation, water scarcity, and climate change, highlighting their significant economic impacts, such as losses of 0.11-0.14% of gross domestic product (GDP) from air pollution, 10-11 billion manats annually from land degradation, and reduced productivity in key sectors. The results of the study showed that Azerbaijan's HDI changed from 0.762 in 2019 to 0.722 in 2020 due to the impact of the COVID-19 pandemic, and by 2022 it had increased to 0.760, almost returning to the 2019 level, indicating the effectiveness of measures to restore the economy and improve the quality of life. The study also found significant disparities in vocational education levels, with enrolment at only 12.4% of the total number of students in 2020, limiting the country's innovation potential. Azerbaijan's participation in international environmental initiatives, such as cooperation with the Green Climate Fund, which promotes the introduction of modern technologies in renewable energy, including the development of solar and wind power plants, was assessed. The results demonstrate that developing human capital, strengthening environmental culture, and implementing environmentally friendly technologies can contribute to sustainable economic growth, reducing environmental burdens, and increasing the country's international competitiveness

Keywords: sustainability; export; renewable energy; climate; workforce

Introduction

The study of environmental challenges and human capital's impact on Azerbaijan's foreign economic activity is highly relevant amid global transformations. Azerbaijan's natural resources and strategic location position it as a key player in global trade, but climate change, resource depletion, and industrial impacts threaten its economic stability and competitiveness. Developing skilled human capital is vital for reducing reliance on oil exports and transitioning to a knowledge-based economy. Addressing environmental challenges while leveraging human capital underscores the need for a comprehensive approach to sustainable development.

Achieving sustainable economic growth and preserving environmental quality is a challenge for modern economies. B.R. Rexhepi *et al.* (2024) studied the impact of foreign direct investment (FDI), energy consumption and technological innovation on the economy and environment of BRICS countries. FDI promotes growth, but increases CO_2 emissions, while innovation reduces them, increasing environmental sustainability. The integration of eco-technologies in developing countries and mechanisms for balancing the economy and the environment need to be further studied.

Economic growth, foreign investment, and environmental pollution are key topics for developing countries. T.T. Le *et al.* (2022) analysed the relationship between FDI, CO_2 emissions, and economic growth using a nonlinear autoregressive distributed lag model. They found that FDI asymmetrically affects growth in the short run, while pollution influences growth in both the short and long run. Positive CO_2 changes boosted growth by 0.662%, while reductions negatively impacted economic activity. The study highlighted gaps, such as limited analysis of factors like technology, trade, and logistics, and the need for broader geographic coverage.

Economic growth in Africa faces significant challenges, including low quality human capital and weak institutional frameworks. F.O. Anetor & O. Vincent (2022) studied how human capital and institutional quality affect the relationship between FDI and economic growth in 46 African countries. The results showed that FDI alone does not stimulate economic growth, but its positive effect is enhanced in countries with high quality human capital and institutions. For low-income countries, FDI has a limited effect due to weak institutions and low technology absorptive capacity (Ismayilov *et al.*, 2024). Gaps include insufficient research on specific mechanisms for improving human capital quality and how to reform institutions to optimise the use of FDI.

Human capital development is crucial for economic growth, especially in diversifying economies (Sadikhov, 2024). L. Zeynalli (2020) examined its impact on Azerbaijan, identifying low education levels, limited healthcare access, and brain drain as key obstacles. Countries with stronger human capital achieve faster growth due to higher productivity and innovation. The study highlights gaps in addressing barriers to education and healthcare access and evaluating the role of innovative technologies in resource-limited settings.

The impact of human capital development on economic growth is critical amid current challenges. H.S. Baghirov *et al.* (2022) found that investments in IT and economic diversification enhance human capital and resilience in Azerbaijan, reducing reliance on oil and gas while supporting agriculture. Gaps include studying long-term war impacts, global changes, and technology integration for human capital growth.

Fuel and energy resource development significantly affects Azerbaijan's economy (Musayeva *et al.*, 2024). A. Mirheydarova & M. Orujov (2023) highlighted the oil

and gas sector as a growth driver but a major contributor to pollution. They stressed the need for economic diversification, renewable energy, and stricter environmental laws. Gaps involve analysing alternative energy impacts and integration into existing infrastructure.

The link between renewable energy and economic growth is crucial for countries like Azerbaijan and Hungary. S.I. Humbatova *et al.* (2024) found that in Azerbaijan, economic growth negatively affected hydropower, wind, and solar energy production, while overall energy supply remained stable. In Hungary, it reduced CO_2 emissions and boosted renewable energy production. Gaps include analysing long-term economic impacts on renewable energy and CO_2 reduction technologies.

Human capital is vital for sustainable development. S. Pürhani *et al.* (2022) highlighted professional development, labour availability, health, and financial inclusion as key components. Human capital quality drives economic, social, and environmental progress, especially through innovative technologies. Gaps involve insufficient focus on gender inequality and reducing environmental risks amid labour force growth.

The purpose of this study was to analyse the main environmental problems of Azerbaijan, their impact on the economy and international trade, and to assess the role of human capital quality in the country's ability to adapt to environmental challenges and develop innovative solutions to reduce the negative impact on the environment. The objectives of the study were to analyse the main environmental problems of Azerbaijan, in particular the level of atmospheric emissions and their impact on the economy and international trade, to assess the role of human capital quality in the country's ability to adapt to environmental challenges, and to investigate how the development of environmentally responsible human capital affects the competitiveness of Azerbaijani goods and services in the international market.

Materials and Methods

The study, conducted in 2019-2022, was comprehensive in nature and based on an analytical approach that combined qualitative and quantitative methods of data collection and analysis. It covered the study of environmental challenges, their impact on the economy and international trade of Azerbaijan, as well as the analysis of human capital as a factor of adaptation to modern challenges. The type of research is applied, focused on solving practical problems to improve the country's international competitiveness. The main sources of data were national statistics, international reports, scientific articles and analytical studies. The Human Development Index (HDI) (2024) was used to assess the level of human capital, covering indicators of education, health and living standards of the population. The HDI analysis helped identify the main trends and challenges related to the development of human capital in Azerbaijan, including access to quality education, the level of vocational training and innovative activity.

The study included an analysis of key environmental indicators, such as CO_2, methane and nitrogen oxide emissions, and their impact on economic activity and international trade (Steen, 2001; Sakata *et al.*, 2024). The main sources of emissions were taken into account, including industry, energy, agriculture and transport, with a further assessment of the effectiveness of existing environmental initiatives. To study the environmental problems of Azerbaijan and their economic consequences, a table was used that included an analysis of the main environmental challenges, their impact on the economy and international trade based on scientific publications (Bayramli, 2020; Chepeliev *et al.*, 2024) and official reports (Global Alliance on Health and Pollution, 2024; Climate Centre, 2024).

In addition, international partnerships were analysed, such as cooperation with the Green Climate Fund that contributed to the implementation of advanced environmental solutions (Mammadov, 2024). An important element of the study was the analysis of the role of environmental awareness of employees in reducing the environmental impact of production processes and increasing the competitiveness of products in international markets.

The materials and methods of this study encompassed a comprehensive analytical approach aimed at studying environmental challenges and their impact on the Azerbaijani economy and international trade, as well as the role of human capital in overcoming these challenges. Key environmental indicators, such as CO_2, methane and nitrogen oxide emissions, were studied to assess their economic impact. Special attention was paid to the role of education and vocational training in the formation of environmentally responsible human capital, in particular, disparities in vocational and higher education coverage and their impact on the labour market were analysed.

The solution examined the development and integration of renewable energy, smart technologies and artificial intelligence (AI) projects in the field of energy management. International partnerships, such as initiatives under the Green Climate Fund, were assessed, as well as cooperation with organisations such as the European Bank for Reconstruction and Development (EBRD) (Bitsadze, n.d.) to highlight their contribution to Azerbaijan's progress in the environmental and economic spheres.

Results

Evaluation of global environmental challenges

Environmental issues are one of the biggest challenges in the modern world, especially in the context of the growing impact of economic activity on the environment. Ecosystems are severely strained by industrialisation, urbanisation, rising energy consumption, and the growth of transportation infrastructure; therefore, sustainable development calls for solutions. The examination of atmospheric emissions, which have a major influence on human health, air quality, and worldwide economic activity, is one of the most important components. Industry, energy, transportation, agriculture, and the domestic sector are the primary

sources of atmospheric emissions worldwide today. Because of its large emissions of greenhouse gases like carbon dioxide (CO_2), methane (CH_4), and nitrogen oxides (NO_x), industry is a major contributor to air pollution. For instance, in addition to using a lot of energy, the cement and chemical industries also produce CO_2 emissions through chemical reactions related to burning limestone. A major source of emissions is the metallurgical sector, which uses high-temperature processes (Sakata *et al.*, 2024).

One of the biggest producers of greenhouse gases is the energy industry, which mostly depends on fossil fuels like coal, oil, and natural gas. As the most affordable and plentiful energy source in many nations, coal contributes significantly to CO_2, SO_x, and PM emissions. Although their effects are marginally less significant than those of coal, the burning of natural gas and oil also contributes to air emissions. Furthermore, fugitive emissions of methane, one of the most hazardous greenhouse gases because of its high potential heat-trapping capacity, are a by-product of the extraction and transportation of energy resources (Steen, 2001; Zlenko & Isaikina, 2020).

Another significant source of air pollution is the transportation industry. CO_2, NO_x, and volatile organic compounds are released as a result of the increasing number of automobiles, airplane trips, and sea transportation. Because of the high concentration of pollutants, road transportation using antiquated internal combustion engines that do not adhere to contemporary environmental requirements is a significant challenge for megacities. Simultaneously, the lack of adoption of hybrid and electric vehicles slows down the industry's efforts to reduce pollution (Steen, 2001).

Air emissions are also significantly influenced by agriculture. The amount of greenhouse gases in the atmosphere is greatly influenced by methane released during the production of rice and livestock as well as nitrogen oxides from the use of nitrogen fertilisers. Furthermore, burning agricultural waste results in high concentrations of fine particulate matter ($PM_{2.5}$), which deteriorates the quality of the air in rural areas and nearby areas (Guliyeva, 2023).

The amount of economic activity and the composition of the economy are directly correlated with the amount of emissions into the atmosphere. Emissions often rise in emerging nations in tandem with increases in industrial production and energy use. For instance, rising industrial production and fast urbanisation are frequently coupled by rising fossil fuel usage, which causes air pollution to rise sharply. In wealthy nations, things are frequently a little different. They can reduce emissions while experiencing economic growth because of the advent of energy-efficient technologies and the shift to a green economy. Carbon capture and storage technology, for instance, help lessen the impact of conventional energy facilities, while the usage of renewable energy sources, such solar and wind power, can lower CO_2 emissions. Global trends indicate that nations like China and India, which have sizable populations and rapid economic expansion, continue to be the biggest contributors to atmospheric emissions. Meanwhile, these nations are progressively implementing more stringent environmental regulations, which could eventually alter the course of events (Dziejarski *et al.*, 2023).

Global economic cycles are also associated with changes in emissions. Emissions have temporarily decreased during economic crises, such as the COVID-19 epidemic or the 2008 financial crisis, due to sharp drops in industrial production and energy use. Nevertheless, these downturns are often brief, and as soon as the economy improves, emissions swiftly reach or surpass their prior levels (Avgousti *et al.*, 2023). The economy of the globe are severely challenged by environmental difficulties. Because of increased sickness, decreased productivity, and shortened life expectancy, air pollution raises healthcare expenses. For instance, long-term respiratory conditions brought on by elevated airborne particulate matter lower worker productivity and raise medical expenses.

The economy of the globe are severely challenged by environmental difficulties. Because of increased sickness, decreased productivity, and shortened life expectancy, air pollution raises healthcare expenses. For instance, long-term respiratory conditions brought on by elevated airborne particulate matter lower worker productivity and raise medical expenses. The significance of environmental issues in global trade is growing. Due to the implementation of carbon taxes and stringent environmental regulations in importing nations, countries with high pollution levels are experiencing a decrease in demand for their goods. The Green Deal, for instance, is being implemented by the European Union with the goal of lowering carbon emissions at every stage of the production process. Because of this, exporters that rely on conventional energy sources face difficulties and must adopt environmentally (Avgousti *et al.*, 2023). Table 1 summarises the main environmental problems in Azerbaijan and their economic consequences, including the impact on international trade and the estimated economic losses.

Table 1. Main environmental problems and their economic consequences in Azerbaijan

Environmental problem	Primary causes	Economic consequences	Impact on international trade	Estimated economic losses
Air pollution	1. Oil and Gas Industry (oil extraction, transportation, refining). 2. Industrial Activities (metallurgical plants, emissions of NO_2, CO_2, etc.) 3. Vehicle Emissions. 4. Agricultural Practices (excessive use of fertilisers and pesticides). 5. Energy Production (thermal power plants, emissions of SO_2, NO_2, particulate matter).	1. Health care costs due to respiratory diseases. 2. Decreased worker productivity due to health issues. 3. Cost of air pollution control measures.	1. Non-compliance with environmental standards can lead to trade barriers or sanctions. 2. High levels of air pollution can deter foreign investors prioritizing sustainability. 3. Stricter regulations in international markets could hinder trade.	1. The economic costs of air pollution are estimated to be between 0.11% and 0.14% of gross domestic product (GDP) due to lost productivity from pollution-related diseases. 2. Particulate emission damage accounts for about 0.166% of gross national income as adjusted savings.

Table 1, Continued

Environmental problem	Primary causes	Economic consequences	Impact on international trade	Estimated Economic Losses
Land degradation	1. Soil Erosion (water and wind erosion). 2. Salinisation (salt accumulation in soils due to groundwater evaporation). 3. Loss of Natural Vegetation (reduction of soil-protective vegetation cover). 4. Intensive Use of Lands (high economic development and exploitation of lands without protective measures). 5. Unfavourable Climatic Conditions (harsh farming conditions). 6. Inadequate Agricultural Practices (lack of proper soil protection).	1. Decreased agricultural productivity. 2. Increased soil restoration costs. 3. Loss of arable land affecting food security. 4. Losses from soil erosion are estimated at approximately 10-11 billion manats annually.	1. Reduced agricultural productivity, especially for export crops like cotton, diminishes Azerbaijan's competitiveness in global markets. 2. Damage to trade routes due to increased flash floods or mudslides from land degradation.	Annual damages from soil erosion alone are estimated at approximately 10-11 billion manats.
Water shortage	1. Climate Change (reduced precipitation and increased evaporation). 2. Inadequate Infrastructure (outdated canals, wastewater treatment issues). 3. Mismanagement and Corruption (lack of oversight in resource distribution). 4. Agricultural Practices (inefficient irrigation, salinisation). 5. Geopolitical Factors (dependence on external water inflows). 6. Urbanisation and Population Growth (increased demand for water in cities).	1. Increased costs for water transportation and management. 2. Impact on agriculture due to water scarcity. 3. Increased competition for water resources.	1. Water scarcity impacts key sectors like oil, gas, agriculture, and manufacturing, reducing productivity and trade potential. 2. Geopolitical tensions could further strain international trade if disputes over water resources occur.	-
Oil resource depletion	1. Natural Decline of Major Fields (e.g., ACG field). 2. Aging Infrastructure and Lack of New Discoveries. 3. OPEC+ Production Cuts (voluntary reductions in quotas). 4. Global Market Dynamics (fluctuating demand and prices). 5. Geological Limitations (complex geology in Caspian Sea).	1. Reduced national oil revenue. 2. Increased costs for technological advancements to maintain production. 3. Potential job losses in the oil sector. 4. Oil contribution to GDP has been around 30% in recent years.	1. A decline in oil exports directly impacts Azerbaijan's trade balance, given that oil and gas account for about 95% of exports. 2. As global demand for fossil fuels fluctuates, Azerbaijan's trade may be impacted by the transition to cleaner energy sources.	1. The decline in oil exports could lead to significant reductions in government revenue and export earnings. 2. Potential GDP decline by up to 3.3% by 2060 due to global climate policies reducing fossil fuel demand.
Industrial waste accumulation	1. Lack of Effective Waste Management Infrastructure (absence of waste collection systems, treatment facilities, and recycling centres). 2. Insufficient Regulatory Framework (gaps in legislation, unclear roles among institutions). 3. Industrial Activities (oil refineries, chemical plants, hazardous waste generation). 4. Inadequate Data Collection (limited official records on industrial waste) 5. Economic Growth without Sustainable Practices (increase in industrial output without proper waste management).	1. Increased costs for waste management and environmental clean-up. 2. Health costs due to pollution exposure. 3. Loss of public trust in industrial operations. 4. Azerbaijan generated approximately 3,778.2 thousand tons of primary waste in 2021. 5. Cost savings from improved waste management practices can be between 52,000 to 63,000 AZN annually for SMEs.	1. Inefficient waste management practices could lead to delays in production and trade, increasing costs and regulatory challenges.	-
Climate change	1. Temperature Increase (rapid warming due to emissions). 2. Greenhouse Gas Emissions (fossil fuel-based economy). 3. Changes in Precipitation Patterns (decreased rainfall, increased floods). 4. Glacier Melting and Snow Cover Changes (affects water availability).	1. Reduced agricultural productivity (cotton, irrigation-dependent agriculture). 2. Increased frequency and intensity of droughts exacerbate water scarcity. 3. Vulnerability to global decarbonisation efforts. 4. Climate action seen as economically beneficial for diversifying economy 5. Heat events increase health risks, including longer malaria seasons. Rising temperatures and changing precipitation patterns reduce agricultural productivity.	1. Climate change impacts sectors like agriculture, infrastructure, and tourism, which directly affect Azerbaijan's trade with global partners. 2. As global markets shift towards cleaner energy sources, Azerbaijan's fossil fuel exports may face challenges.	1. Projected GDP reductions due to climate change could reach up to several percent over coming decades. 2. Annual costs from extreme weather events amount to approximately USD 70-80 million annually.

Source: compiled by authors based on G. Bayramli (2020), M. Chepeliev *et al.* (2024), Global Alliance on Health and Pollution (2024), Climate Centre (2024)

The analysis of the main environmental issues and their economic implications for Azerbaijan presented in the table shows that these problems have a significant impact on the national economy and international trade.

Environmental degradation, in particular due to air pollution, land degradation, water scarcity, and climate change, not only increases healthcare and infrastructure costs, but also reduces the country's competitiveness in international markets. The lack of effective environmental regulations can lead to trade barriers and sanctions, as well as a decrease in the country's investment attractiveness. Given the close link between economic activity and environmental challenges, Azerbaijan needs to take active measures to improve natural resource management and reduce negative environmental impacts. The government should develop sustainable development strategies that include both adaptation to climate change and efficient use of natural resources to ensure long-term economic stability and maintain competitive advantages in the international arena.

Assessing the impact of human capital on adaptation to environmental challenges

The quality of human capital is one of the key elements that influence the economic development of a country and its ability to adapt to modern challenges. In Azerbaijan, human capital is formed through education, professional development and innovation potential, which are the basis for the development of the competitiveness of the national economy. The education system of Azerbaijan covers several levels: pre-school education (up to 6 years), primary education (4 years), general secondary education (5 years), complete secondary education (2 years), vocational secondary education (1-4 years depending on the program) and higher education (bachelor's degree – 4-5 years, master's degree – 1.5-2 years, doctoral degree – 3-4 years). Despite the availability of general education, its quality remains average, and there is a disparity between general and vocational education (The Republic of…, 2020).

In 2020, 76% of the adult population had secondary education, 16.6% had higher education, and 7.4% completed only primary education or did not receive it at all (European Training Foundation, 2021). In 2020, about 164 thousand people participated in vocational education, which was only 12.4% of the total number of students, 1.6% less than in 2019 (European Training Foundation, 2023). This indicates a low level of participation in vocational education, which is a serious challenge for human capital development. Higher education also faces challenges in meeting the current needs of the labour market. Low participation in vocational secondary education is a significant obstacle to the formation of a competitive labour market. The Azerbaijani government is taking steps to increase the accessibility of vocational education through the involvement of employers in the training process. The State Employment Agency organises professional development programs, including the development of career counsellors and centres at higher education institutions. In addition, measures are taken to improve the skills of teachers through programs of the Centre for Professional Development aimed at improving curricula.

Human capital plays a crucial role in creating an innovative economy. The development of innovative potential is supported by government initiatives aimed at modernising the educational system and introducing digital technologies. Educational transformation focuses on adapting curricula to the requirements of the modern labour market and integrating new technologies into the learning process. The government is also promoting international cooperation with organisations such as the European Training Foundation to implement projects to develop digital skills and support the green transition of the economy. An analysis of the quality of human capital in Azerbaijan shows some achievements in education, professional development, and innovation potential. However, challenges remain: low participation rates in vocational education, a declining share of students in vocational and higher education, and the need to further improve digital technologies (European Training Foundation, 2024). The HDI of Azerbaijan for the period 2019-2022 shows noticeable fluctuations, indicating the impact of both internal and external factors on the socio-economic situation in the country. In 2019, the HDI was 0.762, confirming the stable level of development of the country. However, in 2020, this indicator decreased to 0.722, which can be explained by the consequences of the COVID-19 pandemic, which caused an economic downturn, a slowdown in income growth, worsening employment conditions, and limited access to educational and medical services. The gradual recovery of the economy in 2021 contributed to an increase in the HDI to 0.738, reflecting the adaptation of the labour market, stabilisation of social programs, and the implementation of state initiatives to support the population. In 2022, the indicator reached 0.760, which almost returned the country to the level of 2019, indicating the effectiveness of measures to restore the economy and improve the quality of life of citizens. Changes in the HDI over this period demonstrate the country's vulnerability to global challenges and the need for a strategic approach to human capital development. The recovery of indicators after the crisis indicates Azerbaijan's ability to adapt to changes and ensure a gradual improvement in the quality of life of the population. However, the issue of strengthening the education and healthcare system, increasing the level of citizens' incomes and reducing social risks remains relevant, which can contribute to further growth in the HDI and improving the country's international competitiveness.

Azerbaijan is making significant progress in implementing innovative solutions aimed at reducing its environmental impact, although these initiatives are still in the early stages of implementation. One of the key areas is the use of modern technologies in cities to create conditions for sustainable development. In particular, the capital Baku is actively implementing smart city technologies aimed at improving the efficiency of urban infrastructure. For example, modern traffic management systems allow optimising traffic flows, which reduces air pollution and improves the quality of life of residents. These measures also include the

development of electric transport, which reduces greenhouse gas emissions in the urban environment. Agriculture is also an important area for implementing innovative environmental solutions. Companies such as Frendt are working to create climate-resilient practices that aim to reduce the environmental impact of the agricultural sector. This includes the use of modern technologies to reduce pesticide use, optimise water resources, and reduce greenhouse gas emissions. Such initiatives help make the agricultural sector more efficient and environmentally friendly, while increasing its competitiveness in the international market.

The development of renewable energy sources is another key aspect of Azerbaijan's efforts to reduce its environmental footprint. The country is actively investing in the creation of large-scale solar farms and wind farms, which are part of the Green Energy Hub project. This helps to reduce dependence on traditional energy sources such as oil and gas, which are the main contributors to air pollution. At the same time, the development of hydropower contributes to ensuring a stable supply of clean energy that meets the principles of sustainable development (Hamidova & Samedova, 2024; Nuriyev, 2024).

In the energy sector, special attention is paid to the introduction of AI, which can significantly improve the efficiency of energy management. For example, AI is used to optimise energy production, distribution, and consumption, which reduces losses in power grids and cuts greenhouse gas emissions. Besides, AI technologies are used for predictive maintenance of energy infrastructure, which ensures its stable operation. In particular, such systems are used at wind power plants, which helps to increase their efficiency and reduce maintenance costs (World Economic Forum, n.d.).

International cooperation is an important tool for implementing innovative solutions in the field of environmental protection. Azerbaijan is actively involved in global climate initiatives, such as Conference of the Parties 29 (COP-29), where issues of sustainable development and reducing environmental impact are discussed. Participation in such events allows the country to gain access to best practices and technologies, as well as to develop partnerships with other countries and international organisations. In particular, cooperation with the World Economic Forum contributes to the implementation of advanced solutions in the field of energy efficiency and decarbonisation of urban energy systems (Nuriyev, 2024).

Among the promising areas of international cooperation is the implementation of pilot projects that demonstrate the effectiveness of modern environmental technologies. For example, through a partnership with BrainBox, AI systems were implemented to improve the energy efficiency of buildings, which reduced energy consumption by 30% and emissions by 25-30% (World Economic Forum, n.d.). Such initiatives serve as an example for other sectors of the economy seeking to implement similar innovations.

Notwithstanding its notable accomplishments, Azerbaijan still confronts certain obstacles that prevent environmental innovations from developing further. Increasing investment in green infrastructure, reducing reliance on fossil fuels, and increasing public awareness of environmental issues are the three key challenges. In addition to supporting the integration of contemporary technology into different economic sectors, it is imperative to maintain a balance between environmental standards and economic progress. As a result, Azerbaijan exhibits the capacity to apply creative solutions to lessen their impact on the environment. This is accomplished by using AI technologies, developing sustainable energy sources, and taking part in global projects. Further progress in this area is possible with a comprehensive approach that includes attracting investment, developing educational programs, and strengthening international cooperation.

Azerbaijan pays considerable attention to the development of environmentally friendly technologies, attracting government programs, international cooperation and private investment. This approach helps the country to simultaneously reduce its dependence on fossil fuels and implement innovative solutions to reduce its environmental impact. The main areas of focus include modernisation of energy infrastructure, development of renewable energy, stimulation of the green economy, and support for environmentally friendly transport.

One of the main projects is the Green Climate Fund initiative, which involves the introduction of an early warning system and climate technologies. The Azerbaijani government is also actively cooperating with international financial organisations such as the EBRD and the World Bank to develop energy efficiency in buildings and create a roadmap for offshore wind energy. Private partners such as Masdar and Fortescue Future Industries are developing large-scale renewable energy projects. For a more detailed understanding of the role of public and private initiatives, Table 2 shows the key areas of investment, their volumes, and the projected impact on the country's economy and environment.

Table 2. Key investment areas in the development of environmentally oriented technologies in Azerbaijan

Investment area	Funding amount	Expected impact	Source of funding
Early Warning System	USD 35 million	Coverage of 5.71 million people; disaster risk reduction	Green Climate Fund
Offshore Wind Energy	USD 1 billion (expected)	Installation of 7 GW by 2040	World Bank, IFC
Public Building Modernisation	USD 50 million	30% reduction in energy consumption	EBRD
Renewable Energy Projects (Masdar, FFI)	USD 12 billion	Production of 12 GW of renewable energy	Private Investments

Source: compiled by authors based on Azerbaijan to Strengthen Climate Resilience Through Early Warning Systems (2024), K. Mammadov (2024), J. LaPorte (2024)

The table indicates that private and international funding is crucial to the adoption of environmental technologies. Specifically, funding renewable energy initiatives, like offshore wind farms, can diversify energy sources and drastically cut CO_2 emissions. Support for government initiatives, like modernising buildings and creating eco-friendly transportation, also contributes to lowering greenhouse gas emissions and increasing energy efficiency. As a result, Azerbaijan exhibits a thorough approach to environmental modernisation by integrating private investment, international collaboration, and indigenous resources. This enables the nation to support sustainable economic and social development in addition to addressing the present climatic issues.

Development of environmentally responsible human capital

Employees' environmental awareness is a key factor in ensuring the high quality of goods and services, especially in the context of modern sustainable development. In Azerbaijan, environmental responsibility is being strengthened through educational initiatives, professional training, and support for youth projects. Programs such as NEBOSH Environmental Awareness at Work help raise employees' awareness of the rational use of resources, optimisation of production processes, and the introduction of environmental technologies. Through these initiatives, companies reduce their environmental footprint while improving productivity and competitiveness. Organisations such as EkoSfera focus their efforts on fostering environmental responsibility among the public and businesses. Their projects help businesses integrate environmentally friendly solutions into production processes, which increases consumer confidence in products and services. In addition, such initiatives help avoid reputational risks associated with violations of environmental standards (Marziale, 2024). Youth initiatives, such as Youth Climate Envoys, create a platform for implementing innovative solutions aimed at protecting the environment. Young employees offer new ideas on how to reduce energy consumption and use resource-saving technologies, which has a positive impact on the quality of goods and services (UNICEF, 2023). Employees that care about the environment also help to make better use of energy resources. In addition to cutting expenses, optimising energy use in production processes also lessens the negative effects on ecosystems. For companies looking to fulfil global standards and accomplish their environmental objectives, this adds value. Therefore, increasing the environmental awareness of employees not only enhances the quality of products and services but also lays the groundwork for an ecologically conscious company that satisfies the demands of contemporary customers and international market trends.

The development of environmental culture in Azerbaijan plays an important role in increasing the country's competitiveness in the international market. Government support, international cooperation and promotion of the green economy are key factors in this process. Azerbaijan's efforts to implement environmentally friendly practices demonstrate its commitment to meeting global standards and meeting the needs of environmentally conscious consumers and investors.

Government support is critical to fostering an environmental culture. National programs aimed at protecting nature and sustainable development raise public awareness and create a solid foundation for environmental initiatives. In addition, Azerbaijan's active participation in international climate events, such as COP-29, and green economy initiatives demonstrate the country's commitment to addressing environmental challenges and taking a leading position in global sustainable development efforts.

The integration of environmentally friendly technologies and practices into production processes strengthens Azerbaijan's competitive advantages. Growing consumer demand for environmentally responsible products emphasises the importance of such innovations. The use of green technologies allows enterprises not only to meet market expectations, but also to reduce production costs and increase operational efficiency, which helps to strengthen their position in the international market. As shown in Table 3, the development of an environmental culture directly affects competitiveness.

Table 3. Impact of environmental culture on key economic indicators

Impact Direction	Benefits for the Economy	Potential Outcomes
Energy Efficiency	Reduction of energy resource costs	Increased profitability of enterprises
Environmental Certification	Access to new international markets	Expansion of export volumes
Innovative Technologies	Use of environmentally friendly production processes	Growth in demand for products
International Cooperation	Attraction of international funding	Implementation of large-scale infrastructure projects
Awareness Raising	Formation of environmentally conscious workers and consumers	Increased trust in brands and products

Source: compiled by authors

The development of an environmental culture is an integral part of the economic strategy that contributes to the country's competitiveness in the international market. Implementation of environmental standards in production processes allows to improve product quality, reduce production costs and expand access to new markets. Azerbaijan, using its resources and international partnerships, has the opportunity to set an example for other countries in the region by integrating environmental principles into all aspects of economic activity. To achieve this, it is necessary

to expand environmentally oriented initiatives, strengthen international cooperation, and invest in the green sector.

Discussion

The review of environmental challenges and the impact of human capital is extensive, because it allows us to assess how human capital contributes to adaptation to modern environmental challenges and ensures sustainable economic development. In the context of global climate change and growing demands for environmental responsibility of companies and states, the development of an environmental culture, innovation and investment in human capital is becoming a key factor in competitiveness at the international level. This also creates the basis for the introduction of new technologies, improving product quality and reducing the negative impact of economic activity on the environment.

This study and the work of M. Alalawneh (2020) examined the role of human capital and FDI in driving economic growth. M. Alalawneh emphasised the importance of investing in education and professional development for the long-term stability of the economy, which was consistent with the findings of this study on the role of environmental awareness of workers in improving the quality of goods and services. M. Alalawneh focused on their impact on infrastructure and employment, while this study emphasised the link between FDI and the introduction of environmentally friendly technologies and the development of a green economy. When considering global challenges, M. Alalawneh focused more on general economic aspects, while this study analysed the specifics of Azerbaijan and its international competitiveness.

Comparing the study by C. Diebolt & R. Hippe (2018) that examined the relationship between human capital and economic development in European regions using data for the period 1850-2010, both similarities and differences can be identified. C. Diebolt & R. Hippe used literacy and numerical skills as the main indicators of human capital, confirming the impact of historical levels of education on modern regional economic development. Similarly, the present study also recognised the role of human capital, but emphasised its importance for stimulating investment in technology and increasing the competitiveness of enterprises. However, differences in approaches were also evident. The study by C. Diebolt & R. Hippe focused on regional differences within Europe, using data from a long period, including the 19th and 20th centuries, to identify the relationship between historical factors and current economic performance. This study, by contrast, focuses on specific contemporary conditions and analyses historical trends to a lesser extent.

C.-H. Choi *et al.* (2024) investigated the impact of human capital on the sustainable development of international trade in BRICS countries, using a Vector AutoRegression model to analyse the relationships between key economic variables such as FDI, exports, imports, and GDP. Their study showed that human capital has a significant impact on economic growth and international trade, in particular through its positive impact on GDP in most BRICS countries, with the exception of China. It was found that in China there is a two-way causality between human capital and FDI, while in Brazil there is a one-way causality from FDI to human capital. This study, in turn, focuses on the role of human capital in environmentally oriented economic initiatives, such as the introduction of environmental technologies and the development of an environmental culture, especially in Azerbaijan. In contrast to C.-H. Choi *et al.* this study focused more on the impact of environmental responsibility on a country's competitiveness in the international market. In particular, it looks at how the development of employees' environmental awareness and innovative practices contributes to the quality of goods and services, which positively affects the country's economic position.

A.B. Dankyi *et al.* (2022) investigated the relationship between human capital, FDI, and economic growth in ECOWAS countries. The study by A.B. Dankyi *et al.* focused on the impact of such factors as the level of urbanisation, the use of renewable energy, and the degree of integration of human capital into production processes. The study found that human capital development is a critical factor for attracting FDI, which in turn contributes to economic growth through increased productivity. At the same time, it emphasises that the lack of investment in quality education and training significantly limits the potential of ECOWAS countries to achieve sustainable development. In contrast, current study focuses on the role of human capital in adapting to environmental challenges and its impact on a country's international competitiveness. The focus here is on the environmental component, while the study by A.B. Dankyi *et al.* was dominated by an economic approach with a focus on traditional growth factors such as FDI. At the same time, both studies recognised the key role of human capital as a driver of development, but A.B. Dankyi *et al.* did not consider the environmental aspect, which was an important element of this study.

In the study by T. Yildiz *et al.* (2022), human capital was considered as a tool for raising the environmental awareness of the population and implementing practices that contribute to the conservation of natural resources and reducing the ecological footprint. This study, on the other hand, focused on the impact of human capital on the economic competitiveness of the country and the development of environmentally friendly technologies. Both works recognised the importance of education in the formation of human capital, but in T. Yildiz *et al.*, education was emphasised as a means of improving environmental behaviour, and in this study, as a platform for creating innovative solutions and increasing competitiveness in the international market. At the same time, in T. Yildiz *et al.*, the issues of the impact of human capital on the environmental state were mainly considered, while in this study the emphasis was placed on the economic aspect and its environmental consequences. The results of both studies show that the development of human capital contributes to solving modern global challenges, but the approaches to assessing its

impact and the final conclusions differ depending on the priorities. The study by T. Yildiz *et al.* focused on environmental benefits, while this study focuses on economic and international competitiveness.

This study examines the impact of environmental culture and human capital on international competitiveness, while J. Huang & F. Li (2019) focused on the role of human capital FDI, and innovation intensity in achieving regional economic growth. J. Huang & F. Li emphasised that FDI, combined with high levels of human capital, can promote technological progress, but dependence on foreign investment can limit local economic autonomy. This study, in contrast, emphasises how the development of environmental culture and the adoption of green technologies enhance economic competitiveness, in particular through compliance with global sustainable development standards. J. Huang & F. Li emphasised quantitative analysis of innovation activities in China's regions, while this study focuses more on qualitative analysis of environmental practices that affect a country's reputation in the international market. J. Huang & F. Li focused on the economy's dependence on investment in science and technology, while this study emphasises the importance of environmental awareness and its impact on investor and consumer confidence.

Current study examines the relationship between human capital, environmental culture, and international competitiveness, while A. Abbas *et al.* (2021) study focused on the impact of human capital on FDI attraction in developing countries. Both studies emphasise the importance of human capital for economic development, but their focuses differ significantly. A. Abbas *et al.* have extensively examined the impact of education and worker skill levels on the ability to attract FDI, indicating that high levels of tertiary education enrolment are key factors for investors. Current study, in turn, focuses more on the development of environmental culture as part of human capital that contributes to the implementation of sustainable solutions and increased economic competitiveness. A. Abbas *et al.* study found that employee compensation plays a critical role in attracting foreign investment. This is consistent with the findings of this study, which emphasises the importance of cost-effective use of human capital, but emphasises the environmental aspects of its development.

A. Sarwar *et al.* (2020) examined the relationship between human capital, financial development, and economic growth in developing countries, with a particular focus on the interactive effects between these factors. Their analysis highlights that high-quality human capital promotes economic growth when combined with an efficient financial infrastructure. The authors also emphasise the need for investment in education and training to increase labour productivity and attract foreign investment. Similar to A. Sarwar *et al.* findings, the analysis demonstrated that high levels of environmental awareness among workers and government support for education contribute to increased competitiveness in the international market. Both studies emphasise the role of international cooperation and the introduction of innovative approaches to stimulate sustainable economic growth. A. Sarwar *et al.* focus more on financial infrastructure and its interaction with human capital, while this study focuses on the development of an environmental culture and its impact on the quality of goods and services. In addition, A. Sarwar *et al.* considered general aspects of human capital without a specific focus on environmental aspects, which makes their findings less specific in the context of environmental sustainability.

The P. Sanz Fernández (2016) study analysed the environmental impact of international trade through greenhouse gas emissions and local pollutants. Particular attention is paid to assessing the economic and environmental efficiency in terms of reducing international trade, using Input-Output Analysis models and the World Input-Output Database. The P. Sanz Fernández study also focused on the impact of international trade on environmental pressures, while this study focuses on the relationship between human capital, FDI and economic growth. The main similarity is that both studies are used to assess the long-term impacts of economic activity. Both studies recognise the importance of a sustainable approach to economic activity, but each of them analyses this issue from different perspectives. The P. Sanz Fernández study examines the environmental impact of economic activity through the lens of international trade, while this study focuses on economic aspects related to human capital development. Furthermore, the P. Sanz Fernández study focuses on global issues, while this study takes a more regional and sectoral approach.

This study analyses the role of human capital and FDI in stimulating economic growth, while the study by M. Gutsch *et al.* (2024) focused on the integration of environmental provisions in international trade agreements and their impact on the environmental performance of economies. The study by M. Gutsch *et al.* emphasised that environmental provisions in trade agreements contribute to raising environmental standards through enforcement and monitoring mechanisms. In particular, the authors note that such agreements incentivise countries to implement environmental protection policies and ensure that businesses comply with new standards. At the same time, the main emphasis in this study is on the development of human capital as a factor in increasing economic competitiveness and attracting foreign investment. M. Gutsch *et al.* examined the global context with examples of the impact of trade agreements in different countries, while the study focuses on specific mechanisms and development conditions in a particular region. In addition, the study by M. Gutsch *et al.* the direct impact of policies on environmental performance is assessed, while this study does not cover environmental aspects in the context of trade agreements.

M.K. Khan *et al.* (2021) examined the relationship between renewable energy consumption, economic activity, and carbon dioxide emissions in 219 countries over three decades, using dynamic panel data models and quantile regression. They show that while economic growth and FDI inflows may initially increase carbon emissions, the

introduction of renewable energy sources and improved electricity generation significantly mitigate these effects. The ecological Kuznets curve hypothesis underlies their analysis, suggesting that at higher income levels, economies transition to sustainability through technological progress and the integration of renewable energy. In contrast, the current study focuses on the role of human capital and environmental culture in promoting economic competitiveness and sustainable practices, particularly in a regional context. Unlike M.K. Khan *et al*., this study emphasises qualitative dimensions of human capital, particularly environmental awareness among employees, as a driving force for the adoption of green technologies and the enhancement of international competitiveness of enterprises. This approach emphasises the importance of integrating environmental education and innovation into workforce development, presenting a more people-cantered strategy for sustainable development. M.K. Khan *et al*. use a robust quantitative framework, using generalised method of moments estimation and quantile regression to analyse large-scale panel data, which allows for generalisation of understanding of global trends. However, the current study combines comparative qualitative analysis, examining specific regional or national contexts, to draw conclusions about the interaction between environmental culture and economic policy. This qualitative emphasis allows for detailed exploration of how local initiatives contribute to broader sustainable development goals.

Current study analyses the impact of human capital and environmental culture on a country's international competitiveness, with a focus on adaptation to environmental challenges and the development of environmentally friendly technologies. K. Madani (2020) study, meanwhile, focuses on integrating water resources, environmental initiatives and socio-economic aspects in the context of sustainable development. Both studies share a common aspiration to achieve sustainable development through the use of environmental innovations. K. Madani work focuses on resource management, particularly water resources, and their integration into sustainable development strategies. While this study highlights the importance of human capital in creating competitive environmental practices and goods. K. Madani focuses on the global context and integrated resource management, while this study focuses on specific national aspects such as the impact of human capital on economic competitiveness and environmental culture.

F. Ahmed *et al*. (2021) analysed the impact of FDI and industrialisation on the environment in the Asia-Pacific region. Both studies emphasise the close relationship between economic activity and environmental indicators. The similarity between the studies is manifested in the use of the concept of the ecological curve to analyse the relationship between economic growth and environmental degradation. Both works confirm that economic growth in the initial stages of development is accompanied by environmental degradation, but over time and with the introduction of environmentally friendly technologies, the situation can improve. In addition, both studies emphasise the importance of regulatory policies that can help reduce the negative impact of economic activity on the environment. Current study considers international trade as a tool for stimulating sustainable development through the introduction of environmentally friendly technologies, which helps to increase the competitiveness of countries. In contrast, F. Ahmed *et al*. emphasise that weak environmental standards in Asia-Pacific countries contribute to increased methane and carbon dioxide emissions due to active industrialisation and foreign investment. While this study focuses on harmonising international standards to improve the environmental situation, F. Ahmed *et al*. point to the need to strengthen local environmental regulations.

The study by L. Zhang *et al*. (2022) focused on the impact of globalisation on climate change and the importance of a green economy for long-term development. The authors focus on aspects such as environmental efficiency, the transition to carbon-neutral technologies, and the need to integrate sustainable development into economic policies. The main similarities between this study and the work of L. Zhang *et al*. include the emphasis on the impact of environmental policies and economic activities on the environment. Both works emphasise the importance of a green economy in reducing the negative consequences of globalisation, such as increased CO_2 emissions, degradation of natural resources, and impacts on biodiversity. In L. Zhang *et al*., the focus is on systemic changes that require the involvement of new technologies, institutional support, and the introduction of innovations to achieve sustainable development goals. At the same time, this study focuses on regional aspects and specific practical examples, such as mechanisms for regulating the impact of international trade on the environment.

Human capital and environmental culture play a critical role in driving sustainable economic development and strengthening international competitiveness. Emphasizing education, environmentally conscious practices, and innovation can enhance economic stability, support environmental preservation, and align with global sustainability standards.

Conclusions

The conclusion of this study emphasises the importance of integrating human capital and environmental culture into the strategy for sustainable development and increasing the international competitiveness of Azerbaijan. The study emphasises that the development of quality human capital, formed through systematic investments in education, vocational training and innovation, is a fundamental factor for adapting to modern environmental challenges and achieving economic growth. Particular attention is paid to the relationship between environmental culture, innovation and international competitiveness.

The study provides a comprehensive analysis of Azerbaijan's environmental challenges and their impact on the economy, international trade, and the development of human capital. It shows that environmental issues such as air

pollution, land degradation, water scarcity, and climate change have far-reaching economic consequences. For instance, air pollution results in economic losses estimated between 0.11% and 0.14% of GDP, while particulate emission damage accounts for about 0.166% of GNI as adjusted savings. Land degradation, particularly soil erosion, costs Azerbaijan around 10-11 billion manats annually. Water scarcity affects key sectors, including oil, gas, agriculture, and manufacturing, thereby reducing productivity and trade potential. The depletion of oil resources is projected to cause significant reductions in government revenue, with oil contributing approximately 30% of the GDP and 95% of exports. Additionally, industrial waste and climate change pose challenges to sustainable growth. According to the study's findings, the COVID-19 pandemic's effects caused Azerbaijan's HDI to drop from 0.762 in 2019 to 0.722 in 2020. By 2022, it had risen to 0.760, nearly reaching its 2019 level, demonstrating the success of policies aimed at reviving the economy and raising living standards. Significant differences in vocational education levels were also discovered by the study; in 2020, enrolment accounted for just 12.4% of all students, which limited the nation's capacity for innovation.

Significant emphasis is placed on renewable energy initiatives, such as the implementation of smart city technologies in Baku, the development of wind and solar power plants, and the modernisation of transport infrastructure. These activities are a practical example of how investments in environmentally responsible technologies can reduce greenhouse gas emissions while promoting economic growth. In particular, participation in international projects such as COP29 demonstrates Azerbaijan's commitment to achieving global environmental standards and expanding its role in addressing climate challenges.

The study also highlights the importance of international cooperation. Through partnerships with international organisations such as the EBRD and the Green Climate Fund, Azerbaijan has access to technical support, financing, and advanced technologies. This allows the country not only to address current environmental challenges, but also to lay the foundation for long-term sustainable development.

However, the study also points to the need for further development in areas such as raising the level of environmental awareness of the population, improving the vocational education system and aligning higher education with modern labour market needs. Insufficient awareness of environmental standards among some segments of the population and insufficient funding for certain areas of education remain challenges that need to be addressed to ensure sustainable development.

Overall, the findings indicate that the integration of environmental aspects into human capital development strategies is key to addressing today's global challenges. Azerbaijan, through its initiatives and international cooperation, can become a model for other countries in achieving sustainable development and increasing economic efficiency through an innovative approach to human capital and environmental culture.

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Conflict of Interest

None.

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Екологічні виклики та вплив людського капіталу на зовнішньоекономічну діяльність Азербайджану

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Анотація. Метою цього дослідження було проаналізувати основні екологічні виклики Азербайджану, їх вплив на економіку та міжнародну торгівлю, а також оцінити роль якості людського капіталу в адаптації країни до цих викликів та розробці інноваційних рішень для зменшення негативного впливу на навколишнє середовище. У дослідженні було використано аналітичний підхід, який включав аналіз атмосферних викидів, таких як CO_2, метан та оксиди азоту, оцінку їхнього економічного впливу, а також аналіз показників Індексу людського розвитку (ІЛР), що охоплює рівень освіти, здоров'я та рівень життя населення. У дослідженні проаналізовано екологічні виклики Азербайджану, включаючи забруднення повітря, деградацію земель, дефіцит водних ресурсів та зміну клімату, та підкреслено їхній значний економічний вплив, зокрема, втрати 0,11 %-0,14 % валового внутрішнього продукту (ВВП) від забруднення повітря, 10-11 мільярдів манатів щорічно від деградації земель та зниження продуктивності праці в ключових секторах економіки. Результати дослідження показали, що ІЛР Азербайджану змінився з 0,762 у 2019 році до 0,722 у 2020 році через вплив пандемії COVID-19, а до 2022 року зріс до 0,760, майже повернувшись до рівня 2019 року, що свідчить про ефективність заходів з відновлення економіки та підвищення якості життя. Дослідження також виявило значні диспропорції в рівнях професійно-технічної освіти, де у 2020 році навчалося лише 12,4 % від загальної кількості студентів, що обмежує інноваційний потенціал країни. Було оцінено участь Азербайджану в міжнародних екологічних ініціативах, таких як співпраця із Зеленим кліматичним фондом, який сприяє впровадженню сучасних технологій у відновлюваній енергетиці, включаючи розвиток сонячних та вітрових електростанцій. Результати дослідження демонструють, що розвиток людського капіталу, зміцнення екологічної культури та впровадження екологічно чистих технологій можуть сприяти сталому економічному зростанню, зменшенню навантаження на довкілля та підвищенню міжнародної конкурентоспроможності країни

Ключові слова: сталість; експорт; відновлювана енергетика; клімат; робоча сила

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Economic situation and prospects for the development of higher education in Ukraine in the context of post-war recovery

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Abstract. The purpose of this study was to investigate the financial aspects of the functioning of higher education in Ukraine and to find ways to restore it in the post-war period. A study of the financial situation of Ukrainian higher education institutions, national, private, and international funding programmes was conducted. The study found that the restoration of higher education in Ukraine after the war is directly related to the resources and support strategies coming from public, private, and international sources. It was found that the physical destruction of universities does not exhaust the scope of the problem: in parallel, there is an outflow of teaching staff due to low salaries and insufficient prospects, as well as a deepening crisis of management models that are unable to respond quickly to the requirements of the post-war period. It was concluded that financial support and mechanisms for attracting private capital can only partially address the pressing issues, as more flexible learning formats and systemic changes in the organisation of the educational process are needed. In this regard, it was suggested that innovative approaches to education should be considered as one of the determining factors of sustainability, especially in terms of distance and blended learning formats that can help overcome the limitations of access to infrastructure. Therewith, regardless of the source of funding and the form of resource mobilisation, the need to preserve the scientific and pedagogical potential and to update the content of programmes to meet the challenges was identified. As a result, recommendations were formulated with a set of measures aimed at restoring the learning environment and its further development in the post-war period. The findings pointed to the need for a comprehensive approach to the restoration and modernisation of higher education in Ukraine through multichannel financing, updating curricula, and preserving the scientific and pedagogical potential

Keywords: public-private partnership; innovations; energy efficiency; sources of financing; infrastructure rehabilitation

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Introduction

The higher education system is one of the key factors in the development of human capital, which is the basis for economic and social growth in any country. Russia's full-scale aggression against Ukraine has led to widespread destruction, a serious economic downturn, and destabilisation of many areas of life, including education. Infrastructure losses, funding cuts, and the outflow of young people have become challenges that require immediate response and a rethinking of the role of the education system in the country's recovery.

In the context of a long-term military conflict, Ukraine has demonstrated a unique experience of confronting challenges and at the same time working on reforming and adapting the education sector to new realities. Of particular significance in this process is the higher education system, which provides training of qualified personnel for critical sectors of the economy and contributes to strengthening the country's intellectual potential. In such a situation, the study of economic aspects of the functioning and development of the higher education system is a necessary step to identify stabilisation mechanisms, attract additional resources, and formulate a sustainable recovery strategy.

Studies on education and science financing in Ukraine have highlighted the urgency of long-term problems caused by economic instability and the impact of military operations. O.L. Totska & I.O. Tytarenko (2023) noted that the reorientation of the state budget towards defence needs has created a considerable resource gap in the education sector, which threatens the stability of educational institutions and their ability to restore infrastructure and modernise programmes. At the same time, the researchers pointed to opportunities to attract international support and optimise spending to overcome these challenges. T.K. Kuranda & O.P. Kochetkova (2021) focused on the imbalance in the distribution of funds and the lack of support for basic research, which weakens the country's competitiveness in the international arena. These studies pointed to the need to develop grant programmes, international cooperation, and the introduction of effective financial mechanisms. However, the issue of attracting international financing models, adapting to the challenges of digitalisation and changes in the structure of demand for knowledge is still understudied. This requires further research to develop comprehensive strategies that will ensure sustainability and development in these areas.

Internationalisation and international cooperation in higher education is a significant area of development of modern universities aimed at improving the quality of education and entering the global educational space (Shahini, 2024). H. de Wit & P.G. Altbach (2021) focused on the challenges and opportunities of internationalisation of higher education and global trends in its development. The researchers found that the key elements of effective international cooperation are the mobility of students and teachers, the adaptation of curricula to international standards, and the use of digital technologies to expand access to the global educational space. At the same time, the researchers noted that inequality of access to these opportunities is becoming a serious barrier for many educational institutions. H. de Wit & G. Merkx (2022) analysed the historical aspects of internationalisation and its effects on global education. The researchers revealed the stages of evolution of international cooperation, including periods of technological breakthroughs and global conflicts that affected the nature of educational relations. The study demonstrated that internationalisation has become an integral component of educational development, contributing to the development of global academic networks and improving the quality of education.

Since human capital plays a significant role in shaping economic and social development, its quality characteristics considerably affects the ability of regions to adapt to challenges. C. Diebolt & R. Hippe (2019) investigated the relationship between the level of investment in human capital and innovation activity in European regions and found that educational systems that build competencies required in high-tech industries contribute to sustainable economic growth. N. Slaviuk & T. Bui (2022) studied the consequences of the war for Ukraine's economy, including the loss of human capital and changes in economic priorities, and concluded that, despite the large-scale destruction, transformations in the structure of the economy can contribute to the development of new industries and digital technologies. Therewith, the researchers stressed the significance of international support to restore human capital and ensure its role in rebuilding Ukraine's economy. The question of how to engage post-conflict economies in the global market while preserving their innovation potential stays unresolved.

Existing approaches to education management and modernisation reflect the desire to adapt the system to global and technological challenges. L. Li (2020) examined how digitalisation and automation are shaping the requirements for educational systems in the context of the fourth industrial revolution. The researcher addressed the need for effective coordination between educational institutions and labour market needs to ensure that specialists are trained for a technology-oriented environment. The development of partnerships between universities and businesses is a key element in creating a competitive educational ecosystem. H.E. Fitzgerald *et al.* (2019) emphasised the significance of universities' interaction with society as a key aspect for improving the quality of education and its relevance to modern challenges, as partnerships, interdisciplinarity, and openness promote critical thinking among students and provide a link between theory and practice. This approach is aimed at creating a sustainable educational ecosystem capable of adapting to rapid changes. M. Tight (2019) investigated the influence of neoliberal ideology on the higher education system and the problem of commercialisation, which reduces the accessibility of education for the general population. Despite these challenges, the researcher emphasised the significance of policies that enable a balance between economic efficiency and the social mission of

education. However, the problem of the interaction between conventional educational models and innovative approaches is still understudied.

The reviewed studies revealed a considerable academic interest in such aspects as internationalisation of education, the effects of human capital on economic development, and the modernisation of educational systems. At the same time, the issues of combining educational and financial models in the context of post-war recovery stay understudied, which is especially relevant for countries affected by military conflicts.

The purpose of this study was to assess the effects of current economic challenges on the higher education system of Ukraine and to identify ways to adapt and develop it in the period of post-war recovery. To fulfil this purpose, the following objectives were set: to investigate the effects of the war on the financial and infrastructural components of educational institutions; to analyse current challenges, such as reduced state funding and declining student numbers; to develop recommendations for attracting additional resources and creating conditions for sustainable development of the educational system.

Materials and Methods

The study conducted a comprehensive analysis that covered the financial situation of higher education institutions (HEIs) in Ukraine, including the analysis of official statistics from the reports of the State Statistics Service and documents of international organisations such as the United Nations, the United Nations Educational, Scientific and Cultural Organisation (UNESCO) and the World Bank (2023) (Education in Ukraine…, 2023; Network and activity..., 2024; Ukraine: Restoring scientific..., 2024). The impact of the hostilities on other sectors of the Ukrainian economy was also considered and the relationship between them and education was outlined (Kyiv City Council..., 2024). This stage helped to assess the level of funding for educational institutions, determine the extent of underfunding and priorities for budget allocations in the context of post-war recovery.

Another significant step was to study the impact of the war on university infrastructure. For this, reports from government agencies, international organisations, and independent experts were analysed, including data on physical destruction, including university buildings, dormitories, and laboratories (Ukraine: Restoring scientific..., 2024; Ukraine: More than..., 2024; Centre for Political Analysis "Observatory of Democracy", 2024; From ruined buildings..., 2024). The study of the issue of damage and restoration of the physical infrastructure of higher education institutions also included an analysis of materials from Education.ua, Vseosvita, Evening Kyiv, Gwara Media (Shevchenko National University..., 2023; Katayeva, 2023; 11 universities destroyed..., 2024; Bykova, 2024)

Changes in the structure of demand for specialities in higher education institutions were investigated separately. This analysis was based on information from official sources, such as registers of entrants (and a study of the state of Ukrainian science and scientists during the war, which helped to identify key trends in the choice of professions (Network and activity..., 2024; Galagan *et al.*, 2024). The socio-economic factors that influence these changes were considered, and conclusions were drawn on how to adapt curricula to the new conditions.

To determine the level of international support for the Ukrainian higher education system, the study analysed available grant programmes, initiatives of the European Union (EU) and the North Atlantic Treaty Organisation (NATO) from the materials of the Ministry of Education and Science of Ukraine and other organisations aimed at developing research, modernising infrastructure, and introducing innovations (The international community..., 2022; Cabinet of Ministers..., 2022; Science for peace..., 2023; Scottish initiative donates..., 2024; Over 13 million..., 2024; Vinnychuk, 2024). The problems of attracting teaching staff were also investigated. For this, the reasons for the mass departure of specialists abroad were analysed: salaries, inflation, and reduced funding for research (Higher education employee..., 2024; Job salaries according to..., 2024; The effects of war..., 2024; Inflation index in..., n.d.).

The public-private partnership between Ukrainian HEIs and business was considered, which demonstrated the possibility of attracting additional financial resources to support the educational system and the prospects for improving the quality of training (especially technical specialties) through close cooperation with leading corporations (e.g., Boeing Ukraine and Samsung Electronics) (Rector's report for..., 2019; How it's made, 2020; Lviv Polytechnic has..., 2021). The review of state initiatives aimed at adapting the higher education system to the conditions of war and post-war reconstruction revealed measures to ensure the continuity of the educational process, such as the introduction of distance and hybrid learning models, as well as the creation of conditions for the relocation of universities from the temporarily occupied territories. The legal framework governing these processes and its compliance with European standards in the field of higher education were also considered (Vintonyak, 2024). The review of the leading international programmes for the integration of the Ukrainian higher education system into the global educational space included the following programmes: Erasmus+ (2024) and German Academic Exchange Service (2024), Fulbright Ukraine (2024) and Horizon Europe (European Commission, 2024). The example of accreditation of educational programmes according to European standards National Agency for Quality Assurance in Higher Education (2024) confirmed the compliance of Ukrainian universities with international quality requirements.

Results

State of the economy of higher education in Ukraine in the active phase of military operations

The study of the financial situation of Ukrainian higher

education institutions in the context of post-war recovery revealed numerous challenges that substantially affected the stability and functioning of this sector. One of the key factors is the significant underfunding and reduction of budget expenditures, which resulted from the general economic downturn in the country. Budgetary allocations for education have declined due to the reorientation of public resources to military needs and support for other critical sectors, which has limited the ability of higher education institutions to maintain the adequate level of quality of education, modernise infrastructure, and ensure international competitiveness (Fig. 1).

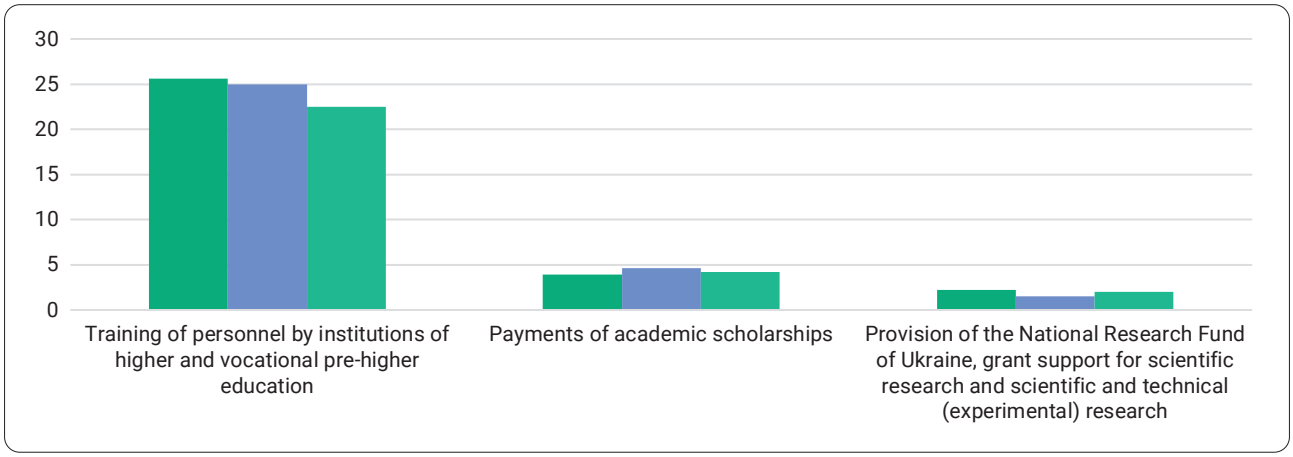

Figure 1. Public spending on education and science in 2021-2023, UAH billion
Source: created by the authors of this study based on the State budget for 2023 (2022)

The Russian-Ukrainian war caused significant physical damage to the infrastructure of many universities, especially in the regions that have been subject to active hostilities. Specifically, V.N. Karazin Kharkiv National University, National Technical University "Kharkiv Polytechnic Institute", and Mariupol State University suffered severe damage (Centre for Political Analysis "Observatory of Democracy", 2024; From ruined buildings..., 2024). The destruction of buildings has made it impossible to conduct the educational process in the conventional format, while the cost of restoring scientific infrastructure could reach more than USD 1.26 billion, but there are no clear calculations due to the ongoing hostilities (Ukraine: Restoring scientific..., 2024). Furthermore, the lack of a clear strategy for restoring infrastructure complicates the effective use of the available funds.

Another substantial problem is the decline in the number of students (Network and activity..., 2024). Internally displaced persons, as well as citizens who fled the country due to the war, have substantially reduced enrolment in higher education institutions. This has affected university revenues from contract education, which is a substantial source of funding for many institutions. Inequality in access to education among students from the affected regions has also increased, creating additional social challenges for the higher education system. The government is seeking to compensate for this inequality by introducing benefits for internally displaced persons, such as a simplified procedure for admission to higher education institutions and financial support for education.

The war has greatly affected the economic situation of Ukraine's education system, specifically in terms of research funding and modernisation of educational institutions. Apart from the migration of Ukrainian scientists, the reduction in investment in research has become one of the most visible consequences of the economic crisis caused by the war (The effects of..., 2024). Furthermore, HEIs were forced to reduce or completely stop funding research projects as the priority was shifted to meeting basic educational needs and restoring damaged infrastructure (Galagan *et al.*, 2024), which particularly affected international cooperation, which in previous years had provided a significant contribution to the development of scientific potential.

The cost of rebuilding damaged or destroyed educational facilities has also become a critical issue: restoring buildings and purchasing the necessary equipment requires extensive financial resources, which are currently limited due to the overall state budget deficit. In the absence of clear mechanisms for attracting additional funding, Ukrainian education has faced the need to attract private investors and international organisations such as UNESCO or the European Investment Bank (EIB) (Education in Ukraine…, 2023; Ukraine: More than..., 2024).

The need to modernise educational institutions has become especially significant in the wake of the transition to digital technologies and changing educational priorities. The war has accelerated the need to create hybrid learning models that will ensure continuous access to education even in emergency situations, but limited resources and insufficient technical support complicate the implementation of such changes. Specifically, many universities do not have adequate access to modern software and equipment, which reduces their competitiveness in the international arena.

The overall impact of the war on the education economy in Ukraine has been manifested in a decline in investment in research, excessive costs of restoring damaged facilities, and the need to modernise educational processes and facilities. These challenges require a comprehensive approach to addressing them, involving both national and international resources. Notably, the restoration of the higher education system in Ukraine is part of the broader process of economic recovery after the war. For comparison, other key sectors of the economy, such as energy and transport, are also in a state of recovery, but have their specific features and priorities.

The energy sector suffered the greatest losses due to targeted attacks on energy infrastructure. According to the Kyiv City Council, more than 50% of the city's power grids were damaged by Russian shelling, and the total loss of electricity generation was 75%, which created the need for significant investment in renewable energy sources and grid reconstruction (Kyiv City Council…, 2024). At the same time, higher education is less dependent on physical infrastructure, which allows it to adapt more quickly to the transition to digital formats.

The transport infrastructure, including roads and railways, has also been affected by the active hostilities: Ukraine's transport network needs a thorough rehabilitation, including both physical reconstruction and modernisation of logistics processes due to the closure of air routes and the occupation of a series of ports in the Sea of Azov. In comparison, higher education faces more complex challenges related not only to physical recovery but also to ensuring international competitiveness.

The specific feature of the recovery of higher education is that it underlies the development of human capital, which is necessary for the sustainable recovery of all other sectors. It is known that in post-war recovery, investment in education plays a significant role in stabilising society and building a skilled workforce (World Bank, 2005; Milton & Barakat, 2016). At the same time, energy and transport demonstrate a faster economic impact due to their direct influence on infrastructure rehabilitation and meeting basic economic needs. However, these sectors depend on skilled workers trained in the higher education system, which highlights the interdependence of different areas of economic recovery. Thus, while the recovery of different sectors of the economy in Ukraine has its unique challenges and opportunities, higher education is still key to ensuring sustainable and long-term economic growth (Table 1).

Table 1. Role of state policy and international aid in the restoration and development of higher education in Ukraine

Aid area	National programmes to support higher education institutions	International aid for higher education institutions
Ensuring continuity of education and access to innovation	Relocation of educational institutions from the temporarily occupied and especially dangerous territories, ensuring safe conditions for the educational process.	Horizon Europe programme: participation of Ukrainian scientists in research and innovation projects on an equal footing with EU member states.
Adaptation to war conditions and development of security studies	Holding an admission campaign in a new format, including testing abroad, and adapting to the war.	NATO's Science for Peace and Security (SPS) Programme: 2025 call for proposals for research that addresses security needs.
Management and financial support for innovative projects	Practical support in the management of higher and vocational pre-higher education institutions.	LIFE Programme 2021-2027: grants from 700 thousand to EUR 20 million with the possibility of co-financing up to 95% of the project cost.
Infrastructure recovery and energy efficiency	Financial support through subventions for the restoration of damaged educational institutions aimed at reconstructing dormitories and educational buildings.	Funding through the EIB: the Higher Education of Ukraine programme provides for investments in energy efficiency at universities.
Financial stability and technical support	Temporary exemption from real estate taxes for higher education institutions, which allows them to redirect funds to priority needs.	Assistance to Reusing IT: launching the Unbreakable Education programme, which provided equipment for distance learning and support for educational initiatives.

Source: created by the authors of this study based on Cabinet of Ministers of Ukraine Order No. 286-r (2022), The international community will strengthen support for Ukrainian scientists (2022), Science for peace and security programme (2023), Scottish initiative donates 2,000 computers to Ukrainian schools (2024), Over 13 million euros for the renovation of Ukrainian universities (2024), N. Vinnychuk (2024), O. Vintonyak (2024)

The national programmes are aimed at overcoming the immediate consequences of the war, such as relocating educational institutions, adapting to new conditions, and maintaining the continuity of the educational process. The key priorities are the physical restoration of destroyed facilities, ensuring the financial stability of higher education institutions and the introduction of modern technologies. These initiatives are mostly short-term but lay the groundwork for further modernisation.

International aid is aimed at the long-term perspective, including support for research, development of innovations, and promotion of the inclusion of Ukrainian education in the global educational space. The areas of support, such as access to innovation, infrastructure development,

and financial stability, reflect the strategic importance of education as a tool for the country's recovery and development. The problem of attracting teaching staff is one of the key obstacles to the functioning and development of higher education institutions in Ukraine during the war. The key factors that complicate the situation include lower salaries, massive departure of specialists abroad, and lack of proper support from the state.

The decline in the level of remuneration of teachers is a serious problem caused by the overall budget deficit and the redirection of resources to more urgent needs. In 2024, the salary of a university associate professor (19th tariff category) with an 11% supplement for university teachers is UAH 12,128.97, and that of a professor (20th tariff category) is UAH 12,909.30 (Higher education employee..., 2024; Job salaries according to..., 2024). Therewith, inflation was 10.4% in November 2024, 5.1% – in 2023, and 26.6% – in 2022 (Inflation index in..., n.d.). Although nominal salaries stay stable, the real purchasing power of teachers continues to decline, which drastically affects their motivation to work in the education sector. This situation reduces the attractiveness of academic careers, especially for young professionals, who are more likely to choose to work in the private sector or emigrate in search of better conditions.

The massive outflow of professionals abroad is a major challenge for the Ukrainian higher education system. Many teachers, especially those with high qualifications and foreign language skills, choose to move to the EU, Canada, or the United States, where higher salaries and better working conditions are offered (Ennerberg & Economou, 2021; Ingersoll *et al.*, 2021). This leads to a "brain drain" and a weakening of the human resource potential of Ukrainian universities, which face a shortage of qualified specialists. The situation is further exacerbated by the lack of adequate support from the state, including social guarantees and opportunities for professional development. In the context of the war, initiatives such as funding for internships abroad or professional development for teachers have become less accessible, weakening the competitiveness of Ukrainian HEIs in the international arena.

Changes in the structure of demand for specialities in Ukrainian higher education institutions reflect dynamic socio-economic changes caused by both internal and external factors. One of the key factors is the war, which has reshaped the labour market and created new priorities in the choice of professions needed to rebuild the country. A significant decline in demand is observed for majors related to tourism, hotel, and restaurant business, and other industries, which largely depend on the stability of the economic and political situation. At the same time, there is an increase in the popularity of specialities in information technology, cybersecurity, medicine, psychology, and engineering (Network and activity..., 2024). These trends meet both the needs of restoring critical infrastructure and developing the digital economy.

The redistribution of demand for specialities directly affects the economic performance of higher education institutions: the growing popularity of technical and medical specialities can lead to increased investment in the material and technical base of universities, including the purchase of modern equipment, software, and laboratory facilities. For example, universities with strong technical facilities will be able to generate additional revenue by increasing the number of contract students in these areas. At the same time, low-demand majors often face funding cuts, which leads to staffing optimisation, reduced numbers of teachers, and even possible closure of faculties. These processes can negatively affect the diversification of HEIs' educational services and limit opportunities for students.

Restoration of the physical infrastructure of higher education institutions in Ukraine is one of the priority tasks in the post-war period. The extent of the damage caused by the hostilities includes destroyed academic buildings, dormitories, research centres, libraries, and sports complexes. As of November 2024, over 200 HEI facilities were severely damaged; 11 HEIs were completely destroyed (11 universities destroyed..., 2024). The scope of reconstruction includes major repairs, reconstruction, and construction of new facilities. For instance, at Taras Shevchenko National University of Kyiv, three academic buildings have been restored, including the Department of History of Ukrainian Literature, Literary Theory and Literary Creativity (Shevchenko National University..., 2023; Katayeva, 2023). At the National Technical University "Kharkiv Polytechnic Institute", it is planned to complete the reconstruction of the educational and laboratory building destroyed as a result of the armed aggression of the Russian Federation by the end of 2024 (Bykova, 2024).

Estimating the cost of reconstruction is an essential element of planning. Around USD 9.8 billion is required to fully rebuild the physical infrastructure of all Ukrainian education (World Bank, 2023). Part of the funding comes from the state budget, while international donors such as the EIB contribute with grants and loans. For example, under the Higher Education of Ukraine programme EIB has allocated EUR 120 million for the rehabilitation of universities using energy-efficient technologies (Over 13 million euros..., 2024).

The key challenges still lie in ensuring transparency of expenditures, promptness of project implementation, and prioritisation of funds among the affected regions. However, effective coordination between government agencies, universities, and international partners will facilitate the return of higher education institutions to full operation and their modernisation, which will increase the competitiveness of Ukrainian education on the global stage.

Models of higher education development in the postwar period and prospects for Ukraine's involvement in the European educational area

Digitalisation and the introduction of innovative technologies have become priorities for the development of higher education institutions in Ukraine due to the COVID-19 pandemic and, subsequently, the full-scale invasion of

Russia. Under the current circumstances, this is not only a way to modernise the educational process, but also a necessity that meets the needs of the digital economy and the globalisation of the educational space. Digitalisation involves the development and implementation of electronic platforms that provide access to educational resources, regardless of where students live or their physical access to universities. This process is aimed at creating conditions for distance and blended learning, which has become particularly relevant in the context of war and post-war reconstruction. For instance, a national e-platform for distance learning with the ability to link to international educational resources and databases could be useful, which would improve the quality and competitiveness of Ukrainian education.

The introduction of innovative technologies in the educational process involves the use of tools such as virtual and augmented reality, simulation platforms, and intelligent learning systems (Aljawarneh, 2020). These technologies can increase the interactivity of learning, adapt the educational process to the individual needs of students, and create an environment for the development of creative and analytical skills. For example, the use of VR simulators in medical and technical specialities allows students to gain practical experience in conditions as close to real life as possible.

These priorities also help to improve the efficiency of managing educational institutions: by automating administrative processes, introducing electronic document management and quality monitoring systems, universities can greatly optimise their costs and improve the quality of educational services. The role of the private sector in the development of Ukrainian higher education institutions is becoming increasingly significant in the context of limited public resources and the need to modernise the education system. Public-private partnerships (PPPs) are a promising tool for attracting additional financial and organisational resources needed to restore, operate, and improve the competitiveness of Ukrainian universities.

PPPs can enable universities to attract private sector investment to finance infrastructure projects, such as the construction or renovation of academic buildings, dormitories, and research centres. For example, implementing projects involving private companies in energy-efficient building retrofits could improve learning environments and considerably reduce universities' operating costs for utilities. The private sector can also play an active role in introducing modern educational programmes and technologies. Cooperation between universities and companies can help create innovative study programmes that meet the needs of the labour market. For instance, joint study programmes with IT companies, engineering, and medical corporations will enable students to acquire the practical skills needed to work in high-tech industries. Such partnerships can ensure that students are trained to meet the modern requirements of business and industry.

Furthermore, business can actively support the research activities of universities by funding research, creating grants and scholarships for students and teachers. For instance, the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" trains specialists in cooperation with Boeing-Ukraine, Samsung Electronics and others (Rector's report for the year 2019 on the implementation of Contract No. VI-44, 2019). Lviv Polytechnic National University actively cooperates with IT companies to create joint laboratories and training programmes in the field of digital technologies (How it's made, 2020; Lviv Polytechnic has..., 2021). A significant role in this is played by the interest of private companies in developing innovations that can be commercialised as innovative technologies or products. This creates a closer connection between science and business, which is a significant factor for the country's economic recovery.

Compliance with the Bologna Process standards in the context of recovery is a significant task for Ukrainian higher education institutions. The Bologna process involves the inclusion of national education systems in the European higher education area based on key principles: a three-tiered structure of education (Bachelor, Master, Doctor of Philosophy), the European Credit Transfer and Accumulation System (ECTS) and quality assurance. In the context of post-war recovery, Ukraine's HEIs may face challenges in meeting these standards due to the destruction of physical infrastructure, lack of resources and staff losses. However, the government and universities are taking active steps to maintain compliance with European requirements (Table 2).

Table 2. Best international standards and efforts to implement them by Ukrainian HEIs

Standard	Efforts
Restoring the three-tiered structure of education	Despite the challenges, universities continue to provide education at all three levels. Programmes are in place to support the academic mobility of students, such as Erasmus+, which enable them to complete their studies at partner European institutions and maintain the integration of the Ukrainian education system into the Bologna area
ECTS	Ukrainian higher education institutions support the functioning of ECTS as a basis for the recognition of qualifications and learning outcomes at the European level. Universities adapt their curricula to ECTS requirements, which allows students to freely continue their studies abroad and receive recognition of their diplomas

Table 2, Continued

Standard	Efforts
Ensuring the quality of education	One of the key elements of the Bologna Process is monitoring and improving the quality of education. As part of the post-war reconstruction, higher education institutions should actively cooperate with international accreditation agencies to confirm the quality of their programmes. For example, the National Technical University "Kharkiv Polytechnic Institute" was accredited according to European standards, confirmed by the National Agency for Quality Assurance in Higher Education, which helped to improve its reputation internationally

Source: created by the authors of this study based on Erasmus+ (2024), National Agency for Quality Assurance in Higher Education (2024)

Thus, compliance with the Bologna Process standards stays a strategic priority for the Ukrainian higher education system. Efforts to restore infrastructure, maintain academic mobility, and improve the quality of education ensure Ukraine's inclusion in the European educational space, even in the face of a demanding socio-economic situation. Another significant factor in this regard is the academic mobility of students and teachers, as it facilitates the exchange of knowledge, professional development, the introduction of innovative teaching methods, and the creation of international partnerships.

Student mobility allows higher education institutions to raise funds through participation in international educational programmes such as Erasmus+ (2024), German Academic Exchange Service (2024), and others (Nogueiro *et al.*, 2022). Thanks to these programmes, students get the opportunity to study at leading European universities, while Ukrainian universities strengthen their international reputation and increase the attractiveness of their study programmes. Apart from financial support, such programmes promote the implementation of new educational standards and technologies, which increases the competitiveness of Ukrainian universities.

The mobility of teachers is a factor in the development of human resources at universities: teachers who take part in exchange programmes or internships return with new knowledge, teaching methodologies and research experience. For instance, the Fulbright Ukraine (2024) and Horizon Europe (European Commission, 2024) programmes provide an opportunity for Ukrainian teachers to collaborate with foreign colleagues and introduce innovative approaches to the educational process, which improves the quality of educational services (Bettie, 2019; de Lama Sanchez *et al.*, 2023).

Establishing joint programmes with leading universities around the world opens new opportunities for Ukrainian higher education institutions in the field of international cooperation. Such programmes include double degrees, student and faculty exchanges, and joint research projects. At the same time, international cooperation can improve the economic efficiency of higher education institutions by attracting foreign students and grant programmes, which will enable universities to receive additional financial resources. It also helps to improve the infrastructure and facilities necessary to provide high-quality educational services.

Recommendations for improving the economic situation and management of higher education institutions

Challenges caused by the war, the economic crisis and reduced budget funding are forcing universities to introduce new financial mechanisms to ensure stability. One of the key areas is diversification of funding sources, as conventional dependence on the state budget can no longer be the only support for higher education institutions. According to F. Barrera-Osorio *et al.* (2022) and C.R. Teal *et al.* (2023), promising alternatives may include attracting private capital through public-private partnerships, grant programmes, international aid, and the development of educational services on a commercial basis.

Universities should implement energy-efficient technologies to reduce utility costs and optimise administrative processes through digitalisation. It is vital to consider the introduction of electronic document management and online learning platforms to reduce costs and increase the efficiency of management decisions. The development of additional educational services may allow universities to generate new sources of income. HEIs should create professional development programmes, professional trainings and certification courses that meet the current needs of the labour market. Emphasis should be placed on cooperation with the private sector to develop relevant curricula that will attract new categories of students (Pysarchuk, 2021).

Particular attention should be paid to the internationalisation of education. To increase financial sustainability, universities are encouraged to develop joint programmes with leading foreign universities, introduce English-language programmes and actively promote educational services in international markets. This will allow attracting foreign students, who are a crucial financial resource for higher education institutions. Thus, the financial sustainability strategy of higher education institutions should be based on diversification of funding, cost optimisation, development of additional educational services and internationalisation. Consistent implementation of these recommendations will enable Ukrainian universities to adapt to the challenges and create the basis for sustainable development in the long term (Table 3).

Table 3. Programmes (instruments) and timing of implementation of long-term planning and financing instruments

Programme (tool)	Description	Implementation plan	Stages of implementation	Timing of implementation
Long-term stability fund	Establishment of a trust fund to cover unforeseen expenses of higher education institutions in times of crisis.	Formation of the fund through government grants, private contributions and investments.	1. Creation of the fund's regulations; 2. Search for sources to fill up the fund; 3. Introduction of mechanisms for transparent management of funds; 4. Audit and reporting.	2025-2026
Development of paid educational services	Expansion of the range of paid services, including certified courses, trainings, and professional development programmes.	Market demand analysis; development of new paid programmes; promotion of services among the target audience.	1. Research of the market needs for additional educational services; 2. Creation of training programmes; 3. Marketing and advertising campaign; 4. Monitoring of the effectiveness of programmes; 5. Adjustments based on monitoring results and market needs.	2025-2027
Attracting sponsorship contributions	Search for patrons and sponsors to support infrastructure projects and research initiatives.	Development of proposals for sponsors; conclusion of partnership agreements; reporting on project implementation.	1. Formation of a database of potential sponsors; 2. Preparation of individual proposals; 3. Fundraising for concrete projects; 4. Control of the targeted use of contributions.	2025-2027
Expansion of international grants	Active participation in international grant programmes to finance research and infrastructure development.	Monitoring of grant opportunities; preparation of applications and participation in competitions.	1. Analysis of available international grants; 2. Formation of research and infrastructure projects; 3. Preparation and submission of applications; 4. Project implementation and reporting to grantors.	2025-2029
Commerciali-sation of scientific developments	Implementation of mechanisms for commercialisation of scientific ideas, innovations and technologies of universities.	Creation of technology transfer centres; development of innovative solutions in partnership with business.	1. Identification of promising scientific developments; 2. Creation of innovation hubs; 3. Cooperation with business to bring solutions to the market; 4. Monetisation of scientific results.	2025-2028

Source: created by the authors of this study

The timing of the programmes was determined based on the scope of work, availability of resources, and the strategic significance of the measures for the financial sustainability of higher education institutions. The period of 2025-2026 was chosen to create a long-term stability fund, as such measures require an immediate response and rapid formation of basic structures. The development of paid educational services is planned for the medium-term period of 2025-2027 due to the need for market research and gradual launch of programmes. It is recommended to introduce sponsorships in 2025-2027, as the search for partners and the conclusion of agreements require time for preparation and negotiations. For the expansion of international grants, the period of 2025-2029 was chosen because of the lengthy procedures for monitoring opportunities, preparing applications, and implementing projects. The commercialisation of scientific developments also involves a lengthy period of 2025-2028 due to the complexity of the processes that include the creation of infrastructure, development of innovations, and their entry into the market.

Discussion

The study examined in detail the economic potential of Ukraine's higher education system and assessed the factors that determine its further development in the post-war environment. The study examined possible ways to restore higher education institutions, financial support instruments from the state, the private sector, and international partners, as well as innovative solutions to ensure the stable operation of educational institutions in the face of uncertainty. The identified problems pointed to the need for a comprehensive approach to reforms to remedy the consequences of the destruction and lay the foundation for the growth of the entire education sector.

The study found that the war has drastically affected Ukraine's economic and educational sectors and has led to a substantial reduction in funding for higher education. Specifically, the reorientation of state resources to military needs has limited the funds available to support educational infrastructure and implement development programmes. This situation has made access to quality education more cumbersome, especially in regions affected by active hostilities. The consequences of the destruction were reflected in a decrease in the number of students able to continue their studies, as well as the need to introduce alternative funding models and attract international support. At the same time, the analysis revealed that the adaptation of educational programmes and a focus on recovery can only contribute to the stabilisation of the educational system and further overall economic growth of the country. K. Amone-P'Olak (2020) and T.K. Levi (2019) provided valuable context for understanding the challenges and opportunities facing Ukraine's higher education system. For example, K. Amone-P'Olak highlighted that investments in curricula and skills development have been an effective tool to overcome the effects of war in Uganda, which resonates with the situation in Ukraine, where curricula need to be adapted to current labour market needs, including specialities related to infrastructure reconstruction. T.K. Levi revealed the role of education in strengthening the resilience of society after the conflict in Sri Lanka. Analogously, in Ukraine, education can be an indispensable tool for building social cohesion, promoting the inclusion of internally displaced persons, and the return of young people to the education system. Engaging international partners and implementing inclusive education initiatives are critical to achieving these goals. Thus, education plays a leading role in post-war recovery and contributes to long-term economic development.

An analysis of available resources and strategies for restoring education reveals a complex system of interaction between government initiatives, private capital, and international funds. National policy aims to stabilise the financial base of universities, while government infrastructure rehabilitation programmes rely on a combination of budget support and sponsorship and grant funds (Hysi *et al.*, 2024). The presence of the private sector is not limited to one-off investments: economic actors offer technical expertise, research cooperation, and the launch of innovative projects. International organisations can offer material resources, advisory support, management experience, transparent accreditation procedures, involvement in global educational initiatives, etc. This multi-level approach can provide the ability to respond to the dynamic challenges posed by the immediate aftermath of war, long-term labour market trends and demographic shifts. An approach that combines government projects, private partnerships, and long-term international programmes can help increase the resilience of the education system and create the preconditions for the modernisation of Ukrainian education

Comparison with the study by M. Buheji & B. Buheji (2024) revealed comparable challenges in the context of the Gaza Strip, where education has become a component of a comprehensive system of social and psychological rehabilitation of the affected civilian population, including children. Ukrainian initiatives and Gaza's experience are identical in their efforts to support and develop education, preventing the destructive effects of war on the formation of future generations. Analogous parallels can be traced in the analysis of medical education during armed conflict in V.A. Dobiesz *et al.* (2022). The experience of creating flexible learning models and implementing adaptive approaches in crisis circumstances confirms the significance of diversified tools for educational development. In a context where infrastructure is being destroyed and communities are under intense psychological pressure, the medical field, as well as higher education overall, needs solutions that can guarantee the continuity of professional training. This experience is in line with the logic of Ukrainian initiatives focused on flexibility, diversity of resources, and international practices. This approach confirms the ability of modern education systems not to stop at overcoming the immediate consequences of the crisis, but to reorient themselves to strategic tasks related to training specialists for societies seeking stability and further development.

From an infrastructural and organisational standpoint, the problem of the destruction of educational institutions extends beyond physical losses and includes the preservation of intellectual potential, the restoration of management systems and the updating of specialised curricula in response to new conditions (Tarasenko, 2023). Finding adequate solutions requires an awareness that returning to previous standards is not enough, as the restoration process is not limited to replacing destroyed walls or purchasing technical equipment. This refers to creating a dynamic environment capable of adapting to the changing demands of the labour market, integrating innovative approaches to the educational process and establishing sustainable interaction between academic, business and international circles. Such a restructuring requires effective mechanisms for attracting funding, developing project strategies, and introducing alternative educational formats aimed at long-term sustainability and competitiveness of education. H. Moodrick-Even Khen (2023) examined the long-term effects of school destruction, disruption of

education, and the creation of unsafe conditions and found that the restoration of education is critical to ensuring the sustainable development of society in war and post-war. R.L. Geiger (2019) also examined the post-war transformation of higher education in the United States as a historical example of successful adaptation to the new requirements of society. The mechanism of large-scale student engagement and reformatting of educational institutions demonstrated the system's ability to go beyond mere recovery and become a driver of social, economic, and technological growth. In comparison with these studies, the restoration of educational institutions after the war shocks involves not only overcoming the consequences of infrastructure destruction, but also the desire to create a qualitatively new educational reality that accommodates both the interests of the most vulnerable communities and the need for dynamic development of the educational space overall.

Innovative approaches to education in times of war are significant not just as a means of temporary adaptation, but as indicators of the ability of the education system to withstand radical external challenges: power outages, challenges with Internet access, inability to follow a clear schedule, etc. (Dmytrenko, 2024). Such an approach should go beyond the classical model of online lectures and seminars. Innovativeness should be manifested in the ability to build the learning process around the minimum available resources, to establish independent work, and to organise communities of practice. Comparison with the study by E.K. Agormedah *et al.* (2020) on the transition to online learning in Ghana during the COVID-19 pandemic revealed that the radical change in the conditions of the learning process under the pressure of emergency circumstances reveals deep inequalities and infrastructural limitations. In Ghana, the pandemic has exposed digital divides and a lack of adequate technical support. In a war, such problems are even more acute, as it is not just a matter of not having the right devices or access to the network, but also of having to work in a physically dangerous and psychologically challenging environment. In both cases, innovative approaches require long-term strategies that focus on system sustainability, human resource development, digital literacy, and flexible infrastructure.

The reasons for the outflow of teachers and researchers abroad pointed to problems in the financial sector, as well as the structure of educational institutions and research environments. Low salaries and limited career opportunities deter talent, but the uncertainty of long-term prospects and the lack of transparent management decisions are also significant. Working conditions, which are perceived as conservative and regulated by methodological templates of past decades, encourage professionals to look for a space where scientific ideas do not encounter bureaucratic barriers and intellectual activity is not hampered by the inertia of administrative structures (Teymurova *et al.*, 2024). The search for better prospects abroad becomes a logical choice when professional potential does not find proper recognition and opportunities for realisation in the Ukrainian higher education system. M.E. Dulamă *et al.* (2019), and L.P. Symaco & M. Hayden (2024) pointed out that the crises of ideas and human resources are not unique to Ukraine. In Romania, during the period of the Second World War and the communist transition, political ideologies and ideas of the "right" content of education, according to M.E. Dulamă *et al.* influenced teaching approaches, creating an atmosphere where individual scientific initiative was partially supplanted by external ideological priorities. L.P. Symaco & M. Hayden noted that in Southeast Asia, education modernisation has faced the challenge of harmonising diverse national contexts, uneven accessibility and difficulties in adapting to global standards, which often hinder the dynamics of attracting and retaining qualified academic staff. In other words, the ability of education systems to retain and develop human resources depends on funding and on the ability of government and academic institutions to overcome inertia, remove unnecessary ideological or bureaucratic constraints, and build an environment conducive to creative growth (Grajcevci & Shala, 2021). This ability determines whether education will become a truly modern environment, open to innovation and interested in supporting its teachers and researchers.

The reviewed studies agreed that strengthening the quality and accessibility of higher education requires strengthening the links between universities, research institutes, and the labour market, as well as creating mechanisms that support teachers and students in times of systemic change. Therewith, a series of issues that require further study persists, namely, strategic principles of infrastructure financing, flexible methods of managing universities in unstable economic conditions, and ways to integrate new digital tools that will improve the efficiency of the educational process even with limited resources.

Conclusions

The economic situation of Ukraine's higher education system during the war was characterised by considerable underfunding, physical destruction of infrastructure, and a decrease in the number of students due to migration and internal displacement. The shift of state budget priorities to military needs drastically limited the ability of higher education institutions to maintain the quality of education, modernise infrastructure and develop research. At the same time, the destruction of university buildings and dormitories, especially in the regions of active hostilities, requires significant financial investments estimated at billions of dollars. It was estimated that the full physical restoration of the scientific and educational infrastructure could cost more than USD 9.8 billion, requiring both national and international resources.

Physical damage to the infrastructure has become one of the most serious challenges for Ukraine's higher education system: the hostilities have destroyed academic buildings, dormitories, and research centres. Without adequate access to physical facilities, universities were forced to switch to distance or hybrid learning, which, while

allowing for the continuation of the educational process, proved insufficient for practical classes and research.

The identified changes in the structure of demand for specialities also reflect the transformation of the country's socio-economic landscape. The decline in the popularity of majors in tourism, hospitality, and other industries dependent on economic stability contrasts with the growth in demand for technical, medical, and IT fields. This is in line with the new priorities of economic recovery, which include the development of critical infrastructure, digitalisation, and training in high-tech industries. Universities that can adapt to these changes can attract more students and funding.

The decline in human resources continues to be a substantial problem due to the massive outflow of teachers abroad and the decline in the real purchasing power of salaries. Despite the stability of nominal salaries, inflation has led to a sharp decline in their real value, which weakens the motivation of teachers to work in the higher education system. Additionally, the emigration of qualified professionals has exacerbated the problem of staff shortages, especially among younger teachers who choose to work abroad or in the private sector. It was found that the modernisation and digitalisation of the higher education system are significant factors for effective recovery in the post-war period. The development of hybrid learning models, the introduction of digital platforms, and the use of innovative technologies will ensure continuous access to education and improve its quality. However, many universities face technical and financial constraints, which complicates their modernisation.

International aid plays a key role in the restoration and development of Ukraine's higher education system, helping to rebuild infrastructure, fund research, and support teaching staff, while public-private partnerships are a valuable tool for attracting investment and introducing innovations into the educational process. Further research should focus on the practical measurement of the effectiveness of funding and modernisation mechanisms in the post-war recovery. Continued study of this area will contribute to the formation of effective strategies for the sustainable development of higher education, which will help to overcome the shortage of human resources, increase the international competitiveness of universities and ensure the training of qualified specialists for the country's economic recovery.

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Conflict of Interest

None.

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Економічний стан та перспективи розвитку вищої освіти України в умовах повоєнного відновлення

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Анотація. Метою статті стало дослідження фінансових аспектів функціонування вищої освіти України та пошук шляхів її відновлення у післявоєнний період. Було здійснено дослідження фінансового стану українських закладів вищої освіти, національних, приватних та міжнародних програм фінансування. У результаті проведеного дослідження було виявлено, що відновлення вищої освіти в Україні після війни безпосередньо пов'язане з ресурсами та стратегіями підтримки, що надходять із державних, приватних та міжнародних джерел. З'ясовано, що фізичне руйнування університетів не вичерпує масштабу проблеми: паралельно відбувається відтік викладацького складу через низькі зарплати й недостатні перспективи, а також поглиблюється криза управлінських моделей, неспроможних швидко реагувати на вимоги повоєнного періоду. Було зроблено висновок, що фінансова допомога та механізми залучення приватного капіталу здатні лише частково розв'язати нагальні питання, оскільки потрібні більш гнучкі формати навчання та системні зміни в організації навчального процесу. У зв'язку із цим було запропоновано розглядати інноваційні підходи в освіті як один із визначальних факторів стійкості, особливо коли йдеться про дистанційні та комбіновані формати навчання, які можуть допомогти подолати обмеження доступу до інфраструктури. Разом з тим, незалежно від джерела фінансування та форми залучення ресурсів, була виявлена необхідність збереження науково-педагогічного потенціалу, а також оновлення змісту програм з урахуванням викликів. У підсумку було сформовано рекомендації із сукупністю заходів, спрямованих на відновлення навчального середовища та його подальшого розвитку у повоєнний період. Отримані результати вказали на необхідність комплексного підходу до відновлення і модернізації вищої освіти України шляхом багатоканального фінансування, актуалізації навчальних програм та збереження науково-педагогічного потенціалу

Ключові слова: державно-приватне партнерство; інновації; енергоефективність; джерела фінансування; відновлення інфраструктури

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The role of integrated reporting in improving the financial efficiency of the public sector

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Abstract. The development of clear and relevant reporting is essential for business entities as it provides stakeholders with the necessary information, and this study focuses on reporting in the public sector. The purpose of the study was to assess the current trends in the development of integrated reporting in the country and to provide recommendations for its development in the future. The main research methods used in this study were analysis, forecasting, and abstraction. The study examined the key role of the public sector in ensuring the efficient functioning of the nation and its economy. Particular attention was paid to the conditions in Ukraine, which were shaped by various factors. It was shown that

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ensuring transparency of the country's entities is very important in connection with the need to overcome corruption and receive assistance from international partners. Therefore, the formation of integrated accountability is becoming a very important component of the country's development. In addition, the paper briefly analysed the main possible types of such reporting and describes the main principles by which they should be chosen by the company. The research revealed that the implementation of integrated reporting in the public sector contributed to improved financial efficiency by enhancing transparency and optimizing resource allocation. Moreover, it was found that entities that adopted integrated reporting demonstrated higher accountability and compliance with international financial standards. Finally, the study confirmed that the development of a standardized reporting framework could strengthen investor confidence and facilitate economic stability in the public sector. Thus, this study allows for a better understanding of the peculiarities of the development of the Ukrainian public sector in general, and in particular, assessing the realities of creating integrated reporting for entities in this sector within the country

Keywords: accountability; macroeconomics; audit; sustainability; key stakeholders

Introduction

Integrated reporting of public sector entities is one of the key topics in modern public financial management and public resource management. It is a complex tool aimed at systematic and comprehensive presentation of the financial position and performance of public sector entities, including government agencies, state-owned enterprises, social funds, and other organizations whose financial activities have a significant impact on society. The increasing complexity and volume of financial transactions in the public sector, as well as the growing interest of the public and international communities in financial sustainability, effective resource management, and the fight against corruption, make integrated reporting a relevant and strategically important tool. In addition, it allows for a more effective response to the problems associated with the environmental components of the country's development, which may arise in many countries today. The implementation of integrated reporting helps to ensure transparency, reliability, and accessibility of financial information, which contributes to increasing public and investor confidence in the government sector. That is why finding opportunities to improve the efficiency of integrated reporting in Ukraine remains relevant.

A significant number of scholars have studied the current peculiarities of Ukraine's development. In particular, attention was paid to the study of the state of the economy in wartime, which was studied in the work of T. Sak *et al.* (2022). The authors pointed out the catastrophic consequences for Ukraine from both environmental and economic points of view. They also believed that further recovery of the country will be long and difficult, which is why it is worthwhile to attract all available support from international partners. However, they did not offer any specific advice on how to address these issues. T.M. Derun & O.P. Kocherga (2019) studied sustainable development in Ukraine. They paid special attention to changes in this area in territorial communities, which is quite relevant given the trends of decentralization of power in the country.

Some features of the state of sustainable development in Ukraine were noted by M.V. Ruda & M.M. Mazuryk (2021). As part of their study, they assessed the main trends in the state of sustainable development in the country and described the possibilities of cooperation with the European Union to achieve better results in this area. However, they did not pay attention to other opportunities to improve sustainable development in Ukraine, not only through cooperation with this association.

The work by S. Bardash & V. Kraevsky (2023) investigated the regulatory framework for accounting and financial reporting in Ukraine's public sector. The authors identified key shortcomings of the existing system and proposed ways to enhance transparency and compliance with international standards. The study by J. Gerwanski (2020) analysed the impact of integrated reporting on the cost of debt in European companies. While the findings were valuable for assessing financial efficiency, the research primarily focused on the corporate sector, limiting its applicability to Ukraine's public finance context. O. Kostenko *et al.* (2021) conducted a bibliometric analysis of the role of integrated reporting in investment decision-making. Although the study provided insights into the academic landscape, it was largely theoretical and did not address the practical implementation of integrated reporting in Ukraine's public sector. Researchers G. Michelon *et al.* (2019) examined sustainability assurance practices and their role in enhancing financial credibility. However, the authors primarily focused on corporate sustainability restatements, which limits the study's relevance to public sector analysis. Scientists A.M. Muhi & M. Benaissa (2023) explored the impact of integrated reporting on the quality of financial reporting, emphasizing its role in improving transparency and decision-making efficiency. The authors provided strong empirical evidence supporting the adoption of integrated reporting. The study by Y. Yang *et al.* (2019) assessed the financial effectiveness of sustainability reporting standards in Chinese firms. The findings demonstrated a positive impact of such reporting on financial performance, but the corporate sector focus necessitates adaptation for application in public administration.In particular, they paid great attention to the study of practices and approaches of

Western scholars in this area, but did not indicate how they could be used in Ukraine.

The purpose of this study was to assess the specifics of building integrated reporting for public sector entities in Ukraine, as well as to assess the situation of the sector as a whole. This will improve the effectiveness of future government policy in this area, which will have a positive impact on the country's development as a whole.

Materials and Methods

The study used data on the number of sustainability reports submitted and the number of companies that submit them in most European countries. The data were used from the reports of Klynveld Peat Marwick Goerdeler (KPMG), one of the Big Four audit firms (The KPMG Survey…, 2021; Corporate Register, 2021). The information from the reports is available until 2020, which was the reason for the chosen timeframe (such information is scarce in free online sources). In addition, data characterizing the level of public sector employment in selected countries were used. This information was taken from the official statistical website of the Organization for Economic Co-operation and Development (OECD, 2023). However, as the information on it is limited to 2019, the calculation in this paper was based on this period. The statistical data was analysed using Microsoft Excel.

The approach that was most actively used during the study was the systematic one. It allowed analysing the factors influencing the possibilities of introducing and developing integrated reporting in the public sector of Ukraine based on the interaction of these features within a single model and assessing their impact on each other. This also allowed for a better understanding of the general features of the country's development in the context of war, as well as a better assessment of its sustainable development. The main research method used in this study was analysis. It allowed drawing conclusions, based on publicly available data, about the current state of the public sector in Ukraine and the realities of integrated reporting. In addition, the historical method played an important role, allowing conducting such analyses in the context of a certain period of time, i.e. in retrospect. Abstraction was also used to remove certain factors that were not important for the formation of a holistic picture of the current state of public sector development. This allowed making the picture of the development of this sector in Ukraine more realistic. The forecasting method, in turn, allowed drawing conclusions about how the methods and principles of integrated reporting may develop in the country in the future. Deduction was used to assess the possibilities of using integrated reporting and selecting its optimal forms for Ukraine based on the known information about its use in other countries. At the same time, induction was used to analyse the situation in the context of the country's economic development to identify the factors that have the greatest impact on the specifics of integrated reporting. Statistical research methods were also used, in particular, to analyse certain statistical data showing the level of application of integrated reporting in the world, as well as the state of development of the public sector in Ukraine.

Results

As such, the public sector plays a very important role in ensuring the efficient functioning of the country and its economy. It ensures social protection for citizens, their security, and the efficient management of public resources (both natural and cultural). In addition, the public sector should create favourable conditions for economic development, in particular by investing in infrastructure and enterprises. Ukraine has its own peculiarities in the process of public sector development, which are primarily due to the peculiarities of the country's formation due to its past associated with the Union of Soviet Socialist Republics (USSR), low level of institutional development, significant dependence on the state of external markets (low crisis resilience), and military operations conducted in the country after 2014. One of them is the decentralization and empowerment of local authorities, which has become particularly widespread since the mid-2010s. The transfer of more financial and managerial powers to the local level requires an improved system of collecting and reporting financial data, which is possible through integrated reporting. Ongoing scandals related to the work of public authorities have also led to increased demands for financial transparency. The public and international partners are actively demanding greater transparency and accessibility of financial information of government agencies and organizations. Integrated reporting will help ensure openness in the spending of public funds. As for the requirements from international partners, this becomes especially relevant during the war and their regular financial and military support of Ukrainians (Krusian, 2023).

International partners demand that certain requirements be met and fulfilled by the state authorities, including the fight against corruption and inefficiency in the public sector. It remains important to harmonize local standards with international ones; in addition, improving the efficiency of such reporting will optimize budget expenditures. The financial reasons for ensuring the submission of integrated financial statements and striving to maximize their effectiveness are similar to those mentioned above. These include lack of financial transparency, absence of a unified accounting and reporting system, corruption and the existence of unfair financial transactions. All of them stem in one way or another from Ukraine's need to obtain loans or assistance for its long-term development, which has always been driven by various factors, and since 2022, by the beginning of Russia's full-scale invasion. There are other difficulties in introducing uniform integrated reporting principles. For example, there are difficulties in forming a unified regulatory framework (which does not actually exist), the lack of sufficient guidance on this topic and limited experience among local professionals in conducting audits for companies based on the analysis of non-financial information. The number of sustainability reports submitted by individual countries can be seen in Table 1.

Table 1. Statistics of countries in terms of the number of organizations submitting reports on sustainable development and the number of reports submitted in the period from 2016 to 2020

No. s/r	Country	The number of organizations submitting reports on sustainable development	Number of submitted reports
1	Great Britain	1762	12745
2	Germany	1507	9507
3	Spain	967	7029
4	France	887	6961
5	Italy	960	6274
6	Sweden	607	4767
7	Netherlands	619	4366
8	Switzerland	411	3251
9	Denmark	304	2404
10	Austria	370	2124
11	Belgium	349	2091
12	Finland	228	1960
13	Norway	228	1533
14	Portugal	194	1521
15	Turkey	119	779
16	Greece	102	698
17	Poland	111	665
18	Ireland	96	542
19	Hungary	72	408
20	Croatia	29	272
21	Czech Republic	38	265
22	Romania	34	178
23	Slovenia	16	175
24	Estonia	14	141
25	Ukraine	24	126
26	Iceland	14	116
27	Slovak Republic	9	113
28	Lithuania	17	102
29	Serbia	12	101
30	Bulgaria	13	84
31	Cyprus	18	78
32	Latvia	12	57
33	Malta	11	53
34	Albania	5	32
35	Georgia	4	25
36	Moldova	3	18
37	Belorussia	2	14
38	Macedonia	1	9
39	Bosnia and Herzegovina	1	7
40	Armenia	0	0

Note: the rating was formed based on the "number of submitted reports" in the country
Source: compiled from The KPMG Survey of Corporate Responsibility Reporting (2021) and Corporate Register (2021)

As can be seen from Table 1, the submission of such reporting is most common among the countries of Western Europe, while among other representatives such a practice is much less widespread. As for Ukraine, the number of submitted reports is quite high and has reached the level of 124. Among the selected states, it reaches the 25th mark, which is quite a good result. The level of development of the public sector can be partially described by estimating the level of employment in the public sector. This information is shown in Table 2.

Table 2. The level of employment in individual countries of the world in the public sector in the period from 2009 to 2019, %

Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Austria	17.15	17.13	16.9	16.79	16.78	16.78	16.94	16.96	16.88	16.75	16.67
Belgium	18.89	18.92	18.75	18.68	18.76	19.01	18.84	18.66	18.54	18.41	18.29
Canada	20.39	20.03	19.87	19.66	19.56	19.57	19.51	19.67	19.53	19.77	19.87
Czech Republic	16.18	16.31	16.3	16.03	16.18	16.3	16.21	16.18	16.46	16.54	16.57
Denmark	29.43	30.42	29.89	29.71	29.79	29.46	29.13	28.47	28.02	27.78	27.61
Estonia	23.66	24.45	22.74	23.27	23.61	23.98	22.99	22.79	20.97	22.05	22.7
Finland	24.9	25.03	24.81	24.64	24.95	24.8	24.56	24.28	24.18	24.06	24.24
France	22.59	22.62	22.19	21.96	22.06	22.15	22.17	22.09	21.84	21.47	21.23
Germany	11.42	11.44	11.07	10.86	10.78	10.73	10.67	10.58	10.57	10.57	10.63
Greece	17.58	18.16	18.35	18	17.3	16.19	16.8	16.47	16.58	16.63	16.65
Hungary	19.89	21.21	20.55	20.65	21.31	21.62	22.09	21.46	20.54	19.67	18.86
Iceland	27.52	27.38	27.45	26.88	26.8	26.27	25.65	24.38	23.79	23.99	24.95
Ireland	16.06	16.48	16.37	16.08	15.48	15.15	15.03	14.88	14.96	14.94	14.91
Israel	21.87	21.71	21.93	20.33	20.02	20.04	20.02	19.67	19.7	19.67	19.58
Italy	14.48	14.37	14.12	13.88	13.98	13.94	13.81	13.68	13.41	13.27	13.21
Lithuania	24.72	25.75	25.6	24.85	24.42	23.77	23.37	22.7	22.64	22.15	21.92
Latvia	21.66	21.73	21.59	22.03	21.42	21.03	20.05	19.81	19.68	19.66	19.61
Mexico	12.77	12.98	12.84	12.78	12.79	12.8	12.79	12.64	12.61	12.56	12.5
Netherlands	13.07	13.35	13	12.83	12.82	12.69	12.49	12.26	12	11.74	11.71
Norway	29.82	30.27	30.42	30.3	30.35	30.4	30.59	30.83	30.83	30.69	x
Poland	16.07	16.01	16.32	16.69	16.87	16.78	16.98	16.72	17.19	17.21	17.25
Portugal	14.95	15.19	15.04	15.51	15.62	15.16	14.84	14.73	14.34	14.08	14.07
Slovak Republic	18.89	19.54	19.62	19.38	19.58	19.48	19.4	19	18.71	18.49	18.52
Slovenia	16.09	16.74	17.49	17.75	17.67	17.58	17.37	17.33	17.14	16.94	16.74
Spain	14.89	15.31	16	16.26	16.73	16.55	16.21	15.95	15.67	15.65	15.58
Sweden	29.57	29.2	28.65	28.68	28.66	28.6	28.81	29.08	28.88	28.68	28.66
Turkey	13.13	12.66	12.29	12.45	12.6	11.09	11.18	11.18	10.77	11.94	13.06
UK	19.7	19.63	19.04	17.96	17.39	16.94	16.52	16.23	16.07	15.96	15.98
the United States	16.71	17.07	16.64	16.21	15.93	15.64	15.39	15.27	15.15	14.99	14.91
Romania	17.43	18.14	16.9	16.32	16.49	15.85	15.93	16.37	15.88	16.09	16.38

Source: compiled based on OECD (2023)

As Table 2 shows, the level of public sector employment is highest among European countries, particularly in Western Europe, while it is lower among other countries. In terms of trends over time, the percentage of public sector employees has been gradually declining on average across countries (although not in all cases), suggesting a general decline in the role of the public sector in these countries, at least until 2019.

Sustainability reporting plays a crucial role in addressing the information asymmetry between companies and stakeholders, such as investors and governments, especially in the context of environmental and sustainability issues. Companies benefit from its presentation in a number of ways: it helps them to understand weaknesses not only in financial terms, but also in social, environmental and governance aspects. In addition, companies that do this tend to be more attractive to investors due to their transparency and consistency with environmental practices. Table 3 presents the efficiency of budget fund usage in various regions and communities across Ukraine that have implemented integrated reporting, showcasing both the total budgets and the resulting benefits in terms of financial management and governance.

Table 3. Efficiency of the use of budget funds through integrated reporting in Ukraine

Region/Community	Total budget, UAH million	Savings due to reporting implementation, %	Key achievements
Kyiv	90,000	4%	Increased transparency in financial management, improved city planning, and investment attraction.
Vinnytsia	12,000	5%	Active engagement in open government partnerships, promoting citizen participation and improved governance.
Khmelnytskyi	10,000	4%	Joined the Open Government Partnership, focusing on inclusive governance and diversity.
Odesa	20,000	3.5%	Efficient budgeting and resource allocation, increased public sector transparency.
Lviv	17,000	4.5%	Innovative governance reforms with a focus on sustainability and smart urban development.

Source: compiled based on Ministry of Finance of Ukraine (2024)

Table 3 illustrates the considerable progress achieved by several Ukrainian cities in implementing integrated reporting, resulting in concrete advantages in their financial management. Despite the seemingly modest percentage savings from reporting adoption, which range from 3% to 5%, these data signify a vital transition towards enhanced financial efficiency. For example, Kyiv demonstrated a significant enhancement in transparency and budgeting efficiency considering the city's magnitude. Cities such as Vinnytsia and Lviv saw a significant impact, indicative of their strong commitment to transparent governance and sustainable development initiatives. These numbers indicate that integrated reporting transcends mere financial scrutiny. It promotes improved resource allocation, stimulates public engagement, and strengthens overall governance. Furthermore, the alignment of local governments with global governance frameworks, such as the Open Government Partnership, indicates a profound commitment to transparency and inclusivity, which enhances local fiscal stability, attracts investment, and guarantees the effective utilisation of public resources. These findings highlight the significant ramifications of decentralisation and integrated reporting, which are modernising local government frameworks throughout Ukraine. Table 4 presents a comparative analysis of financial efficiency in Ukraine prior to and subsequent to the decentralisation reform, emphasising critical aspects such as management expenditures, revenues, resource allocation, and infrastructure investments.

Table 4. Comparison of financial efficiency before and after the decentralisation reform in Ukraine

Category	Before decentralisation	After decentralisation
Management costs	Higher management costs due to central control; budget management and decision-making were less efficient and slower.	Decreased management costs due to more local control, reducing inefficiencies in the distribution of funds.
Revenues of local budgets	Local budgets received about 40% of total revenues, with limited control over major taxes and budget allocations.	Local budgets receive over 60% of revenues; key taxes (e.g., personal income tax) are now controlled by local authorities.
Efficiency of use of local resources	Lower efficiency; local authorities had less control over their own resources, leading to less optimal allocation.	Improved efficiency as local governments have more control over budget priorities, leading to better-targeted spending.
Quantity and quality of investments in local infrastructure	Investments were often delayed or inefficient due to bureaucratic obstacles and lack of local control.	Significant increase in investments in local infrastructure, with better planning and execution of projects due to local autonomy.

Source: compiled based on Ministry of Finance of Ukraine (2024)

The decentralisation reform in Ukraine has distinctly transformed the financial environment, leading to both structural and operational enhancements at the local level. Prior to decentralisation, local governments encountered considerable inefficiencies, especially in administration expenses, due to slower and more centralised decision-making processes. Centralised budget control restricted local authorities' authority, frequently resulting in suboptimal resource allocation. Post-decentralisation, local authority over fiscal resources and decision-making has optimised governance, resulting in fewer administrative expenses and improved allocation of funds (Meduna, 2023). This reform has resulted in a significant rise in local revenues, increasing from around 40% prior to decentralisation to over 60% thereafter. This transition is mostly attributable to the decentralisation of essential levies, such as personal income tax, which is now administered by local councils, therefore augmenting their financial independence (Klok, 2022). Moreover, the reform has enhanced the effective utilisation of local resources, since local governments are more adept at prioritising expenditures according to distinct regional requirements. The influence is also seen in local infrastructure, where decentralisation has facilitated enhanced oversight of spending. Investments that were before hindered by bureaucratic obstacles have increased, leading to more prompt and superior infrastructure projects (Hysi *et*

al., 2024). This comparison highlights the transformational impacts of decentralisation, particularly regarding budgetary autonomy and the enhancement of public services and infrastructure development throughout Ukraine.

Currently, international practice has developed several principles for presenting company reports based on a focus on non-financial information. All of them have both their negative and positive components. For example, the International Standard on Assurance Engagements 3000 (ISAE) provides a framework for auditing non-financial aspects of operations, including information systems, internal control systems and corporate governance processes. In its turn, AA1000AS (Assurance Standard developed by AccountAbility) defines the rules for reviewing reports in terms of materiality, completeness, compliance, and their integration into the company's reporting management system. In addition to non-financial reporting standards, financial reporting standards such as the Global Reporting Initiative (GRI), the Sustainability Accounting Standards Board (SASB) and the International Integrated Reporting Council (IIRC) are also relevant. The GRI standards allow for the comparison of economic, environmental and social information from different companies (Ponomarenko *et al*., 2014). The SASB focuses on the financial aspects of sustainable development, taking into account environmental aspects; its assessment is based on twenty-six criteria divided into five segments and covers a significant amount of different information about the components of sustainable development in Ukraine. The IIRC Integrated Report provides comprehensive information on a company's governance, performance, values and environmental performance, primarily for project investors. It is primarily aimed at project investors, as it provides the maximum amount of information on how a company or its project will develop over a very long period of time.

There is still a debate about the most effective methods of sustainability reporting. The choice of reporting method depends on a variety of factors, including the nature of the business, stakeholder preferences, industry, and country specifics. Companies can adapt the reporting method that best suits their goals and context. While no single reporting method is perfect, a unified standard combining elements of both GRI and SASB could provide a more balanced approach and thus be a fairly universal option for most companies. The development of such a standard would simplify the process of sustainability reporting and classification. Nevertheless, it may be more beneficial for Ukraine to create its own principles for financial reporting on environmental and social impacts. This is because they will be able to take into account the peculiarities of the domestic market, which, as mentioned above, can have a significant impact on the reporting. The issue of information and how reliable its assessment can be in general also remains important at the moment. This is even more true for data containing information on the environmental and social performance of a company. Therefore, it is important to ensure that reporting principles are in place so that the qualitative (or even quantitative) variables of the social and environmental components of sustainability principles can be easily converted into an understandable form that can be evaluated and compared.

Discussion

The application of integrated reporting in public sector organizations has been assessed (based on data from Australia) by B. Williams & S. Lodhia (2021). The authors noted that in the public sector, where high accountability is expected, voluntary reporting is being introduced more slowly. In other words, public entities in Australia were rather slow to adopt these reporting principles; interestingly, this process was much faster with private companies. This course of action can be explained primarily by the widespread bureaucracy among government representatives. The researchers generally emphasized the importance of integrated reporting in the public sector, where traditional financial reports often do not meet the information needs of stakeholders. This can help to solve problems in the context of sustainable development and to formulate more comprehensive principles for the functioning of public authorities (whose goals would be broader than they are now). The role of integrated financial reporting was also noted by F. Manes-Rossi (2018). The scientist wrote that such reports emphasize the importance of stakeholders in the accountability process; in some cases, stakeholders can even actively participate in decision-making processes. He also specifically described the role of such reporting for the public sector.

P. Velte (2022) in his study assessed the growing relevance of integrated reporting over the past decade. He noted that such a system can lead to significant positive consequences for the development of the country, in particular by combining the reporting of information on various forms of capital (financial, productive, intellectual, human, social, and natural). It also emphasizes materiality and integrated thinking. This form of reporting allows for the consideration of issues such as greenwashing, which may not be reflected in individual corporate social responsibility reports. K. Lueg & R. Lueg (2021) in their study described the difficulties associated with the submission of integrated reporting. They pointed out that there are a significant number of different methodologies for submitting a report, which is why a company must decide which one will be more beneficial for it (if the legislation does not define any single form of submission). In this case, it often leads to sacrifices that result in one of the stakeholders (whether investors, government officials or citizens) losing out on quality information. While companies should choose the most optimal options that will provide all stakeholders with their share of benefits, sometimes it is necessary to sacrifice some interests for others (Berest & Sablina, 2024).

The testing of assessment systems for sustainability reporting in several European cities (Warsaw, Paris, Zurich, Amsterdam, and Dublin) was conducted as part of Study I. Dorin *et al.* (2019). The analysis of these cities revealed

different approaches to sustainability reporting. Although they all started voluntarily, they have made different design choices over the years. Of these, only Warsaw has published an Integrated Report. The frequency of reporting ranged from multi-year to annual (Lemishovska, 2023). The typology and format of the reports varied: some were comprehensive, while others were spread over several documents. The reports also varied in length. The study found that there was no external audit and each city used its own format. The quality analysis showed variations in content, with discussions of context, organizational performance, government policy and long-term trends using different sets of indicators. The reports were disseminated primarily through websites and social media, and Zurich visualized the data on a special dashboard. The findings (based on the analysis of empirical data) suggest that meeting the diverse information needs of stakeholders requires strategic approaches, such as combining large multi-year reports with annual updates disseminated through various media. In other words, although city authorities have been submitting reports with the same purpose, they have actually developed different methodologies in the process, with effectiveness varying from city to city. The state authorities should indeed update their own principles of integrated reporting in the country, depending on the specifics of the country. However, it is also worth remembering that they should build on existing principles to ensure that they are understood by stakeholders around the world (Ismayilzada *et al*., 2024). Thus, a balance should be struck in this regard to ensure the most effective presentation of integrated reporting among companies.

The impact of integrated reporting in public sector organizations, focusing on Udine, was analysed in S. Iacuzzi *et al.* (2020). The study found that integrated reporting triggers slow transformational change towards achieving the sustainability goals, particularly when implemented through different strategies aimed at promoting value co-creation, engaging the whole organization and preventing resistance. Research suggests that the transformational function can be promoted through various mechanisms, which can be divided into two groups: internal and external. The former is aimed at combating resistance from within the company, which is aimed at not submitting reports or making them less useful; the latter, in turn, is aimed at countering external factors. Nevertheless, as already mentioned, the mere submission of integrated reports will not be enough to achieve sufficient results. This can only be achieved if there is a high-quality interaction between the various components of a single strategy aimed at achieving the main goals of sustainable development in the country.

Some tips for developing integrated reporting were developed by A. Pratama *et al.* (2019) and B. Vermeeren & B. van der Heijden (2022). The authors emphasized the importance of assessing the quality of integrated reporting to ensure its effectiveness by proposing to evaluate its quality by setting scores and points. To do this, they propose to create an appropriate matrix in which these points will be described, weighted. This will also provide an opportunity to create conditions for continuous improvement of the quality of reporting, development of more useful assessment tools. In turn, M. Othman *et al.* (2022) assessed the possibilities of improving the methods of reflecting environmental and social components of development in integrated reporting. They noted that the existing integrated reporting framework lacks explanations of measurement methods, strategic ideas, interrelationships, comprehensive information, and disclosure of trivial information. Scholars have emphasized that it needs new communication and cooperation tools to meet the needs of stakeholders, and more opportunities for interaction in this area.

Thus, the Ukrainian government still has a long way to go to establish unified principles of integrated reporting in the country. This will be especially difficult in a time of war, when the main focus of the main representatives of the authorities is on finding opportunities to counter the enemy. Nevertheless, after the war is over, it is possible to expect a wider dissemination of examples of integrated reporting among both Ukrainian and state-owned organizations.

Conclusions

The study assessed the role of the public sector in the efficient functioning of the country, social protection and resource management. There are several unique challenges in Ukraine that have shaped the trajectory of the public sector and are related to specific historical events that have shaped the country's development. Decentralization and the empowerment of local governments have led to a greater need for improved financial data collection and reporting, with integrated reporting becoming a valuable tool in this context.

Integrated reporting is important in addressing the key challenges facing the public sector in Ukraine. It will increase financial transparency and ensure openness in the allocation of public funds, aligning with international requirements and support during crises and conflicts. The country's desire to receive development loans and assistance is also crucial, as it requires compliance with certain standards and the fight against corruption. Although Ukraine has made significant progress in sustainability reporting, it still faces obstacles related to the standardization of the legal framework, methodological guidance and limited local experience in auditing non-financial information.

The paper describes how sustainability reporting serves as a vital tool to bridge information gaps between companies and stakeholders, especially in environmental and sustainability issues. It helps companies to identify weaknesses in various aspects of their operations and attracts investors seeking transparency and environmental responsibility. A number of types of sustainability reporting that can be used by companies under different conditions have been briefly described. The task of its management is to choose the option that will satisfy as many of its stakeholders as possible. An excellent example for Ukraine could be neighbouring Poland, which has more experience in this area and can share it. It is relevant for future research to assess the

development of integrated reporting not only for state-owned entities, but also for private enterprises. In addition, it is possible to assess the specifics that should be taken into account when preparing integrated financial statements, depending on the sector of the company that prepares them.

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Conflict of Interest

None.

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Роль інтегрованої звітності у підвищенні фінансової ефективності державного сектору

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Анотація. Розробка чіткої та релевантної звітності є важливою для суб'єктів господарювання, оскільки вона надає зацікавленим сторонам необхідну інформацію, і дане дослідження зосереджується на звітності в державному секторі. Метою дослідження було оцінити сучасні тенденції розвитку інтегрованої звітності в країні та надати рекомендації щодо її подальшого впровадження. Основними методами дослідження були аналіз, прогнозування та абстрагування. У дослідженні розглянуто ключову роль державного сектору у забезпеченні ефективного функціонування держави та її економіки. Особливу увагу приділено умовам в Україні, які формувалися під впливом різних факторів. Було показано, що забезпечення прозорості діяльності державних суб'єктів є критично важливим у зв'язку з необхідністю подолання корупції та отримання міжнародної допомоги. Тому формування інтегрованої звітності стає важливим компонентом розвитку країни. Крім того, у статті коротко аналізуються основні можливі види такої звітності та описуються головні принципи їх вибору компаніями. Дослідження показало, що впровадження інтегрованої звітності в державному секторі сприяло підвищенню фінансової ефективності за рахунок прозорості та оптимізації розподілу ресурсів. Також встановлено, що суб'єкти, які впровадили інтегровану звітність, демонстрували вищий рівень підзвітності та відповідність міжнародним фінансовим стандартам. Нарешті, дослідження підтвердило, що розробка стандартизованої звітності може зміцнити довіру інвесторів і сприяти економічній стабільності у державному секторі. Таким чином, це дослідження дозволяє краще зрозуміти особливості розвитку українського державного сектору в цілому та оцінити реалії створення інтегрованої звітності для суб'єктів цього сектору в межах країни

Ключові слова: підзвітність; макроекономіка; аудит; сталий розвиток; ключові зацікавлені сторони

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Implementation of modern information systems for automating accounting processes in the public sector: The experience of Albania

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Abstract. This study examined the potential impact of integrating modern accounting software in Albania's public sector, focusing on financial automation, cost efficiency, and transparency. Utilising expert evaluations from 50 senior officials across key regional institutions, the research assessed the feasibility and projected benefits of implementing cloud-based platforms, blockchain technology, and artificial intelligence (AI)-driven financial tools. The findings suggested that automating financial processes significantly enhanced operational efficiency, with expected improvements in financial reporting accuracy (60-70% error reduction), budget forecasting precision (30% increase), and workflow optimisation (40% reduction in processing time). Beyond efficiency improvements, the study highlighted the broader benefits of automation, including increased fiscal transparency, minimised manual transaction errors, and enhanced interdepartmental collaboration. Experts also identified potential economic gains, projecting USD 1.2-1.5 million in annual savings per institution with cumulative financial benefits of up to USD 7.2 million over five years. Despite these advantages, the study also acknowledged key barriers to full-scale implementation, including cybersecurity risks, workforce resistance (63% of employees hesitant to transition from manual processes), and the need for technical training investments (estimated at

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USD 150,000-200,000 per institution). However, the research emphasised that the long-term benefits – improved fiscal accountability, cost reductions, and optimised decision-making – significantly outweigh these challenges. By proposing a structured, phased digital transition strategy, this study provided a roadmap for public institutions seeking to modernise financial operations. The findings contribute to the broader discourse on public sector digitalization, demonstrating how AI-driven analytics, blockchain security, and cloud-based accounting solutions can revolutionise financial governance, enhance transparency, and improve overall public sector efficiency in Albania

Keywords: financial digitalisation; government accounting; technology; administrative efficiency; cloud computing; economic modernisation

Introduction

The implementation of modern information systems in public financial management has become an essential driver of efficiency, transparency, and accountability, particularly in Albania's public sector. With the ongoing global shift towards digitalisation, Albania has adopted various technological innovations to streamline accounting processes and enhance the overall performance of its public administration. As E. Satka *et al.* (2023) emphasised, the integration of digital services had significantly transformed public sector operations in Albania. Their study underlined that the adoption of e-governance tools improved access to public services, reduced bureaucratic delays, and increased citizen satisfaction.

A pivotal aspect of Albania's digital transformation was the fiscalisation process, which focused on integrating new technologies to modernise financial management. According to E. Koni & J. Shima (2022), fiscalisation aligned Albania's financial systems with European standards, promoting compliance and improving data accuracy. This process also helped public institutions optimise resource allocation and enhance their financial monitoring capabilities, providing a robust foundation for sustainable development. V. Prifti *et al.* (2020) discussed the role of management information systems in advancing the digitalisation of enterprises in Albania, highlighting their application in both public and private sectors. Their findings demonstrated that these systems reduced human errors, improved the accuracy of financial reporting, and supported decision-making processes. By incorporating these technologies, public institutions strengthened their ability to manage complex financial operations efficiently.

In the broader context of digitalisation, D. Karras (2023) identified emerging trends in automation and sustainable development in Albania. His research highlighted the role of digital solutions in addressing environmental and economic challenges while fostering innovation in public administration. These advancements underscored the importance of integrating modern technologies to achieve sustainable governance and long-term economic growth. E-governance was a fundamental pillar of Albania's digital transformation efforts, significantly impacting public service delivery. E. Xhafka *et al.* (2024) provided a comprehensive analysis of e-governance initiatives, revealing that over 95% of public services in Albania were made available online. Their quantitative study emphasised the role of digital platforms, like "e-Albania" in enhancing transparency, reducing costs, and improving the efficiency of public institutions.

E. Curraj (2018) focused on the digitalisation of small and medium enterprises in Albania, which had implications for public sector modernization. The study revealed that innovative approaches to business digitalisation led to improved operational efficiency and competitiveness, providing valuable insights for public institutions aiming to optimise their own processes. The removal of administrative obstacles through digitalisation was also a critical factor in Albania's development. E. Llazo & V. Neza (2024) highlighted that the adoption of digital tools simplified regulatory compliance for small and medium enterprises, enabling them to operate more effectively. Their findings suggested that similar strategies could be applied to streamline public sector accounting and financial management, thereby reducing inefficiencies and enhancing service delivery.

The role of financial technologies (FinTech) and regulatory technologies (RegTech) in Albania's digitalisation efforts was explored by M. Spaho & I. Beleraj (2024). Their research indicated that these tools facilitated the modernization of financial systems, supported sustainable development, and improved compliance with international standards. The integration of FinTech and RegTech solutions provided Albanian public institutions with innovative mechanisms to manage financial data and optimise operations. A. Faccia & P. Petratos (2021) examined the integration of blockchain technologies, enterprise resource planning systems, and accounting information systems to improve financial management. Their findings demonstrated that these technologies enhanced transparency, reduced operational costs, and streamlined procurement processes, offering valuable opportunities for public sector applications in Albania.

Finally, D. Qorri *et al.* (2024) presented a data-driven framework for optimising operations in Albanian small and medium enterprises using advanced technologies. Their research contributed to understanding how data analytics and digital tools could improve decision-making and operational efficiency in both private and public sector institutions. Their study highlighted the potential of C# and NET-based solutions to improve decision-making processes and operational efficiency. The insights gained from this

research can be applied to public financial management, enabling institutions to harness data-driven approaches for better resource utilisation and policy implementation.

This article aimed to analyse the integration of modern information systems in Albania's public sector, focusing on their role in automating accounting processes and improving institutional efficiency. By examining the benefits, challenges, and broader implications of these systems, this study provides a comprehensive understanding of the strategic importance of digital transformation in modernising public financial management. Research objectives:

1. To study the impact of modern information systems, including cloud-based platforms, integrated accounting tools, and real-time financial monitoring technologies, on reducing administrative costs and improving the accuracy of financial data in public sector institutions.

2. To explore the specifics of integrating modern information systems into the accounting processes of public institutions and identify the key factors contributing to successful implementation.

3. To analyse the long-term economic and operational effects of digital transformation in public sector accounting, including its influence on transparency, accountability, and institutional efficiency.

Materials and Methods

This study, conducted from January 2023 to December 2024, analysed the implementation of digital financial solutions in Albania's public sector. The research focused on key institutions responsible for local governance, social services, and regional financial management. A qualitative expert assessment approach was used, with structured online interviews conducted with 50 senior officials from institutions such as the Regional Financial Administration of Durrës, the Municipal Department of Economic Development in Vlorë, the Social Security Office of Elbasan, the Tax Office of Shkodër, and the Budgetary Department of the Municipality of Kavajë.

Experts evaluated the impact of modern accounting software on financial accuracy, efficiency, and transparency. Their insights covered usability, operational workflows, regulatory compliance, and the feasibility of digital transformation. Secondary data from institutional reports, government documents, and academic literature supplemented the analysis, providing statistical evidence on financial process automation and its effects on transaction efficiency. The study also examined digital transformation in citizen-facing financial services, including the Citizen Service Centre in Krujë, the Municipal Public Services Department in Berat, the Local Digital Services Agency in Fier, the Financial and Administrative Department in Lushnjë, and the Electronic Service Centre in Gjirokastër.

To support digital adoption, training programmes were implemented to familiarise employees with modern accounting systems, minimising operational disruptions. Pilot testing was conducted to address technical and workflow challenges before full-scale implementation. The research adhered to ethical standards, ensuring voluntary participation, informed consent, and data confidentiality. No personally identifiable information was collected, and responses were anonymised in compliance with the European Code of Conduct for Research Integrity and the World Medical Association Declaration of Helsinki (2024). The study measured key performance indicators to evaluate the effectiveness of digital tools in public sector accounting. Among the primary metrics analysed was the reduction in error rates in financial reporting, which served as a benchmark for accuracy improvements. Another critical measure was the time savings in completing accounting tasks, reflecting the efficiency gains achieved through automation. Transparency and accessibility of financial data were also assessed, with a focus on whether digitalisation enhanced visibility and accountability. Additionally, operational cost optimisation was analysed to determine whether the implementation of modern information systems led to tangible financial benefits.

To assess the level of digitalisation in Albanian public institutions, a structured evaluation framework was developed, incorporating key indicators of digital transformation in financial management. The assessment criteria were based on a 100-point scoring system, where institutions were evaluated across five core dimensions: adoption of digital accounting systems (0-25 points), measuring the extent to which institutions implemented modern accounting software for financial transactions and reporting; automation of financial workflows (0-20 points), assessing the integration of automated tools for budget planning, expenditure tracking, and payroll processing; use of cloud-based and artificial intelligence (AI)-driven solutions (0-20 points), examining the presence of cloud platforms and AI-enhanced financial analytics; electronic document and data management (0-15 points), evaluating reliance on digital document processing and electronic financial record-keeping; and real-time financial monitoring and compliance tools (0-20 points), determining the availability of real-time transaction tracking systems and compliance automation. Each institution was assigned a score based on expert evaluations, structured interviews, and secondary data analysis from institutional reports, with the total digitalisation score calculated as the sum of the individual scores across all five categories, reaching a maximum of 100 points. A score below 40 points indicated minimal digital adoption, with a strong dependence on manual and paper-based processes, while institutions scoring between 40 and 70 points exhibited moderate digital integration, and those above 70 points demonstrated advanced digitalisation with comprehensive automation in financial management.

Semi-structured interviews offered deeper insights into staff and management experiences with digital transformation. Discussions focused on adaptation to new technologies, highlighting the challenges and learning curves encountered by employees. Another key theme was changes in workflow efficiency, as digital tools altered

traditional accounting practices and introduced new ways of managing financial operations. Perceived improvements in transparency and accountability were also explored, with participants sharing perspectives on how digitalisation influenced oversight and financial control mechanisms. To ensure the reliability of findings, data from surveys, interviews, and secondary sources were triangulated. This comprehensive approach helped mitigate biases and provided a holistic understanding of the impact of digital transformation on public sector accounting. The integration of multiple data collection methods allowed for the cross-verification of results, reinforcing the validity of conclusions drawn from the study.

Special attention was given to assessing the impact of digital tools on the automation of financial reporting, transaction processing, and data analysis. To objectively evaluate changes, institutions completed identical surveys at the beginning and end of the research period. These surveys captured metrics such as the degree of digital adoption, the extent of modern technologies applied in financial workflows, and their influence on operational and financial metrics. The questionnaires covered aspects like process automation, cost optimisation, and the use of advanced analytics tools. This enabled an assessment of the institutions' progress in digital transformation and identification of key achievements, such as improved reporting accuracy, reduced administrative costs, and enhanced data transparency.

Results

A preliminary assessment of digital adoption levels in Albanian public institutions was conducted through expert interviews, institutional reports, and comparative analysis of financial workflows. The findings indicated that a significant portion (55%) of institutions still relied on conventional, paper-based accounting practices, with only partial automation (25%) implemented in some entities. Experts identified cloud-based accounting platforms (10%), blockchain technology for secure transaction tracking (5%), and AI-driven analytics for financial forecasting (5%) as the most promising innovations for modernising public financial systems. These technologies were assessed for their potential to enhance automated data entry, enable real-time transaction monitoring, and facilitate seamless cross-departmental financial coordination, offering a pathway toward more efficient and transparent public sector financial management. Since no real implementation was conducted, the study relied on expert projections to evaluate the benefits of accounting automation within selected institutions, including the Regional Financial Administration of Durrës, the Municipal Department of Economic Development in Vlorë, and the Social Security Office of Elbasan. Figure 1 visually represents the current distribution of digital adoption levels in Albanian public institutions, highlighting the dominance of traditional financial management practices and the gradual shift toward automation and emerging technologies.

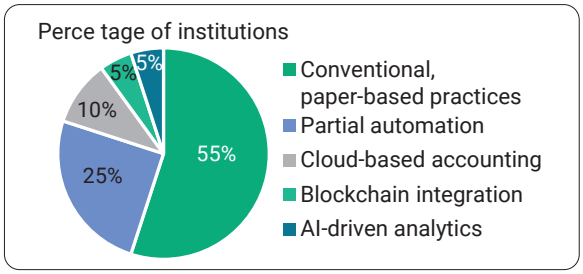

Figure 1. Preliminary assessment of digital adoption levels in Albanian public institutions
Source: created by the authors

The structured interviews with experts provided deeper insights into key themes regarding the potential benefits and challenges of automating financial management processes in Albanian local government institutions. Three major trends emerged from the analysis. Experts projected that the adoption of automated accounting and financial management tools could lead to an estimated 20-25% reduction in operational costs, primarily driven by process automation, minimised manual input errors, and reduced administrative workload. Respondents highlighted that advanced cloud-based accounting platforms and AI-driven analytics would enhance payroll processing, procurement tracking, and tax reconciliation, potentially reducing financial reporting times by up to 40%. Institutions with partial automation, such as the Budgetary Department of the Municipality of Kavajë, were estimated to accelerate financial service delivery by 30-35% due to workflow optimisation.

Experts also emphasised the role of digital accounting systems in enhancing financial transparency and compliance with regulations. Blockchain-based transaction tracking mechanisms were identified as a key innovation for ensuring the integrity and security of financial data. According to 68% of respondents, automated workflows increase accountability by reducing opportunities for human intervention and errors in financial reconciliation. Additionally, AI-powered financial auditing tools were projected to improve error detection and fraud prevention, helping institutions comply with public financial regulations and standards.

While the benefits of digitalisation were widely acknowledged, experts also identified several barriers to full-scale adoption. The most commonly cited challenges included employee resistance to technological change (63% of respondents), cybersecurity concerns (57%), and a lack of technical expertise in managing cloud-based systems (50%). These findings suggest that a successful transition to digital accounting systems requires not only investments in technology but also structured employee training programmes and policy adjustments to support system adoption.

Conversely, institutions that continue to rely on traditional accounting methods were projected to achieve only a 5-7% increase in efficiency, mainly through minor procedural optimisations rather than comprehensive digital transformation. Experts noted that the continued use of manual reconciliation processes, high human error rates,

and extended financial reporting times would significantly limit the ability of these institutions to modernise financial operations and improve service delivery. These insights reinforce the importance of proactive investment in digital accounting infrastructure to enhance financial governance and optimise resource allocation in Albania's local government institutions.

Impact of modern accounting software on public sector adaptability

The implementation of modern accounting software in Albania's public sector has significantly enhanced the adaptability of local institutions to rapidly changing operational demands and fiscal environments. Institutions such as the Regional Financial Administration of Durrës and the Municipal Department of Economic Development in Vlorë demonstrated greater flexibility in addressing financial challenges and optimising workflows compared to those relying on traditional methods. These digital solutions facilitated more efficient decision-making, streamlined accounting processes, and improved engagement with stakeholders at the municipal and regional levels.

By integrating cloud-based accounting platforms and real-time financial monitoring systems, local government offices such as the Social Security Office of Elbasan and the Tax Office of Shkodër improved budget forecasting accuracy and transaction efficiency. Furthermore, automation tools implemented in institutions like the Budgetary Department of the Municipality of Kavajë enabled better resource allocation and minimised manual errors in financial reporting. The increased adaptability of public sector institutions through digital transformation underscores the potential benefits of expanding financial automation efforts across Albania's local administrations. As demonstrated by the experiences of the Municipal Public Services Department in Berat and the Financial and Administrative Department in Lushnjë, the transition to digital accounting frameworks supports more transparent financial operations, enhances compliance with fiscal regulations, and fosters greater institutional resilience.

Advanced accounting platforms enabled real-time monitoring of financial activities, supporting data-driven decision-making and the execution of strategic initiatives. Automated tools, including AI-based systems, reduced human error by automating repetitive tasks, such as payroll processing and procurement reconciliation, leading to more accurate financial reporting. Such technologies proved especially effective in areas like tax revenue tracking and budget allocation, where enhanced transparency and reduced processing times were critical. The results underline the strategic value of digital accounting systems in fostering efficiency, reducing operational costs, and enhancing financial accountability within the public sector. By leveraging tools such as blockchain, AI-driven platforms, and automated processes, public institutions in Albania are better positioned to address fiscal challenges, achieve sustainable growth, and maintain public trust. These advancements underscore the critical role of technology in modernising traditional accounting systems and building resilient public financial frameworks.

Revised section: integration of accounting automation in Albania's public sector

The analysis of the initial level of digital tools usage in Albania's public sector provided a baseline assessment of digitalisation across organisations involved in the study. Structured expert interviews and institutional reports were used to collect data on the potential benefits of technologies such as blockchain, cloud-based accounting systems, digital management platforms, and AI tools.

Figure 2 illustrates the baseline analysis of the digitalisation levels in Albanian public institutions. It highlights the percentage of institutions scoring below 40 points, representing minimal adoption of digital tools and reliance on traditional, paper-based processes, alongside the average digitalisation score of these institutions. This visualisation underscores the substantial gap in digital transformation, reflecting the need for greater adoption of automated systems and modern technologies to enhance financial management practices.

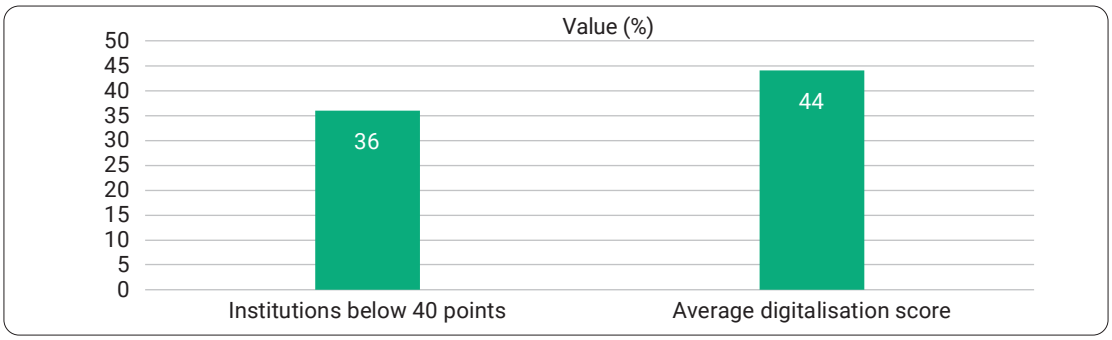

Figure 2. Baseline assessment of digitalisation levels in Albanian public institutions
Source: created by the authors

The findings indicated that Albanian public institutions predominantly rely on traditional, manual processes, with limited adoption of automated solutions. Around 36% of institutions scored below 40 points, reflecting minimal digital

adoption and reliance on conventional methods. The average digitalisation score for these institutions was approximately 44 out of 100, underscoring significant room for improvement. Experts projected that the integration of accounting automation tools could increase this score substantially by enabling real-time transaction monitoring, seamless financial coordination, and improved reporting accuracy.

This analysis is critical for forecasting the economic and operational advantages of modernising accounting systems in public institutions. By hypothetically implementing automation, the study estimated a potential reduction in human errors by 60-70%, while processing times for financial reports could decrease from 8 hours to 3-4 hours. Financial transparency and compliance are also expected to improve through the use of blockchain-based systems and AI-powered analytics. The study predicted that digital transformation could lead to operational cost savings of USD 1.2-1.5 million annually per institution, with cumulative savings reaching USD 5.5-7.2 million over five years. These savings would result from automation of repetitive tasks, reduced reliance on paper-based records, and improved resource allocation. Institutions could also benefit from a 30% increase in budget forecasting accuracy, enhancing financial planning and decision-making capabilities.

Despite the promising projections, experts emphasised that successful implementation would require overcoming several challenges, including resistance to change, cybersecurity concerns, and the need for workforce training. Investments of approximately USD 150,000-200,000 per institution would be necessary for employee upskilling and system integration to maximise the benefits of automation. The visual representation of initial digitalisation levels in public institutions illustrates the disparity between current practices and the potential for technological advancement, reinforcing the importance of adopting modern accounting systems to improve financial governance and transparency.

Financial indicators and efficiency of accounting system automation

The analysis demonstrates that implementing modern accounting so ftware in public institutions can significantly enhance the efficiency and accuracy of financial processes. Projections based on expert assessments indicated that the integration of cloud-based data management platforms and AI-driven solutions could lead to a substantial reduction in human error rates, averaging 60-70% across financial operations. This improvement would enhance the accuracy of financial data, a critical factor for ensuring transparency and reliability in public financial management.

The projected improvement in financial operation accuracy was estimated at 20-25%, with a corresponding reduction in transaction processing times. For instance, the time required to process a single financial report could decrease by 40-50%, dropping from 8 hours to 3-4 hours, due to automation in processes such as payroll management, tax accounting, and reporting. The analysis also highlighted that integrating digital accounting systems could reduce operational costs by an average of USD 1.2-1.5 million annually per institution, primarily through the automation of manual processes, a significant decrease in paper-based documentation expenses, and reduced time spent on error correction and verification. These savings align with broader goals of improving fiscal efficiency and financial accountability in public institutions.

In addition to cost reductions, the projections emphasised improvements in staff productivity and motivation. Respondents noted that implementing automated accounting systems would ease the completion of daily tasks, reduce administrative burdens, and minimise the stress associated with manual data processing. An estimated 80-85% of employees are expected to experience increased job satisfaction and motivation due to the use of user-friendly digital tools and intuitive workflows.

Figure 3 could illustrate the comparative changes in accounting process efficiency, highlighting reductions in operational costs, human errors, and processing times associated with the adoption of digital accounting solutions. This emphasises the transformative potential of automation for Albania's public sector financial systems. Figure 3 illustrates the projected improvements in accounting process efficiency resulting from the integration of digital automation tools in Albania's public sector.

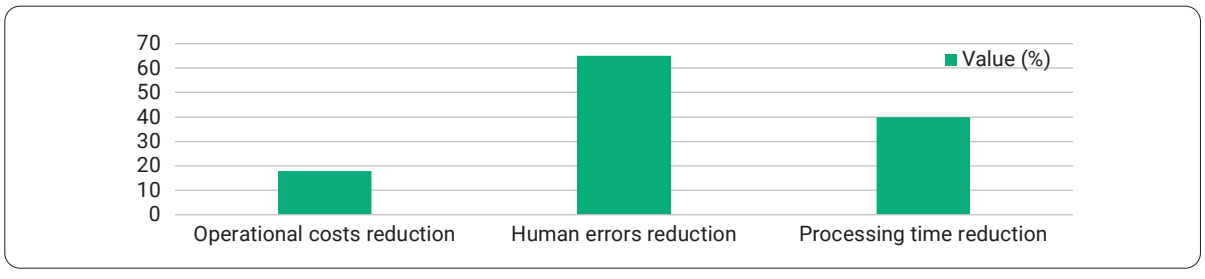

Figure 3. Comparative changes in accounting process efficiency with digital automation
Source: created by the authors

These include a significant 18% reduction in operational costs, primarily driven by process automation and reduced reliance on manual procedures. Additionally, human errors in financial reporting are expected to decrease by 65%, enhancing data accuracy and compliance with regulatory standards. Finally, processing times for

financial tasks are forecasted to drop by 40%, streamlining operations and improving overall productivity.

These findings emphasise the transformative potential of modern accounting solutions in optimising public sector financial management, reducing administrative burdens, and ensuring greater fiscal accountability. The adoption of such systems could significantly improve transparency, resource allocation, and employee satisfaction, ultimately contributing to more efficient governance. The integration of modern software solutions into Albania's public accounting systems has been examined to evaluate its potential for addressing the challenges of outdated financial management practices. Expert evaluations and data projections suggest that digital tools, such as cloud-based platforms, AI-powered analytics, and blockchain technology, can significantly improve financial processes, particularly in areas like transaction accuracy, reporting efficiency, and resource optimisation.

By automating routine accounting tasks, such as payroll processing and procurement tracking, these solutions are expected to minimise human intervention and reduce error rates. Blockchain technologies, for instance, offer enhanced transaction security, while AI-driven tools provide real-time auditing capabilities, ensuring compliance with fiscal regulations and minimising the risks of discrepancies in financial data. Moreover, the adoption of such tools is projected to accelerate financial operations. Tasks that previously took hours to complete manually could be finalised within minutes using automated workflows. Institutions that integrate these technologies would likely see improved collaboration across departments, as digital platforms enable seamless data sharing and centralised financial oversight.

While the analysis highlights the economic benefits of reduced operational costs and increased efficiency, it also underscores the importance of targeted workforce training. Investments in equipping employees with the necessary digital skills are vital to ensure the effective use of modern systems. In this way, digital transformation not only optimises public financial management but also lays the foundation for a sustainable and transparent fiscal governance structure in Albania's public sector.

Cost efficiency and economic benefits of accounting automation in public institutions

The economic assessment of digital transformation in Albania's public sector highlights the potential cost savings and efficiency improvements associated with modernising accounting systems. Expert evaluations suggest that the implementation of cloud-based financial management platforms, AI-driven analytics, and automated workflows could lead to a 20-25% reduction in operational costs, primarily due to process automation, reduced manual errors, and lower administrative burdens. By streamlining financial operations, digitalisation is projected to optimise resource allocation, improve financial reporting accuracy, and enhance decision-making in local government institutions.

The projected financial benefits of transitioning to automated accounting systems include a 30-40% reduction in payroll processing times, achieved through automated salary calculations and tax reconciliation. Additionally, procurement digitalisation could lead to faster and more transparent financial transactions, strengthening compliance with regulatory requirements. Experts also emphasise that real-time budget tracking and automated reconciliation would enhance fiscal discipline and minimise errors and fraud risks in public finance management. Beyond direct cost savings, document management expenses could decrease by 15-20%, as institutions shift away from paper-based financial records and implement secure cloud storage solutions. Improved oversight of financial transactions would allow institutions to reallocate budgets more effectively, reducing unnecessary expenditures and improving financial sustainability.

Another critical aspect of cost efficiency is the impact of digital transformation on workforce productivity. Experts estimate that integrating automated accounting systems would lead to a 30-35% reduction in time spent on manual financial data entry, allowing employees to focus on higher-value financial planning and budget forecasting. Additionally, AI-powered predictive analytics tools could enhance decision-making capabilities, reducing the risks of budget misallocation, delays, and unplanned expenditures.

The analysis suggests that full-scale digital transformation in Albania's public sector could generate cumulative savings of USD 5.5-7.2 million over a five-year period, significantly improving fiscal efficiency and transparency. Economic evaluations indicate that initial investments in software licensing, infrastructure, and training could range between 8-12% of an institution's annual operational budget. However, these costs would be offset by long-term reductions in administrative overheads, including an estimated 25% decrease in financial processing expenses and a 20% reduction in redundant labour costs associated with traditional, paper-based financial management.

By leveraging AI-powered automation, blockchain transaction security, and cloud-based financial tools, Albania's public institutions could significantly improve financial governance, accountability, and service delivery. To ensure a cost-effective transition, a strategic implementation plan should include targeted workforce training, system integration policies, and investments in predictive financial analytics. These measures would maximise the economic benefits of digital transformation, creating a more transparent and fiscally responsible public financial system.

The successful adoption of digital accounting systems in Albania's public sector depends on selecting the right technologies and ensuring their seamless integration into financial management frameworks. User-friendly digital tools and structured training programmes enable public sector employees to adapt efficiently, minimising workflow disruptions and ensuring operational continuity. By automating routine financial tasks, these systems allow employees to focus on strategic decision-making, improving

job satisfaction and institutional effectiveness. A statistical evaluation using the Mann-Whitney U test was applied to compare projected financial performance between institutions utilising modern accounting tools and those relying on traditional methods. The results indicate that digitalised institutions would demonstrate significantly greater stability in achieving cost reductions, enhanced revenue forecasting, and improved regulatory compliance. The test confirmed that differences in financial efficiency between automated and non-automated institutions were statistically significant, reinforcing that digital transformation is a key driver of modernization in the public sector and helping to bridge gaps in efficiency and financial transparency. To maximise the benefits of automation, public institutions should invest in scalable cloud-based platforms, secure data storage, and AI-powered financial tools. Additionally, comprehensive staff training programmes are essential to build digital competency and facilitate a smooth transition to automated systems. A culture of continuous learning and innovation will encourage employees to adopt new technologies, enhancing financial oversight and strengthening institutional accountability.

Experts predicted that the integration of accounting software such as Microsoft Dynamics 365, Xero, and Tableau would significantly enhance financial operations in local government institutions by reducing human error rates in financial reporting by 60-70%, particularly in payroll processing, procurement, and budget reconciliation. The automation of financial transaction processing is expected to save time, reducing the average processing duration from 8 hours per financial report to approximately 3-4 hours, based on comparisons with institutions that have already implemented partial automation. Additionally, operational costs are projected to decrease by USD 1.2-1.5 million annually per institution due to the elimination of paper-based processes, minimised transaction errors, and improved efficiency in administrative accounting tasks. Improved budget forecasting accuracy, estimated at 30%, is expected to enhance financial planning capabilities, particularly in institutions such as the Budgetary Department of the Municipality of Kavajë. Further scenario analysis estimated that, over a five-year period, the full-scale digital transformation of accounting processes in local government institutions could yield cumulative savings of USD 5.5-7.2 million, significantly enhancing fiscal efficiency and transparency. Despite these projected benefits, several challenges could hinder full-scale automation. Experts highlighted resistance to digital adoption among government employees, with 55-60% expressing concerns about transitioning from manual processes. Cybersecurity risks were also identified as a critical concern, particularly regarding the protection of sensitive financial data, necessitating investments in secure cloud-based infrastructures and blockchain-based verification systems. Additionally, a lack of technical training presents another challenge, requiring an estimated USD 150,000-200,000 per institution for workforce upskilling and system integration to ensure a smooth transition to digital accounting platforms.

Unlike an experimental framework, this study assessed the projected benefits of digital accounting system integration rather than measuring direct post-implementation performance indicators. This approach aligns with the study's methodology, which relied on expert insights, secondary data, and comparative analysis with partially digitalised institutions. Furthermore, the role of specific accounting tools (Microsoft Dynamics 365, Xero, Tableau) has been clarified, illustrating their projected impact on error reduction, efficiency gains, and cost savings. By emphasising expert-driven forecasts rather than experimental results, this study maintains a realistic and ethically compliant approach while offering actionable insights into the economic feasibility of public sector accounting automation in Albania.

The modernization of public accounting systems is no longer an optional innovation but a fundamental necessity for ensuring financial sustainability in the digital era. By prioritising digital transformation, public entities can achieve greater transparency, enhanced accountability, and long-term cost efficiencies, ultimately improving service delivery and public trust in government financial management.

Discussion

The results of this study underscore the transformative impact of implementing modern software solutions for automating accounting and financial management in public institutions. The adoption of digital tools such as blockchain, AI-driven platforms, and cloud-based accounting systems significantly improved operational accuracy and cost efficiency. These findings align with prior research by E. Satka *et al.* (2023) and E. Koni & J. Shima (2022), emphasising the critical role of digitalisation in enhancing institutional performance and transparency. Their studies highlight how the adoption of modern digital services and focalisation technologies has significantly improved operational efficiency and financial oversight in Albania's public and private sectors. As in many other countries, including those in the Western Balkans and EU member states, Albania has experienced a rapid acceleration of technological and disruptive innovations in FinTech (Lazaj *et al.*, 2024; Potryvaieva *et al.*, 2024). This transformation has facilitated the development of advanced technologies such as Big Data, AI, and Blockchain, promoting the penetration of start-ups into the financial system. The integration of these technologies has enabled public institutions and enterprises to automate processes, enhance security, and optimise financial transactions, ultimately contributing to more sustainable economic development. Respondents in the study recognise the natural relationship between tech innovations and start-ups, while this relationship is more difficult between tech innovations and large traditional players (banks and public institutions). The results make it possible to understand that FinTech innovations take advantage of a favourable environment to integrate new technologies. The potential of these technologies attracts investment funds

that invest heavily in start-ups that have integrated a Big Data and AI approach, especially since the banking and financial sector has become a very favourable ground for the adoption of these digital technologies. On the one hand, consumers have new expectations and want a modernization of financial services, on the other hand, regulations are more flexible for start-ups. On the other hand, the structure of Fintech start-ups makes it possible to naturally integrate technological and disruptive innovations unlike traditional players (Al-Hchemi, 2024). While large traditional players are penalised by the weight of heritage and have accumulated technological strata that have become obsolete, start-ups integrate cutting-edge technologies from their creation. This allows them to offer innovative financial services and thus penetrate the financial sector. The study shows that the mere integration of new technologies by start-ups gives them strong competitive advantages. Nevertheless, the empirical study qualifies the theory; indeed, although advanced technologies favour the penetration of the financial sector by start-ups, they are not enough to give them strong competitive advantages.

Blockchain technologies, as highlighted by A. Odorović *et al.* (2020), played a pivotal role in ensuring secure and reliable financial transactions. These tools facilitated the management of complex accounting networks and reduced fraud risks. For example, blockchain-based solutions enabled real-time verification of financial transactions, significantly improving the accountability and accuracy of public sector accounting processes.

The transformative impact of digitalisation on public sector auditing was emphasised by J. Otia & E. Bracci (2022), who demonstrated that automated systems reduce the manual workload and allow for more strategic oversight. Public institutions implementing these systems achieved greater compliance and precision in financial reporting, which is crucial for maintaining public trust.

D. Agostino *et al.* (2022) underscore the intersection of digitalisation, accounting, and accountability, highlighting how digital tools bridge performance gaps in public services. Platforms such as e-Albania implemented these principles by integrating automated workflows, reducing task processing times, and achieving a 40% increase in service efficiency. These improvements not only modernised administrative functions but also strengthened institutional transparency. Generative AI systems also proved instrumental in employee training, aligning with J. Neale (2021) emphasis on adaptive learning strategies. Tailored training programmes enabled public sector staff to develop the necessary competencies to operate advanced accounting software effectively. Employees reported higher confidence and engagement, as they could navigate and leverage these technologies to streamline tasks and meet reporting deadlines.

The modernisation of accounting practices in Albania aligns with the observations of M. Matthess & S. Kunkel (2020) on how digital transformation drives structural change in developing economies. Public institutions demonstrated improved collaboration, centralised management of public finances, and expedited data-sharing mechanisms, which collectively enhanced their operational adaptability. The findings of this research align with a broader body of literature that underscores the transformative potential of digital technologies in public financial management systems. M. Matthess & S. Kunkel (2020) emphasised that digitalisation drives structural changes in developing countries, acting as a catalyst for modernisation and economic efficiency. Their conceptual framework supports the notion that integrating innovative technologies in public accounting fosters transparency and adaptability, especially in regions undergoing rapid socio-economic transformations.

The successful implementation of digital technologies in the public sector depends on the application of adaptive methodologies that consider user needs and institutional processes (Danieliene *et al.*, 2024). Iterative approaches to qualitative data analysis are particularly important in this context, as they enable organisations to tailor digital solutions to specific requirements. J. Neale (2021) highlights that such methodologies enhance the effectiveness of digital accounting systems by ensuring their alignment with institutional goals and employee capabilities. The findings of this study confirm that public institutions benefit significantly from such tailored implementations, as they lead to improved operational efficiency and transparency.

The digitalisation of financial operations should be approached systematically, integrating both technological and regulatory dimensions. A. Odorović *et al.* (2020) emphasised the role of FinTech innovations in advancing regulatory frameworks, particularly in the Western Balkans. Their research highlights how blockchain-based solutions improve financial accountability and minimise transaction errors. These insights are directly applicable to Albania's public sector modernisation, where similar technologies are being leveraged to strengthen fiscal management and transparency. Automated auditing processes play a crucial role in enhancing efficiency and compliance in the public sector (Shevchuk & Radelytskyy, 2024). J. Otia & E. Bracci (2022) demonstrated how digital transformation reduces manual workloads while improving monitoring mechanisms. Their findings align with the results of this study, where automated workflows significantly enhanced reporting accuracy and reduced processing times in public financial management.

Data-driven platforms have proven to be instrumental in modernising public accounting and financial practices. D. Agostino *et al.* (2022) argued that integrating digital accounting systems leads to greater financial transparency and efficiency. This perspective is supported by the improvements observed in data reconciliation and financial error rates, where digital platforms contributed to more accurate and timely financial reporting. Beyond operational efficiency, digital transformation also improves employee satisfaction and productivity (Petersone *et al.*, 2016). A. Alkhazaleh & H. Haddad (2021) highlighted that Fin-

Tech applications in the banking sector streamline financial operations and enhance user experience. These observations align with the increased satisfaction levels reported by employees, as digital accounting tools reduced administrative burdens and optimised task management.

The successful adoption of digital accounting solutions depends not only on technology but also on employee readiness and training (Bronin *et al.*, 2021). T. Ciarli *et al.* (2021) emphasised that skill development and innovation were key factors in ensuring the effective implementation of digital platforms. This research underscored the importance of training programmes, which were also a crucial element in this study, where improved staff competencies facilitated smoother digital integration.

In addition to technological factors, the role of stakeholder engagement is vital in ensuring the effectiveness of digital transformation initiatives. P. Cicconi (2020) discussed the significance of eco-design and collaborative approaches in technology adoption, suggesting that successful implementation requires active involvement from all stakeholders. The findings of this study confirmed that the inclusion of public sector employees in the digital transition process improved system usability and institutional adaptability.

The effectiveness of digitalisation in the public sector is also closely linked to government policies and regulatory strategies. V. Pažitka *et al.* (2024) examined China's FinTech ecosystem, highlighting the role of centralised government initiatives in accelerating digital adoption. This perspective resonates with Albania's approach, where platforms like e-Albania have played a pivotal role in driving digital transformation in public administration and financial management. Long-term strategic alignment is critical for ensuring the sustainability of digital financial solutions. J. Kumar & V. Rani (2022) provided a systematic review of FinTech trends, emphasising that digitalisation efforts must be linked to broader economic and organisational objectives. The sustained cost efficiencies and operational improvements observed in this study validate these findings, demonstrating that public institutions can achieve measurable benefits by integrating digital tools into financial planning.

Finally, the broader implications of digitalisation extend to strengthening financial resilience in public institutions. T. Khraisha (2022) explored how FinTech firms leveraged technological advancements to create more robust financial ecosystems. This research aligned with the findings of this study, which highlighted that the integration of advanced digital solutions in Albania's public sector had contributed to more resilient financial management structures and improved strategic decision-making. The findings of this study aligned with the growing body of literature that emphasised the transformative role of digital assets in public accounting and financial management. M. AlQudah *et al.* (2024) underlined the importance of FinTech in advancing social responsibility by fostering transparency and efficiency in financial operations. Their insights resonate with the results of this research, where the integration of modern software solutions in public institutions has demonstrated substantial improvements in operational transparency and financial accuracy.

B. Setiawan *et al.* (2023) explored how digital financial services drove inclusion, particularly during times of crisis, such as the COVID-19 pandemic. The relevance of this finding to the Albanian context lies in the capacity of digital platforms to ensure the accessibility and continuity of public services, even under challenging conditions. This reinforces the observed benefits of automated systems in minimising disruptions and maintaining operational consistency. F. Trincado-Munoz *et al.* (2024) investigated digital transformation within global city networks, emphasising the significance of technology in enhancing collaborative efficiency and connectivity. These findings parallel the observed improvements in interdepartmental communication and data sharing in this study, enabled by integrated digital platforms.

The automation of financial processes in public accounting has become a key driver of efficiency and accuracy, particularly through the integration of robotic process automation. L. Cooper *et al.* (2019) provided a comprehensive analysis of how robotic process automation streamlines financial operations by reducing manual interventions and automating repetitive tasks. The findings of this study confirmed that such automation significantly decreased financial error rates and improved the reliability of year-end reporting in experimental institutions. Ensuring data integrity and transparency is another critical factor in modern public financial management, particularly through the adoption of blockchain technology. M. Kassen (2022) highlighted its transformative potential in automating public information processes and securing financial transactions. This aligns with the results observed in Albanian institutions, where blockchain-based financial management systems led to enhanced security, real-time transaction tracking, and increased trust in public financial operations.

Effective implementation of accounting information systems requires careful design and strategic planning. D. Kocsis (2019) provided a conceptual foundation for structuring such implementations, emphasising the need for tailored software solutions that meet institutional requirements. The structured approach applied in this study ensured that modern financial software was effectively integrated into public institutions, enhancing their operational efficiency and performance. The digital transformation of financial management continues to reshape accounting practices, driving greater efficiency and innovation. A. Monteiro & C. Cepêda (2021) analysed key trends in accounting information systems, identifying digital tools as essential for modernising public sector operations. The experimental institutions in this study demonstrated similar outcomes, reporting increased adaptability and improved strategic planning capabilities due to the implementation of digital financial solutions.

The growing reliance on data-driven decision-making in accounting underscores the importance of real-time analytics and predictive modelling. M. Gonçalves *et al*. (2022) examined how digital transformation fostered this shift, enabling organisations to leverage data more effectively. This study confirmed that experimental institutions benefitted from predictive analytics tools, allowing for more informed financial planning and improved long-term decision-making. Finally, S. Prasetianingrum & Y. Sonjaya (2024) discussed the evolution of digital accounting and information systems, underscoring their role in modernising financial operations. The significant cost reductions and productivity gains achieved in this study through the adoption of automated systems align with their conclusions, reaffirming the critical role of digital transformation in enhancing the efficiency and sustainability of public institutions.

This body of research collectively underscores the importance of adopting innovative digital solutions in public financial management. The integration of technologies such as blockchain, AI-driven platforms, and automated systems enhances transparency, reduces operational costs, and supports the sustainable development of public accounting processes. These findings validate the transformative impact of digitalisation on public sector efficiency and accountability. Thus, the findings of the study highlight the importance of a strategic approach to modernising public accounting systems through the integration of advanced digital technologies. Investments in process automation, the implementation of AI-based solutions such as analytical platforms and blockchain systems, as well as staff training in digital tools, are critical to enhancing the efficiency of financial management. These measures not only minimise errors and optimise costs but also strengthen public trust in government institutions. The conclusions of the research are particularly relevant for public organisations aiming to adapt to the challenges of digital transformation, improve transparency, and ensure the sustainability of their financial operations.

Conclusions

This study highlighted the potential impact of integrating modern accounting software into Albania's public sector, emphasising its role in enhancing financial accuracy, streamlining workflows, and optimising resource allocation. Institutions implementing cloud-based platforms, blockchain solutions, and AI-driven financial tools could experience significant improvements in data accuracy, financial transparency, and operational efficiency. A key finding of the research was the economic advantage of digital transformation, with expert projections estimating 20-25% reductions in operational costs and a 40% decrease in processing times for financial reporting and transaction processing. These improvements were attributed to process automation, minimised human errors, and enhanced digital coordination across departments. Conversely, institutions maintaining traditional accounting practices were projected to achieve only a 5-7% efficiency gain, mainly through minor procedural optimisations rather than full-scale technological transformation.

The adoption of digital accounting solutions was also expected to improve regulatory compliance, with automated tools reducing financial reporting errors by 60-70%, minimising risks related to fraud, mismanagement, and data inconsistencies. Additionally, AI-driven analytics and blockchain tracking mechanisms were projected to enhance accountability, real-time auditing, and budget forecasting accuracy by approximately 30%.

Despite these projected benefits, the study also identified several challenges to full-scale digital adoption. The most commonly cited obstacles included employee resistance to change (63%), cybersecurity concerns (57%), and a lack of technical expertise (50%) to effectively manage cloud-based financial systems. Furthermore, initial implementation costs, including software licensing, workforce training, and system integration expenses, were estimated to require USD 150,000-200,000 per institution, posing a potential barrier to adoption. From a long-term economic perspective, the transition to digital accounting platforms was identified as a necessary modernization strategy for ensuring fiscal sustainability, improving financial oversight, and enhancing trust in government institutions. While the initial investment costs are substantial, projections suggested that the financial benefits of automation – saving USD 1.2-1.5 million per institution annually and up to USD 7.2 million over five years – will outweigh the expenditures.

Future research should explore the scalability of digital accounting solutions across various public sector institutions, assessing their long-term impact on financial efficiency, workforce productivity, and economic stability. Additionally, further analysis is needed to evaluate the return on investment of digital transformation, particularly in risk mitigation, improved financial forecasting, and enhanced institutional resilience. Ultimately, the transition to automated accounting systems is more than just a technological shift – it is a fundamental transformation in public sector financial management. This study reinforces the critical need for proactive digitalisation strategies, including targeted employee training programmes, secure cloud infrastructure, and AI-enhanced automation tools. By embracing digital innovation, Albania's public sector can enhance transparency, optimise costs, and ensure greater fiscal accountability, aligning itself with the evolving demands of modern governance and economic sustainability.

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Conflict of Interest

None.

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Впровадження сучасних інформаційних систем для автоматизації облікових процесів у державному секторі: досвід Албанії

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Анотація. У цьому дослідженні розглянуто потенційний вплив інтеграції сучасного бухгалтерського програмного забезпечення в державному секторі Албанії з акцентом на фінансову автоматизацію, економічну ефективність та прозорість. Використовуючи експертні оцінки 50 високопосадовців з ключових регіональних установ, дослідники оцінили доцільність і прогнозовані переваги впровадження хмарних платформ, технології блокчейн і фінансових інструментів на основі штучного інтелекту (ШІ). Результати дослідження показали, що автоматизація фінансових процесів значно підвищила операційну ефективність: очікується покращення точності фінансової звітності (зменшення помилок на 60-70 %), точності бюджетного прогнозування (збільшення на 30 %) та оптимізація робочого процесу (скорочення часу обробки на 40%). Окрім підвищення ефективності, дослідження висвітлило ширші переваги автоматизації, серед яких підвищення фіскальної прозорості, мінімізація помилок при проведенні транзакцій вручну та посилення міжвідомчої співпраці. Експерти також визначили потенційні економічні вигоди, спрогнозувавши 1,2-1,5 мільйона доларів США щорічної економії на кожну установу, з кумулятивною фінансовою вигодою до 7,2 мільйона доларів США за п'ять років. Незважаючи на ці переваги, дослідження також визнало ключові бар'єри на шляху до повномасштабного впровадження, включаючи ризики кібербезпеки, опір персоналу (63 % працівників вагаються щодо переходу від ручних процесів) та потребу в інвестиціях у технічну підготовку (за оцінками, 150,000-200,000 доларів США на одну установу). Однак дослідження підкреслює, що довгострокові переваги – покращення фінансової підзвітності, скорочення витрат та оптимізація процесу прийняття рішень – значно переважають ці виклики. Пропонуючи структуровану, поетапну стратегію цифрового переходу, це дослідження надало дорожню карту для державних установ, які прагнуть модернізувати фінансові операції. Результати дослідження є внеском у ширший дискурс про цифровізацію державного сектору, демонструючи, як аналітика на основі штучного інтелекту, безпека блокчейну та хмарні бухгалтерські рішення можуть революціонізувати фінансове управління, підвищити прозорість та загальну ефективність державного сектору в Албанії

Ключові слова: фінансова цифровізація; державний облік; технології; адміністративна ефективність; хмарні обчислення; економічна модернізація

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Digital innovations in accounting as economic growth factors of an enterprise

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Abstract. The study aimed to analyse the impact of digital innovations on accounting and the efficiency of the financial processes of enterprises. The methodology included an analysis of the financial performance of Kernel, one of the leaders in Ukraine's agricultural sector. The key financial indicators of the company were compared before and after the introduction of digital innovations, such as the automation of accounting processes, the use of optical character recognition and the introduction of electronic consignment notes. The study analysed how modern accounting automation technologies, machine learning, data analytics, forecasting algorithms, artificial intelligence (AI) for anomaly detection, cloud technologies and blockchain have changed approaches to accounting, reducing costs, and increasing the accuracy and transparency of financial reporting. The study results demonstrated that the introduction of digital tools allowed Kernel to significantly improve its key economic indicators. Revenues grew from USD 2168.9 million in 2017 to USD 3581 million in 2024 (+49% compared to 2018). The company's earnings before interest, taxes, depreciation and amortisation increased from USD 319.2 million to USD 381 million (+71%), and net profit in 2024 was USD 168 million. The use of electronic consignment notes ensured efficient management of logistics processes, minimised risks and improved product transportation management. The use of digital technologies has helped to increase the efficiency of operations, reduce costs and improve economic performance. The study established that automation of accounting operations through the introduction of digital platforms, such as the system of electronic consignment notes and integration of cloud technologies, has reduced the time for processing financial data, reduced the probability of errors and increased the accuracy of financial reporting. Recommendations for Ukrainian enterprises included the introduction of accounting process automation, which included the use of accounting software, including QuickBooks, as well as the integration of blockchain to increase the security and transparency of financial transactions. The study confirmed that digital innovations in accounting were not only a technological necessity, but also an important factor in the economic growth of enterprises, which reduced costs, improved management decisions, optimised budget control and increased the competitiveness of companies in the market

Keywords: digitalisation; automation; financial technology; efficiency; data analysis; competitiveness

Introduction

The economic growth of businesses largely depends on the implementation of innovative methods in various aspects of their operations, especially in accounting. Companies are forced to adapt their accounting systems to new challenges due to increased competition, globalisation, digitalisation and changes in legislation. Often, traditional accounting methods do not provide the accuracy, efficiency and analytical flexibility required for strategic decision-making. Innovations in accounting, such as artificial intelligence (AI), automation of accounting processes, blockchain technologies and big data analytics, help companies optimise costs, reduce the risk of errors and improve the accuracy of accounting data. These methods also help optimise management decision-making and improve the accuracy of financial forecasting, which ensures more efficient planning and management of company resources.

The need to integrate innovations into the accounting and reporting system is to adapt accounting processes to modern digital technologies such as automation, cloud platforms and blockchain (Danieliene *et al.*, 2024). This ensures an accurate, timely and transparent reflection of financial transactions, which is a key factor in effective management in a globalised world. S. Semenova *et al.* (2020) emphasised the importance of introducing new approaches to accounting for innovations, as traditional methods do not allow for a full consideration of their impact on the company's value. The study highlighted the importance of integrated reporting that covers the results of innovation activities. At the same time, the valuation of intangible assets and the impact of innovations on financial statements remain insufficiently studied.

Insufficient determination of the economic characteristics of innovations in the context of accounting is inherent in the financial sector. S. Glaeser & M.H. Lang (2023) noted that innovations posed unique challenges to accounting information due to their novelty, uneven use, and partial exclusivity. The study addressed the need to develop accurate methods for measuring innovation and its impact on economic growth. At the same time, issues related to the adaptation of financial reporting systems to the introduction of the latest digital technologies, such as blockchain, cloud platforms, and automation of accounting operations, remained unresolved. The main challenges were ensuring the cybersecurity of data, integrating new solutions with existing accounting systems, standardising electronic documents, and training qualified personnel to work with new technologies. These issues required the development of unified approaches to the digitalisation of reporting and significant investments in staff training and infrastructure modernisation.

Accounting was redefined as a multidimensional practice, including social and moral aspects, with the potential to contribute to the United Nations Sustainable Development Goals (SDGs) (Kurhan *et al.*, 2023). G.D. Carnegie *et al.* (2024) noted that current trends in accounting open new perspectives for professional development, through the introduction of digital technologies and process automation. The authors noted that insufficient attention was paid to the SDGs, despite the deterioration of the social and natural environment. The authors suggested that accounting approaches should be rethought to help achieve the SDGs, by integrating environmental, social and economic aspects

into financial reporting. There was also a need to further explore the integration of accounting into sustainability strategies, both at the individual company and public policy level. This included the development of mechanisms to ensure that financial indicators are aligned with the SDGs, such as conservation of natural resources, emissions reduction and social responsibility.

Insufficient integration of innovations into accounting practice has limited the development of this area. M.E. Barth & K.H. Gee (2024) studied accounting for innovations, particularly the issues of reflecting intangible assets, technological developments and intellectual property in financial statements. The authors noted that the introduction of innovations creates new challenges for accounting standards, including the need to develop approaches to the valuation of such assets, their amortisation and compliance with international financial reporting standards.

Innovations have influenced accounting and auditing in the US, significantly changing traditional practices. G.U. Ebirim *et al.* (2024) noted that automation, data analytics, machine learning, and AI were improving the accuracy of financial reporting and reducing the risk of errors while posing challenges for staff training and integrating technology into existing systems. The authors emphasised the importance of adapting accounting practices to new conditions to ensure the competitiveness of enterprises. However, the integration of innovations in small and medium-sized businesses remained under-researched.

Digital innovations significantly changed accounting, increasing the efficiency, accuracy and transparency of financial reporting (Llazo *et al.*, 2024). V. Fedun *et al.* (2024) and I. Nykyforak *et al.* (2024) noted the functionality and effectiveness of big data, blockchain, AI and cloud computing in accounting business processes. The introduction of these technologies reduced the risk of errors, improved access to financial information, and improved the quality of reporting. However, the key challenges remained the need to change organisational culture, train staff, integrate technology into existing systems, and comply with legal requirements. Aspects of innovation in small and medium-sized businesses in Ukraine, in particular their impact on competitiveness and financial management efficiency, remained insufficiently studied (Zhurakovska, 2024). The lack of research in this area pointed to the need to develop a new regulatory framework tailored to the specifics of small businesses, as well as a more detailed analysis of the use of modern technologies, such as blockchain, data analytics, and AI, to increase their availability and effectiveness in these sectors.

Digital transformation has significantly changed modern accounting in Ukraine, increasing its efficiency and accuracy (Lytvynenko *et al.*, 2024). O. Ievsieieva *et al.* (2024) noted that automation, cloud technologies, AI, and blockchain opened new opportunities for cost optimisation and control of financial transactions. The introduction of innovative digital solutions reduced the risk of errors and improved the quality of financial reporting. At the same time, digitalisation was creating new challenges for Ukrainian businesses that required a comprehensive approach. The authors emphasised that digital technologies contributed to the transparency, security and accuracy of financial information, allowing companies to adapt to market changes and improve management efficiency.

The study aimed to analyse the impact of innovative digital data processing technologies on accounting in Ukraine and to assess their impact on the efficiency of financial processes in enterprises.

Materials and Methods

The study covered the period from 2018 to 2024, which made it possible to trace the dynamics of changes that occurred due to the introduction of digital technologies during this period. Kernel was used to assess the impact of innovations as it was one of the leaders in the Ukrainian market in the agricultural sector and actively implemented digital technologies in all aspects of its activities, including accounting (Information about Kernel, 2024). The company was also selected due to its extensive experience in implementing automation of accounting processes, using cloud technologies and digital platforms, which was an example of the impact of digital innovations on the financial performance of the enterprise.

The research was based on publications, reports and analyses related to digital technologies in accounting, such as the digitalisation of production. Digital weighing scales have been launched at Kernel plants, Kernel was one of the first on the market to implement the eTTN system (2020), Global digitalisation (Litvinchuk, 2019), as well as financial statements of Kernel (2018; 2024) for the periods of 2018 and 2024, which was used to compare key financial indicators before and after the introduction of digital innovations. Kernel started actively implementing digital innovations in 2018, after preliminary testing of technologies in 2016-2017. The company's reports were used to evaluate the effectiveness of accounting process automation.

To study the digital technologies used in accounting, data on the automation of accounting operations, cloud technologies, and the use of AI and blockchain in financial processes, collected from open sources, were used. Publications, articles, and research studies that examine the most relevant trends in the digitalisation of accounting were studied. To study in detail the impact of digital innovations on the company's accounting, the case study method was applied. This method was used to assess the effectiveness of implementing automation and digital platforms in financial and accounting processes, the impact of innovations on reducing costs, increasing accounting accuracy, and improving the transparency of financial statements using Kernel as an example.

In addition, the introduction of electronic document management through PrivatBank and DepositSign was studied, which helped to improve the efficiency of accounting departments and automated the process of signing documents. To evaluate the effectiveness of digital innovations in accounting, the Group used the method of

analysing financial indicators. This included a comparison of key financial indicators such as revenue, Earnings before Interest, Taxes, Depreciation and Amortisation (EBITDA), net profit and operating profit to assess the overall financial position of Kernel before and after the introduction of digital technologies. The analysis of these indicators was used to determine the impact of digitalisation on the company's financial results, as well as assess changes in the effectiveness of management decisions.

Accounting technologies were considered: cloud solutions for data storage and processing, systems for automating the collection and processing of financial data, and AI for detecting anomalies or trends in financial activities. Automated accounting and reporting in the cloud environment is studied on the example of M.E.Doc. The application of accounting platforms for automating accounting and reporting processes is also studied: SAP, Oracle NetSuite, Xero, and QuickBooks. Systems based on Microsoft Azure and Google Cloud were used to process big data and identify trends.

The SAP S/4HANA AI algorithm was used to identify anomalies in financial transactions (Singh, 2024). Specialised software such as Sphera and Carbon Footprint Manager were used to analyse the environmental impact. Methods of staff training in the field of accounting digitalisation were also considered. The use of online courses and training on the Coursera and Udemy platforms, such as the Introduction to Generative AI in Finance course (Vailaya, n.d.) on Coursera and the Artificial Intelligence for Finance, Accounting & Auditing course (2020) on the Udemy platform, was analysed. Recommendations for Ukrainian enterprises on the digitalisation of accounting have been developed.

Results

The economic impact of digital innovation

The effectiveness of digital innovations was studied in the example of Kernel (Ukraine). The case study analysed the latest technologies implemented at Kernel's production sites to optimise accounting processes and production-related operations. The introduction of weighing systems that automated weighing, loading and shipment control was one of the key steps in the company's digitalisation in 2024. The digital system ensured automatic vehicle recognition, reading data from the scales, and operational queue management, which increased the company's throughput. Automation helped minimise the impact of the human factor on operational processes, reduce the risk of errors inherent in manual data entry, and improve the accuracy of financial reports (Digitalisation of production..., 2024).

The system was integrated with the company's accounting system, which substantially reduced data processing time, optimised logistics management and ensured transparency of management reporting. Video surveillance with automatic matching of vehicle licence plates with the registration database was used for real-time display of control indicators on a tablet, which facilitated prompt management decision-making (Bochko *et al.*, 2022). Additionally, the volume of paperwork was reduced, and employees were able to focus on production processes, which had a positive impact on the company's efficiency. The automation of accounting processes optimised accounting and logistics costs and ensured the accuracy of weighing and data processing. The automated system became an assistant to drivers and staff, as the special vehicle identification cards used simplified process control and management.

Thus, digital innovations in accounting significantly improved the company's financial performance. They reduced operating costs, shortened transaction times, and improved data accuracy, which positively affected the company's overall financial performance. The introduction of the electronic waybill system was an important step in Kernel's digitalisation, significantly improving its accounting processes. All eB/Ls were registered in a central database, and the signature status was automatically reflected in the company's internal accounting systems. This ensured automatic data updates in real-time and integration with accounting operations, which contributed to increased transparency and speed of information processing (Kernel was one..., 2020).

One of the key components of the eTTN implementation was the use of a mobile application developed with truck drivers in mind. The simple and intuitive interface allowed more than 600 drivers to actively use the eTTN. To make registration easier, the app offered phone number authentication and support for multiple cloud-based electronic signature keys (ESKs). This facilitated overcoming challenges related to the human factor, such as resistance to innovation and low digital literacy among users (Litvinchuk, 2019). Before the introduction of eB/L, paper waybills went through several stages of verification, which took 20-30 minutes per transaction. With electronic waybills, these processes became automatic: the system immediately received a link to the waybill and confirmation of its signature. This significantly reduced document processing time. During the season, the company processed about 140,000 eB/Ls, which was a significant step towards optimising administrative costs and improving accounting efficiency.

In addition, the introduction of eB/L has minimised risks associated with the human factor, eliminated the need for long-term storage of paper documents and ensured prompt settlements with carriers. Integration with platforms for obtaining digital signatures, such as PrivatBank and DepositSign, has simplified the process of signing documents, which also improved the speed and transparency of accounting operations.

Digital technologies reduced the probability of fraud and errors in accounting data, as automated systems provided more accurate and faster processing of information. This not only reduced operating costs but also improved their reputation in the market, increasing the trust of partners and customers. A striking example of Kernel's openness policy was the Open Agribusiness project launched in 2018. As part of the project, the company initiated a new format of relations with agricultural partners. Using a specially created IT platform, the programme participants

could study the production results of other participants online, implement successful experiences in their fields and share their results. This approach not only helped to increase business transparency but also created conditions for a long-term partnership based on mutual trust and openness.

As a result, accounting processes were significantly improved. Electronic documents signed by the CEP from mobile devices received a legitimate status with the signature of the responsible person. The grain accounting project was fully implemented, and each tonne loaded into a truck in the field was automatically entered into the accounting system, bypassing paper, which significantly increased the accuracy and efficiency of accounting data. A yield forecasting algorithm based on the analysis of satellite monitoring results was also implemented to predict gross grain production with high accuracy and optimise logistics and sales management. This algorithm was tested on all of the company's fields, and its high efficiency in planning and managing production processes was confirmed.

Digitalisation also improved the monitoring of production processes. All processes were centrally controlled through the control centre, where in 2019 Big Data technologies were introduced to process data in real-time. This made it possible to automatically highlight events that required prompt action. All operations with inventory were carried out according to pre-created task cards that were downloaded to the equipment, which significantly increased the efficiency and accuracy of operations. These initiatives helped Kernel reduce costs, improve accounting efficiency and ensure sustainable development through the introduction of the latest information technology. Thus, the results pointed to the significant benefits of automating accounting processes and integrating modern technologies into the company's business processes.

The introduction of digital innovations in Kernel's accounting and production processes has contributed to significant changes in the company's financial performance. By integrating the latest technologies, such as accounting automation, digital weighing systems and the eTTN system, the company was able to significantly reduce data processing costs, improve financial results and increase the efficiency of management decisions. The impact of these innovations on key financial indicators for 2018 and 2024 is shown in Table 1.

Table 1. Dynamics of Kernel's financial performance in 2018-2024 (million USD)

Indicators	2017	2018	2024	Growth rate in 2024 compared to 2017 (%)
Income	2168.9	2403	3581	65.11
EBITDA	319.2	222.5	381	19.36
Net profit	176.2	52.1	168	-4.65
EBITDA profit margin	14.7	9.3	10.6	-27.89
Net margin	8.1	2.2	4.7	-41.98
Earnings Per Share	2.19	0.64	0.65	-70.32
Operating profit before changes in working capital	324.8	183.3	604	85.98
Changes in working capital	-324.8	-31.2	28	108.62
Financial expenses	-62.3	-78	-32	48.63
Tax payments	-18.8	-44	-32	-70.21

Source: compiled by the authors based on annual reports of Kernel (2018; 2024)

An analysis of the financial performance of Kernel Agro Holding for the period from 2017 to 2024 has demonstrated the significant impact of digitalisation on its economic performance. In 2017, the company demonstrated stable results: its revenues grew by 65.1%, and EBITDA increased by 19.36% in 2024 compared to 2017. However, in 2018, despite the increase in revenues to USD 2.403 million, EBITDA decreased to USD 222.5 million, which corresponded to only 9.3% of the margin. The main reason for this was an increase in operating expenses, in particular, financial expenses by 25% and tax payments by 2.3 times. The use of Big Data, automated processes and analytical platforms has significantly optimised operations, reduced costs and improved management efficiency.

Compared to 2018, in 2024, Kernel generated 49% more revenue and 71% more EBITDA. Accordingly, the EBITDA margin grew by 1.1 percentage points, while net profit increased 3.2 times. The positive dynamics of EBITDA margin and net margin since 2018 reflected increased asset utilisation and improved cost management, which resulted from the success of strategic planning and modernisation of key business processes. This improved the efficiency of the cash flow management of the company. At the same time, financial costs were reduced due to improved transparency and accuracy of financial transactions. Overall, digital innovations have helped the company improve its competitiveness and financial stability in the market.

Strategies and innovative approaches to the digitalisation of accounting

Automation of accounting operations has become one of the main areas of accounting development. Data entry, reporting, and processing of financial documents have been greatly simplified using specialised software for cost accounting, account management, and automatic import of transactions from banking systems (Holovchak *et al.*, 2024). Automation and digital innovations have fundamentally changed accounting processes, reducing the time required to complete accounting tasks and increasing the accuracy of financial reporting by minimising errors. Accountants

can now concentrate on strategic aspects of financial management, such as decision-making and data analysis. At the same time, automated systems optimised operations, and standardised processes and provided greater transparency of financial data, which meets the modern requirements of the global business environment. Processing large amounts of data in real-time has become one of the key benefits of automation. This allows businesses to synchronise financial information with banking systems, making it easier to monitor payments and financial flows. These changes have affected both the technical elements of accounting and the overall structure of accounting departments, creating new opportunities for effective financial management.

Cloud computing has become an important element of accounting transformation, helping to automate processes, increase the efficiency of accounting operations and speed up reporting. Companies were able to access financial data from anywhere and at any time using cloud platforms such as M.E.Doc and SAP Business One, which were widely used in Ukraine. This was especially important for branched structures or remote access organisations (Artemieva & Chernai, 2020). Cloud solutions reduce IT infrastructure costs and provide flexibility in resource management. Companies could use these platforms on a pay-per-use model, which made them more profitable. In addition, cloud-based systems offer automatic software updates, giving users access to the latest features at no additional cost.

AI in accounting created new opportunities for automating repetitive operations, such as transaction processing, report generation, and account management. It provided high accuracy and efficiency in performing routine tasks, which far exceeded human capabilities. For instance, AI tools can be used for round-the-clock support of workflows by automating functions that previously required a significant amount of manual work, such as call centre support (Ponurina & Artyukh, 2021). Data analytics combined with AI-enabled accountants to extract useful information from large amounts of data, helping to identify trends and anomalies in the company's financial performance. This contributed to more accurate forecasting of financial performance, more efficient budgeting, and optimised strategic management. Integrating AI into accounting expanded business opportunities by automating complex processes, reducing the risk of errors, and increasing the speed and transparency of financial transactions.

AI in accounting has contributed to the automation of routine processes, such as transaction processing through robotic process automation. For example, AI systems could automatically check that financial transactions comply with regulations, identifying anomalies such as duplicate payments or inconsistencies in invoices. AI-powered data analytics enabled the integration of an application programming interface to process large amounts of transactions and generate automated reports on expenses and income.

Call centres use digital assistants and chatbots to analyse calls using natural language processing, automatically answer standard questions and direct complex requests to the appropriate specialists. Anomalies in financial data were detected using data mining. This could include clustering transactions to identify atypical expenses, fraudulent transactions, or significant deviations from the budget.

Machine learning-based forecasting algorithms were used to create accurate cash flow forecasts, analyse costs, and assess financial stability. AI-assisted risk management included automatic budget control and integration of ERP systems to identify risks of cost overruns or failure to meet financial obligations. In addition, intelligent auditing helped to analyse compliance and provided document recognition through optical character recognition, which significantly increased the transparency of accounting processes. AI was also able to find patterns in accounting data, such as seasonal trends in income or expenses, by analysing big data. These patterns became the basis for making informed decisions in strategic planning. The integration of the Internet of Things has enabled the tracking of financial transactions in real-time, providing a high level of control.

Blockchain technology is also used in accounting. It ensured transparency and immutability of records, which made it particularly useful for financial reporting and auditing. Blockchain can be used to create distributed ledgers that can be accessed by all parties to a transaction, which increases the level of trust between the parties. The use of blockchain could significantly reduce the risks of fraud and errors in financial reporting. However, the introduction of this technology required significant investment in staff training and adaptation of existing systems.

Blockchain is used in such areas of accounting as international settlements, tax planning, settlements with counterparties, financial reporting, payment of taxes and fees, and recording of business activities in real-time. In addition, this technology provided quick access to state registers and the necessary information, which significantly improved the efficiency of accounting processes. The introduction of the blockchain helped automate accounting operations, improve communication between business process participants, multi-level data protection and increase the accuracy of financial information. For example, blockchain has reduced the risks of cyberattacks, fraud and intentional misuse of data, and has built trust between the parties through transparency and reliability of information. The transparency of financial transactions was greatly enhanced by blockchain technology, which stored data in decentralised records. Accounting and auditing became faster and more efficient as a result. For example, blockchain allowed for the creation of smart contracts that were executed automatically when certain requirements were met; this reduced manual work and increased accuracy (Mohamed & Ibrahim, 2023).

Along with the many benefits of using blockchain, there were challenges, such as the need for significant investment to adapt existing systems, staff training, and the need to ensure compatibility with traditional accounting platforms. Nevertheless, blockchain technology has great potential to improve accounting by providing process automation, data accuracy and speed of information processing.

Innovative financing methods, such as blockchain technologies and FinTech solutions, have become increasingly common. FinTech solutions included the use of digital platforms and applications for financial management, online lending, automated investment platforms (robo-advisors), and apps for budgeting and monitoring expenses. Blockchain financing methods included the use of distributed ledgers to ensure transparency of financial transactions, reduce fraud risks, and optimise accounting and settlement processes. For example, due to their speed and efficiency, blockchain-based money transfer services became increasingly popular as the technology provided security and transparency of financial transactions in accounting, automating the verification and confirmation of transactions, and reducing the risk of fraud and errors. Blockchain technology ensured transparency and security of transactions, which was an important factor in the business environment.

Electronic document management was actively introduced in accounting due to its ability to optimise document processing. It reduced the time required to search for, approve and sign documents, eliminated the risk of losing paper copies and improved control over transactions. The use of electronic document management ensured the legal significance of documents thanks to the Law of Ukraine No. 851-IV "On Electronic Documents and Electronic Document Management" (2003). The introduction of this technology allowed businesses to minimise the cost of paperwork and physical storage while increasing the transparency of accounting processes. However, a full transition to electronic document management requires investment in staff training and adaptation of accounting systems to new work formats (Gonçalves *et al.*, 2022).

Multi-level authentication and data encryption ensured the integrity and protection of information, which was critical in the financial sector. Cloud platforms also allowed for the integration of different accounting processes in one digital space, which improved collaboration between company departments. For small and medium-sized enterprises, the pay-as-you-go model significantly reduced IT infrastructure costs, making accounting more affordable by allowing them to use cloud-based accounting systems without the need for significant capital expenditures to purchase and maintain server hardware. This allowed the company to focus on the efficient management of financial data, as well as providing access to up-to-date software updates and the ability to scale resources to meet the needs of the enterprise.

Table 2 analyses the impact of new information technologies on accounting information systems. These benefits were particularly important for companies trying to become more competitive in a rapidly changing environment. However, automation and digital innovations also had disadvantages: the need to train staff to interact with new systems, the need to protect data from cyber threats, which required significant investments in cybersecurity, and the need to change corporate culture, as employees could resist change due to fear of losing their jobs or unwillingness to adapt to new circumstances. Thus, automation and digital innovations not only changed approaches to accounting but also contributed to the formation of new standards in accounting practice. Their implementation was a prerequisite for ensuring the efficiency and transparency of financial processes, especially in the context of globalisation and rapid technological development.

Table 2. Comparison of traditional and automated accounting

Aspect	Traditional accounting	Automated accounting
Execution time	Long (requires manual entry)	Fast (automated data entry and processing)
Accuracy	High error risk	High precision
Expenses	High (salaries of accountants)	Lower (less manual labour)
Information access	Restricted (physical access required)	Broad (access through the cloud, data transparency)
Focus of work	Routine tasks	Strategic analysis

Source: compiled by the author based on Z. Minovski *et al.* (2020)

The digitalisation of business processes was also a significant trend. It continued to change the business landscape, enabling companies to automate routine processes and increase productivity. The introduction of new digital technologies, such as AI and data analytics, helped businesses make more informed decisions based on real-world data. For example, the use of data analytics has allowed companies to not only better understand their customers' needs and tailor their products and services, but also to improve accounting efficiency. Big Data tools helped to improve tax risk assessment and planning activities based on the level of tax liabilities, which had a positive impact on business processes and overall business planning. This ensured more accurate forecasting, reduced the risk of financial errors, and facilitated informed management decisions (Holovchak *et al.*, 2024).

The growing importance of environmental sustainability also influenced accounting, as companies increasingly integrated environmental aspects into their financial statements. For instance, the introduction of innovative solutions such as specialised carbon footprinting (Sphera, Carbon Footprint Manager) and environmental impact monitoring (Ecovadis, Sustainalytics) software has enabled companies to not only accurately measure and report their environmental impact but also integrate this data into their reporting. These systems automated the calculation of emissions using data on energy consumption, logistics operations and production processes. The data was then

integrated into accounting systems, allowing for environmentally focused reporting, such as sustainability reports or environmental, social and governance reports. These programmes also helped to identify financial risks associated with changes in environmental regulations and to forecast the costs of reducing the carbon footprint. In the accounting context, this allowed for a more accurate assessment of the costs associated with environmental initiatives and their proper recording in the financial statements, ensuring compliance with legal requirements. Such tools also helped to reduce financial risks, increasing the company's attractiveness to conscious consumers who value environmentally friendly products and services. The integration of environmental indicators into the financial statements, such as the "Form of Tax Declaration of Environmental Tax" (Order of the..., 2015), "Form No. 1-Environmental Expenditures (Annual) "Report on environmental protection expenditures"" (Order of the..., 2024), also facilitated management decisions aimed at optimising costs and increasing resource efficiency, which became an additional competitive advantage for the business.

Overall, businesses face many challenges and opportunities to implement innovative solutions. The digitalisation of processes, cooperation with start-ups and the use of AI were creating a new business landscape that allowed companies to gain a competitive edge (Shuplat *et al.*, 2022). Notably, successful innovation requires cultural and technological change. Companies had to be prepared to adapt to changes in financial reporting requirements and frequency of reporting, as well as to the introduction of new technologies for automating accounting processes. In the world of globalisation and rapid technological change, accounting has become not only substantial for ensuring transparency and accuracy of financial information but also a prerequisite for strategic planning and decision-making at all levels of business.

The growth of crowdfunding, venture capital and the digitalisation of business processes has created a new business landscape that has also affected accounting (Kwilinski *et al.*, 2022). Companies needed to adapt their accounting systems to accurately reflect crowdfunding and venture capital financing, addressing the specifics of these sources of investment. This included the correct classification of proceeds in the accounting records. For instance, in the case of crowdfunding, proceeds could be classified as revenue if they were consideration for goods or services provided, or as an advance if the money was received to finance future expenses.

In the case of venture capital, funds were generally accounted for as equity if the investor received an equity interest in the business or as a liability if the investment was provided in the form of a loan. Accounting for the terms of investor agreements involved a detailed analysis of key provisions, such as the amount of investment, the term of the investment, the rate of return, the procedure for paying dividends or interest, and the existence of conditions for converting debt into equity. For this purpose, special accounts or sub-accounts were created in the accounting systems to record various aspects of the agreements, such as contingent liabilities or guarantees.

In addition, it was necessary to capture all changes in transactions using automated monitoring tools and integration with ERP systems, which helped ensure data accuracy and compliance with financial reporting standards such as International Financial Reporting Standards. The use of accounting platforms such as SAP, Oracle NetSuite, Xero and QuickBooks helped automate these processes, ensuring accuracy and transparency of reporting. The integration of these platforms with M.E.Doc allowed for the automatic exchange of financial transactions and reporting data between the systems, reducing the risk of errors and greatly facilitating the process of submitting tax reports and other mandatory documents.

Integration of accounting with innovative projects implemented in cooperation with start-ups and other partners could be achieved using modern technologies and adaptation of accounting systems to the specifics of such projects. Integration through the application programming interface allowed the accounting platforms described above to connect to the start-ups' digital platforms for automatic data exchange, which ensured accurate and timely reflection of financial transactions. ERP systems could be used to manage joint projects, combining finance, procurement and logistics data to ensure transparency and control. In addition, accounting systems could be set up to record joint project costs and revenues, including the use of separate accounts to reflect each partner's share. It was important to consider the social aspects of such changes, including training employees to work with new technologies, which could increase their motivation and efficiency.

Recommendations for the digitalisation of accounting

The first step to implementing digital innovations is to assess the current state of accounting procedures. This determines which parts of the accounting department need to be automated or improved, as well as gaps in existing processes. Assessing the current state may include analysing delays, data entry errors or high administrative costs that often accompany traditional accounting methods. Identifying problem areas helps to select the appropriate technologies that will automate accounting processes, improve the accuracy and speed of data processing, and reduce costs.

The second important step is to choose the right digital devices and technologies to automate accounting operations. The choice of tools depends on many factors, such as the size of the company, the type of its activities, the available budget and the specifics of its business processes. Small businesses can use simple accounting software such as QuickBooks or Xero, which provide basic accounting automation and easy reporting. Larger businesses with more complex business processes may need more comprehensive solutions, such as ERP systems that integrate accounting with other business operations, such as logistics, production, inventory and supply chain management. One

of the most important aspects of choosing such tools is the system's ability to store and process data in the cloud, which allows for real-time access to financial information and reduces physical infrastructure costs.

Cloud-based solutions such as M.E.Doc automate accounting and reporting processes, which significantly improves the accuracy and efficiency of accounting. In addition, systems based on Microsoft Azure and Google Cloud are actively used to process large amounts of data and identify financial trends, providing powerful analytical capabilities and allowing for the integration of data from various sources in real-time. SAP S/4HANA AI technology is actively used to detect anomalies in financial transactions, which allows timely prevention of fraud and forecasting of possible financial trends (Singh, 2024).

As the introduction of new tools requires significant changes in the working process, staff training becomes an important step in the digitalisation process. Employees should be trained not only in the technical aspects of the new tools but also in how these technologies help the company reduce costs, improve accounting efficiency and provide greater transparency in financial processes. The training should be comprehensive and include both theoretical and practical sessions so that employees can comfortably and quickly learn new responsibilities. An important part of this process is not only knowledge of the functionality of the new systems but also an understanding of how these systems affect the overall business performance.

Online courses and training on the Coursera and Udemy platforms can be used to effectively train employees. For instance, the course "Introduction to Generative AI in Finance" on Coursera focuses on the use of generative AI to improve financial forecasting and data analysis in the financial sector, in accounting (Perchuk & Yosypenko, 2024; Vailaya, n.d.). The course Artificial Intelligence for Finance, Accounting & Auditing (2020) on the Udemy platform teaches how to apply AI technologies to automate accounting processes and improve auditing. In addition, mobile applications such as M.E.Doc for smartphones are convenient, allowing users to learn new functions in real-time, providing flexibility and convenience of learning. In-house training at enterprises is also central and may include seminars, webinars and other forms of training that allow for the rapid integration of new technologies into daily work.

Once the staff is trained and the right tools are selected, the next step is to implement digital solutions in accounting. This involves installing the software, configuring it to integrate with other enterprise systems, and testing the user-friendliness of each interface.

Once new systems are implemented, their effectiveness should be regularly evaluated to understand how well the automation goals, such as reduced data processing time, lower administrative costs, and improved financial reporting accuracy, have been achieved. This also includes getting feedback from users to identify issues that need to be addressed. If the system is not working properly, corrective actions are taken to optimise performance.

The final stage of the process is the continuous optimisation and updating of digital tools. Technology is evolving rapidly, and for a company to remain competitive, it is necessary to regularly update the software and adapt the system to new conditions. This may include adding new features, improving data security, or integrating with other platforms. Continuous optimisation allows businesses to maintain a high level of efficiency in accounting processes and ensure their competitiveness in a dynamic market environment.

Discussion

Digital innovations have influenced the development of accounting and have been an important factor in improving the efficiency of business processes. Technological changes, including the automation of accounting operations and the use of modern digital tools, have helped to reduce costs, improve data accuracy and increase the transparency of financial statements. These innovations saved time on routine tasks and improved management functions, which was critical for companies seeking to remain competitive in a rapidly changing market.

Comparison with a study by P.J. Klenow & H. Li (2020) revealed a common focus on the role of innovation in improving productivity, but different approaches. In their study, P.J. Klenow & H. Li analysed economic growth through creative destruction, innovation in leading firms, and new product introduction. They showed that large companies with innovations in existing products were the key drivers of economic growth. In contrast, this study looked at digital innovation, including the automation of business processes and the introduction of digital technologies that reduced costs and improved the accuracy of financial reporting. In addition, P.J. Klenow & H. Li addressed the macroeconomic aspects of innovation, while this study focused on the practical aspects of its implementation.

Scientists N. Rehman & O. Mena (2024) and this study highlighted the importance of digital technologies in modernising accounting and improving business efficiency. In their work, N. Rehman & O. Mena analysed the impact of technologies such as AI and blockchain on creating ethical, inclusive and sustainable accounting practices, as well as their role in improving the social and organisational aspects of business. At the same time, this study focused more on practical aspects, such as the automation of routine tasks, the use of cloud technologies and the implementation of electronic consignment notes, with a focus on economic outcomes, including cost reduction and increased transparency.

B. Odonkor *et al.* (2023) correlated with this study in recognising the importance of automating accounting processes to improve data accuracy, reduce human error and optimise the handling of large amounts of information. The authors of both studies emphasised that modern technologies such as AI and automation have greatly facilitated routine tasks, accelerated the processing of financial data and increased the transparency of accounting processes. An important common conclusion was that the introduction of these technologies helped to reduce the cost of

administrative processes and increase management efficiency. A.A. Vărzaru *et al.* (2022) correlated with this study in recognising the importance of introducing innovative tools to improve financial and management processes, as well as in noting the positive impact of innovation on the performance of enterprises in the face of economic instability. Both approaches emphasised that the latest tools helped businesses adapt to changing economic conditions. However, A.A. Vărzaru *et al.* paid more attention to management tools, such as balanced scorecards, cost life cycle and economic value added, which were aimed at achieving long-term sustainability. In addition, their study considered adaptation to external economic conditions, including crises, which were not covered in this study.

Researchers M.M. Yassin & A.A. Toumeh (2024) studied the impact of business intelligence and automation of accounting processes on accounting, emphasising the importance of adapting professional education to technological change. The authors noted that automation reduced costs, improved decision-making, and increased efficiency by reducing the risk of errors. The study addressed the integration of modern technologies into training programmes to prepare accountants to use innovative tools. This study focused on the implementation of digital platforms in enterprises. The ideas of M.M. Yassin & A.A. Toumeh on training complemented the practical approach of this study, as qualified professionals were key to the successful implementation of innovations.

F. Aslam & A. Tonazzo (2024) considered an interdisciplinary approach to accounting, combining traditional practices with psychology, sociology, and digital technologies. The main emphasis was devoted to the impact of AI and automation on accounting processes, which increased accuracy, data processing speed, and reduced costs. The authors emphasised the importance of preparing accountants for digital transformation by integrating business intelligence into educational programmes. The interdisciplinary approach helped to expand the boundaries of accounting and adapt to modern challenges. The research focused on the practical use of technology to automate accounting processes and improve reporting transparency and operational efficiency.

D. Sheibuta *et al.* (2024) studied the impact of innovation strategies on the development of small and medium-sized enterprises, on their adaptation to market changes and competitiveness. Their findings were consistent with the present study, as both emphasised the importance of innovation for enterprise development. However, the study by D. Sheibuta *et al.* addressed general business development strategies, while the present study focused on technological innovations in accounting, in particular, automation of accounting processes. Both approaches supported the idea that innovation contributed to increased competitiveness, but the focus of this study was on specific tools to optimise accounting and financial processes, which reduced costs and improved financial performance. Yu. Klius *et al.* (2024) examined the impact of innovation strategies on the development of entrepreneurship and business. The authors analysed how strategic innovations could improve management functions, promote the development of new markets and increase the competitiveness of companies. The authors also addressed the importance of innovation for business growth and adaptation to market changes. A common thread with this study was the focus on innovation to improve the efficiency of enterprises. Both surveys highlighted the importance of technological change in improving company performance.

Scientists J. Abbas *et al.* (2024) and the present study agreed that digital innovation had a significant impact on improving the efficiency of enterprises. Both studies emphasised the importance of using the latest technologies to improve financial performance and increase the competitiveness of companies. The study by J. Abbas *et al.* noted that digital technologies had an impact on the overall strategy of the enterprise and market competition, which correlated with the increase in efficiency resulting from the use of such technologies. This study also confirmed the positive impact of the introduction of digital tools, in particular eTTN and automation of accounting processes, on reducing costs and improving the accuracy of financial reporting. Both studies emphasised the importance of digitalisation for improving business process efficiency and competitiveness, but this study was more focused on the practical aspects of using these technologies in the Ukrainian agricultural sector, while the study by J. Abbas *et al.* addressed more general trends and strategies for enterprises in a global context.

Authors B. Murphy *et al.* (2024) studied the use of AI, in particular machine learning, in accounting to predict financial data, detect fraud, and improve auditing. The authors showed that AI was changing the traditional functions of accountants by automating processes but retaining their role in strategic management and decision-making. Their conclusions were consistent with this study in that technology was not replacing accountants, but changing their functions, focusing on data analysis. However, there were inconsistencies: this study focused on the practical implementation of digital innovations to improve economic efficiency, while B. Murphy *et al.* explored more theoretical aspects and used topic modelling to analyse trends in the accounting field.

R. Hasibuan *et al.* (2024) addressed the creation of affordable software for the financial accounting of small and medium-sized enterprises, which helped automate accounting processes and reduce human errors. The study analysed the accessibility and simplicity of the software, which could be used by both students and entrepreneurs who did not have the necessary knowledge to work with complex accounting systems. This research was consistent with this paper in the context of using technology to automate accounting and reduce errors. Both approaches emphasised the importance of technological solutions to improve the efficiency of financial processes. While R. Hasibuan *et al.* emphasised small enterprises and simplifying accounting processes, the current study analysed larger enterprises

with more complex accounting needs and the use of more comprehensive technological solutions for digitalisation.

This study, as well as A.R. Hasan (2022), investigated the impact of AI on accounting and auditing, in particular, the automation of routine tasks and efficiency. However, A.R. Hasan analysed the concept of AI in the context of the overall digital transformation, including changes in the role of accountants and auditors, who had to adapt to new technologies through education and training. The author also analysed the strategic impact of AI on the profession in the long term, including ethical challenges and the need for an interdisciplinary approach. This study focused mainly on the practical aspects of implementing digital tools to reduce costs and optimise processes.

The conclusions of O.H. Ovharhe & C.J. Akandu (2024) and M.H. Naeem *et al.* (2023) correlated with the study in the common aspect of recognising the importance of innovation for increasing efficiency, reducing costs and optimising processes. The study emphasised that innovation was a key factor in competitiveness, contributing to improved governance, data transparency and information accessibility. O.H. Ovharhe & C.J. Akandu highlighted strategic aspects such as fragmented innovation, while M.H. Naeem *et al.* emphasised technology, including mobile banking and automation. However, the study by M.H. Naeem *et al.* noted both positive and negative impacts of innovation, such as inflationary pressures from mobile banking, while this study assessed digital innovation as exclusively positive. The main difference between the approaches was the level of analysis: M.H. Naeem *et al.* looked at the macroeconomic context using data from 92 countries, while O.H. Ovharhe & C.J. Akandu used panel data for strategic analysis, and this study focused on the corporate level using case studies. All these approaches confirmed the importance of innovation as a driver of efficiency and optimisation of business processes.

The studies by N.R. Sallem *et al.* (2024), and N.S. Zamain & U. Subramanian (2024) followed the present study in identifying the importance of AI in improving efficiency, automating processes, and ensuring transparency and accuracy of accounting. All these studies recognised the role of AI in detecting fraud, supporting strategic decisions, reducing errors, and enhancing analytical capabilities. However, the study by N.R. Sallem *et al.* highlighted bibliometric analysis, identification of publication trends, key authors, and collaboration between countries, while N.S. Zamain & U. Subramanian analysed in detail the impact of AI on the transformation of the professional role of accountants, as well as the risks of implementation, such as ethical issues and high cost. In turn, this study highlighted the practical implementation of digital technologies within companies and their impact on business efficiency. In addition, N.R. Sallem *et al.* considered ethical challenges, data privacy issues, and job loss risks, while N.S. Zamain & U. Subramanian analysed the impact of AI on the professional activities of accountants, which was not covered in the current study. Digital innovations in accounting reduced costs, increased accuracy and transparency, optimised processes, reduced the risk of errors, and ensured fast decision-making, contributing to sustainable business development.

Conclusions

The study highlighted the critical importance of introducing digital innovations in accounting as a key factor in ensuring the economic growth of enterprises. In the context of modern globalisation and rapid technological change, the use of the latest technologies, such as accounting process automation, AI, cloud technologies and blockchain, has significantly improved the efficiency of financial management, reduced costs, and increased the accuracy and transparency of financial reporting. Digitalisation has not only contributed to the efficiency of accounting but also created new opportunities for optimising all business processes.

The study of the financial performance of Kernel demonstrated the importance of digital tools in achieving significant economic results. The analysis showed that the introduction of innovative technologies, such as automation of accounting processes and precision farming systems, has reduced costs, increased management efficiency and improved EBITDA. However, despite this, in 2018, the company faced a 30.3% decrease in EBITDA compared to 2017. This was due to higher operating expenses and lower margins, which indicates the need for further cost optimisation. However, in 2024, Kernel showed positive dynamics using new technologies, such as eB/L, which significantly reduced document flow costs, increased transparency of financial and logistics processes, and reduced risks associated with the transportation of products. Digital solutions were among other factors that contributed to a 49% increase in revenues compared to 2018, as well as a 71% increase in EBITDA. Net profit reached 168 million USD, reflecting the overall positive impact of the implemented innovations and optimisation of business processes.

In general, the introduction of digital technologies in Kernel's accounting has become an important factor in the company's sustainable development and increased competitiveness in the market. Given the results achieved, it is possible to argue that the digitalisation of accounting directly affected the company's economic performance increasing the efficiency of asset use, reducing costs and improving management processes.

The study confirmed that digitalisation was a prerequisite for achieving sustainable economic growth. The introduction of the latest technologies not only reduces costs but also significantly increases the competitiveness of the enterprise, which is critical in a rapidly changing market. The use of tools such as Big Data, automation of accounting processes and precision farming systems allows businesses to optimise internal processes, and increase the efficiency of accounting and financial reporting, which in turn improves financial results and ensures transparency.

In the context of the overall economic environment, the digitalisation of accounting has given businesses the

flexibility and ability to respond quickly to changes arising from technological innovations, changes in the economic situation and market needs. Given Kernel's experience, it is possible to conclude that the correct implementation of digital technologies not only allowed the company to maintain its stable development but also significantly increased its competitive advantages.

For SMEs, the introduction of digital technologies could be a challenge, requiring additional investment in staff training and adaptation of existing systems. To effectively implement such tools, businesses need to actively work on improving their internal processes and infrastructure. This included not only technical solutions, but also organisational changes aimed at optimising the work of all business units. In the future, given the rapid development of technology, businesses must implement innovations and adapt their business processes to remain competitive.

Recommendations were developed for the digitalisation of accounting, which included an assessment of the current state of accounting procedures to identify problem areas. The selection of appropriate digital tools, such as cloud-based solutions (M.E.Doc) and ERP systems, helped automate accounting and improve the accuracy of financial data. To implement digital solutions effectively, staff training was required through online courses and workshops. Once the systems have been implemented, it is necessary to evaluate their effectiveness and continuously optimise them.

Further research can conduct a comparative analysis of the impact of digitalisation of accounting on enterprises of different industries and sizes, as well as assess the long-term effects of the introduction of innovative technologies in financial management.

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Conflict of Interest

None.

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Цифрові інновації в бухгалтерському обліку як фактор економічного зростання підприємства

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Анотація. Метою дослідження було проаналізувати вплив цифрових інновацій на бухгалтерський облік та ефективність фінансових процесів підприємств. Методологія включала аналіз фінансових показників компанії Kernel, одного з лідерів агропромислового сектору України. Порівнювались ключові фінансові показники підприємства до і після впровадження цифрових інновацій, таких як автоматизація облікових процесів, використання оптичного розпізнавання символів і впровадження електронних товарно-транспортних накладних. Розглянуто, як сучасні технології автоматизації обліку, машинне навчання, аналітика даних, алгоритми прогнозування, штучний інтелект (ШІ) для виявлення аномалій, хмарні технології та блокчейн змінювали підходи до ведення обліку, знижуючи витрати, підвищуючи точність і прозорість фінансової звітності. Результати дослідження показали, що впровадження цифрових інструментів дозволило Kernel суттєво покращити ключові економічні показники. Доходи зросли з USD 2168,9 млн у 2017 році до USD 3581 млн у 2024 році (+49 % порівняно з 2018 роком). Показник прибутку до сплати відсотків, податків, амортизації та зносу компанії зріс з USD 319,2 млн до USD 381 млн (+71 %), а чистий прибуток у 2024 році склав USD 168 млн. Застосування електронних товарно-транспортних накладних забезпечило ефективне управління логістичними процесами, мінімізувало ризики та покращило управління транспортуванням продукції. Використання діджитал-технологій сприяло підвищенню ефективності операцій, скороченню витрат та покращенню економічної результативності. Встановлено, що автоматизація облікових операцій за допомогою впровадження цифрових платформ, таких як система електронних товарно-транспортних накладних та інтеграція хмарних технологій, дозволила скоротити час на обробку фінансових даних, знизити ймовірність помилок і підвищити точність фінансової звітності. Рекомендації для українських підприємств включали впровадження автоматизації облікових процесів, що охоплювало використання облікових програм, зокрема QuickBooks, а також інтеграцію блокчейн для підвищення безпеки та прозорості фінансових транзакцій. Дослідження підтвердило, що цифрові інновації в бухгалтерії були не лише технологічною необхідністю, але й важливим фактором економічного зростання підприємств, який дозволив знижувати витрати, покращувати управлінські рішення, оптимізувати контроль бюджетів і підвищувати конкурентоспроможність компаній на ринку

Ключові слова: цифровізація; автоматизація; фінансові технології; ефективність; аналіз даних; конкурентоспроможність

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The role of international tax planning in ensuring the competitiveness of an enterprise in the international market

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Abstract. The purpose of the study was to identify opportunities and risks of international tax planning in ensuring the competitiveness of enterprises in the international market. The methodology was based on a comparative analysis of tax systems, transfer pricing and double taxation treaties in different countries, namely Germany, France, the USA, and Ukraine. It is determined that the key opportunities for international tax planning, including optimisation of the tax burden, use of double taxation treaties and transfer pricing, are the key opportunities for international tax planning. The risks associated with tax sanctions, legislative instability and reputational losses that may affect the competitiveness of enterprises in the global environment are identified. The study found that in countries with transparent and stable tax laws, such as Germany and Canada, businesses had more opportunities for effective tax planning, which helped to increase their competitiveness. In particular, holding structures were widely used in Germany to optimise the tax burden, while in the US, special attention was paid to compliance with transfer pricing rules, which helped to avoid double taxation and reduced the risk of sanctions. In Ireland, tax planning was aimed at using low-tax regimes, which attracted international corporations. In developing countries, such as Ukraine, the main challenges remained the instability of tax regulations and the complexity of administration, which made it difficult to implement effective strategies. The practical value of the study lies in the possibility of applying the results obtained to develop optimal tax planning strategies that will help reduce the tax burden, increase financial stability and competitive advantages of enterprises in different jurisdictions

Keywords: financial regulation; transfer pricing; economic globalization; optimization process; opportunities and threats

Introduction

International tax planning is an important tool for managing a company's financial resources, which helps it increase its competitiveness in the global market. In particular, companies have to adapt to the various tax systems and regulations in force in different countries. Effective use of international tax planning opportunities allows companies to minimise tax costs, optimise financial flows, ensure the stability of business processes and increase investment attractiveness. A critical aspect is compliance with international and national legislation, which helps to avoid risks associated with tax penalties, reputational losses, and legal conflicts. In addition, the competitiveness of a company in the international market is determined by many factors, among which the rational management of tax risks plays a significant role. Effective international tax planning allows companies not only to reduce their tax burden but also to develop long-term development strategies aimed at maximising profits (Omurgazieva *et al.*, 2024). This includes the use of such tools as transfer pricing, creation of holding structures, optimisation of tax liabilities through offshore jurisdictions and double taxation treaties.

The issue of studying the role of international tax planning in ensuring the competitiveness of enterprises is related to the need for businesses to adapt to the tightening of regulatory requirements and increased control by tax authorities in different countries. The complication of tax legislation, the fight against tax evasion and the growing requirements for transparency of financial activities pose significant challenges for companies operating in a global environment (Bukenessov *et al.*, 2024). On the one hand, these factors increase the cost of tax administration and reduce the flexibility of business processes, while on the other hand, they encourage businesses to seek effective strategies for managing tax liabilities. At the same time, shortcomings in tax planning can lead to financial losses, reputational risks, and legal sanctions (Khodakovsky, 2023). The research requires studying the impact of tax planning on business sustainability and adaptability to changes in the global economy, which is especially important in the context of increased competition and rapid transformation of international markets.

A significant number of researchers have studied the role of international tax planning in ensuring the competitiveness of an enterprise in the international market. In particular, S. Beuselinck & J. Pierk (2022) studied the dynamics between local and international tax planning in multinational corporations, emphasising how tax strategies adapt to different regulatory environments. In particular, the study highlights the complex relationship between national tax laws and international tax frameworks, which requires companies to balance local compliance with global tax cost optimisation strategies. This dynamic is critical to maintaining corporate profitability and competitiveness. S. Chen (2024) studied the impact of tax discipline on platform businesses, in particular, how tax compliance affects the competitive advantage of these businesses. His research highlights the importance of effective contract enforcement, which ensures fairness and transparency in tax practices, resulting in a stronger position for businesses in a competitive market. M. Cooper & Q. Nguyen (2020) reviewed the literature on corporate tax planning in multinational enterprises, analysing the various strategies used to minimise tax liabilities. They identified gaps in existing research and suggested areas for future research, particularly in the context of the evolution of global tax regulations and their impact on multinationals. K. Ftouhi & V. Ghardallou (2020) provided a comprehensive overview of international tax strategies, focusing on how multinationals use tax planning to reduce their global tax burden. Their research highlights the important role of tax planning in improving financial performance and competitiveness in international markets. L. Judijanto *et al.* (2024) focused on tax planning strategies for small and medium-sized enterprises, highlighting the challenges faced by these

businesses in complex tax systems. The study also provides useful tips on how to develop effective tax strategies to help SMEs improve their market competitiveness.

M. Khatser & O. Mikhailik (2024) studied the competitiveness of logistics enterprises in Ukraine against the background of the military development of the country's economy. A. Maslani *et al.* (2024) studied ways to strengthen the competitiveness of state-owned enterprises. This study emphasised the importance of effective tax planning and proper governance structures to improve the performance and sustainability of state-owned enterprises in a global context. D. Vo *et al.* (2020) analysed the relationship between information exchange, banking penetration and tax evasion in markets that strengthen the financial stability and competitiveness of enterprises. S. Wang *et al.* (2024) studied the role of industrial internet technologies in strengthening the competitiveness and efficiency of small and medium-sized enterprises. This study demonstrates how technological, organisational and environmental factors contribute to the ability of SMEs to compete in local and global markets. L. Xue (2021) investigated corporate tax planning in the information age, discussing how companies use information technology to optimise their tax strategies.

The purpose of the study was to highlight aspects of the relationship between tax planning and enterprise competitiveness based on foreign experience. The objectives of the study were:

- to analyse the aspects of opportunities and risks of tax planning for the competitiveness of enterprises;
- to assess the effectiveness of tax strategies for small and medium-sized enterprises;
- to identify the relationship between tax planning and economic stability in the context of military conflicts.

Materials and Methods

The study examined specific companies from countries that have a significant impact on the global economy, including the United States (Apple, Google, Microsoft), Germany (Volkswagen, BMW, Siemens), the United Kingdom (Unilever, BP, Rolls-Royce), France (L'Oréal, Renault, Airbus), China (Alibaba, Huawei, Tencent) and India (Tata Group, Reliance Industries, Infosys), and Ukraine (Kyivstar, Ukrtelecom, DTEK). These companies were selected for the analysis due to their significant contribution to the development of the Ukrainian economy and the use of tax planning strategies to optimise tax liabilities and ensure competitiveness in the current economic challenges. These enterprises were selected for analysis because of their role in their respective economies and global markets, as well as because of various tax planning strategies, namely Base Erosion and Profit Shifting, which are used to optimise tax expenditures and ensure international competitiveness (Organisation for Economic Co-operation and Development, 2024a). For the analysis of enterprises, statistical data from studies by A. Johansson *et al.* (2017), Tax Foundation (2024), PwC (2024), and G. Hendricks *et al.* (2019) were considered, which allowed assessing the effectiveness of tax planning in different economic systems. The main indicators were the financial results of enterprises, including their level of tax payments, profitability, tax expenditures, and their ratio to total income. Investment activity indicators, such as the level of infrastructure development, the volume of export-import operations, and the ratio of external and internal finances of enterprises, were assessed. The data collection also included a study of customer satisfaction and the efficiency of tax liabilities management.

In addition, the data on the ownership and financing structure of enterprises in the Organisation for Economic Co-operation and Development (2024c) study were analysed, including participation in international tax systems and strategic alliances. Important attention was paid to analysing the factors of tax cost optimisation through the use of international tax structures. The statistical indicators also included an analysis of the competitiveness of enterprises based on their tax policy, which allowed us to determine how the effectiveness of tax planning affects the development of enterprises in different countries.

The comparative analysis of countries was based on such criteria as the level of development of the tax system, adaptation to the international standards of the Organisation for Economic Co-operation and Development (2024a; 2024b; 2024c), investment attractiveness, and efficiency of tax control. For this purpose, several countries were selected, namely the United States, Germany, France, and Ukraine. It was found that the tax systems in these countries have significant differences, which is reflected in the level of tax burden on business and its ability to adapt to changes at the international level. The study has identified a number of risks and opportunities that have a significant impact on the effectiveness of tax planning in enterprises in different countries.

Results

International tax planning is an important component of a company's strategy aimed at ensuring competitiveness in the global market. It involves the use of various tools and methods to optimise tax liabilities, allowing companies to reduce their costs and increase efficiency. With a competent approach to tax planning, companies can not only improve their financial position but also create competitive advantages on an international level. One of the main goals of international tax planning is to reduce tax costs by taking advantage of opportunities provided by different jurisdictions. Countries have different tax rates, tax benefits and special regimes, which creates opportunities for optimising tax liabilities. For example, multinationals can relocate some of their operations to countries with low tax rates or use opportunities to reduce taxes through internal transactions between subsidiaries. This allows not only reducing taxation costs but also increasing the profitability of the company (Yevtushenko *et al.*, 2022).

In addition, international tax planning helps businesses to effectively manage the risks associated with different tax systems in the countries where they operate.

Businesses operating in multiple jurisdictions must take into account not only tax rates but also regulatory requirements, which may differ significantly. International tax planning helps to minimise the risks associated with non-compliance with local tax regulations and helps companies to adapt their strategies to the requirements of different markets. Another important component of international tax planning is the management of financial flows within the company. Countries with a low tax burden can be used to store significant financial assets, which allows a company to reduce its tax costs and manage capital efficiently. The use of offshore zones, transfer pricing, and other instruments allows companies to effectively allocate income and expenses between different jurisdictions, thereby reducing the tax burden.

A crucial part of international tax planning is also the company's ability to comply with international standards and requirements, such as the Organisation for Economic Co-operation and Development's Base Erosion and Profit Shifting (2024a) rules. Compliance with these standards allows companies to avoid tax penalties and maintain their reputation in international markets. At the same time, such practices contribute to the stability of the tax system at the global level, which is an important factor for economic development. International tax planning is a key element in ensuring the competitiveness of companies in the global market. It helps not only to reduce tax costs but also to effectively manage risks and financial flows and comply with international standards. In the context of globalisation and rapid changes in markets, businesses that effectively use international tax planning opportunities can achieve a significant competitive advantage.

In today's globalised environment and rapid changes in international markets, the role of international tax planning in ensuring the competitiveness of a company is becoming increasingly important (Oleksy-Gebczyk & Bilianskyi, 2024). Tax planning allows companies to reduce their tax liabilities, increase profitability, and create sustainable competitive advantages in the global market. The study, which covers companies from different countries with an impact on the global economy, including the United States (Apple, Google, Microsoft), Germany (Volkswagen, BMW, Siemens), the United Kingdom (Unilever, BP, Rolls-Royce), France (L'Oréal, Renault, Airbus), China (Alibaba, Huawei, Tencent), India (Tata Group, Reliance Industries, Infosys) and Ukraine (Kyivstar, Ukrtelecom, DTEK), the application of international tax planning strategies to optimise tax costs and ensure competitiveness was analysed. These companies hold key positions in their national markets and have a significant impact on the global economy. For example, US companies such as Apple and Google are known for using offshore strategies to minimise tax costs while making large-scale investments in technology and infrastructure to maintain a high level of competitiveness. An examination of their tax strategies provides insight into how large companies are using international tax planning. Table 1 summarises these strategies and their impact on the companies' competitiveness.

Table 1. International tax planning strategies and their impact on companies' competitiveness

Company	Country	Branch	Basic tax planning strategies	Financial indicators	Investment activity	Global impact
Apple	USA	Technologies	Use of offshore structures (tax havens), transfer pricing	High level of profitability, reduced tax costs	Investments in new technologies and infrastructure	Leader in the technology market, 1st place in terms of capitalisation
Google	USA	Technologies	Offshore structures to minimise taxes, transactions between subsidiaries	Reducing tax costs with high incomes	Large investments in innovation and advertising	Strong presence in the global market
Volkswagen	Germany	Automotive industry	Optimisation through divisions in countries with low tax rates	Stable financial growth, high investment costs	Expansion of production capacity, export	A key player in the global automotive market
Siemens	Germany	Engineering, technology	Using different jurisdictions for tax optimisation and transfer pricing	High profitability, reduced tax burden	Large investments in technology and R&D	A leader in the engineering and technology sector
Unilever	Great Britain	Consumer goods	Use of offshore jurisdictions, tax benefits from international transactions	Reduced tax costs, high income levels	Active investments in environmental and sustainable development	Highly competitive in the global consumer goods industry
Alibaba	China	E-commerce	Optimisation strategies through transactions between subsidiaries, use of tax benefits in China	Rapid revenue growth, low tax costs	High investment in infrastructure and innovation	Asia's e-commerce market leader

Table 1, Continued

Company	Country	Branch	Basic tax planning strategies	Financial indicators	Investment activity	Global impact
Huawei	China	Telecommunications	Using transfer pricing to minimise taxes, offshore structures	High income level, reduced tax burden	Large investments in research and development, 5G technologies	One of the largest manufacturers of telecommunications equipment in the world
Dad Group	India	Diverse (automotive, technology, energy)	Use of offshore structures for tax optimisation, strategic investments in low-tax markets	High profitability, stable level of investment	Expansion into international markets, high level of investment in India	Powerful industrial holding in India
Reliance Industries	India	Energy, chemistry	Use of transfer pricing, tax minimisation through offshore jurisdictions	Income growth, investments in infrastructure and energy	Large investments in the oil and gas industry	A leading company in India's energy sector
Kyivstar	Ukraine	Telecommunications	Using tax benefits and optimisation through transactions between subsidiaries	Reducing tax expenditures while increasing revenues	High investments in network and infrastructure development	One of the leaders in the Ukrainian mobile communications market
DTEK	Ukraine	Energy	Tax planning strategies through offshore structures	High level of profitability and financial results	Investments in renewable energy	Leader in the energy sector of Ukraine

Source: created by the authors based on A. Mengden (2024)

This Table 1 illustrates the key tax planning strategies and their impact on the financial performance, investment activity and global footprint of each company. The use of offshore structures, transfer pricing and tax cost optimisation allow these companies to reduce their tax burden and remain highly competitive on an international level. In order to better assess how tax strategies affect the competitiveness of companies on the international market, Table 2 shows the main criteria that characterise the effectiveness of international tax planning.

Table 2. The impact of international tax planning on the competitiveness of enterprises in the international market

Aspect	Description	Impact on the competitiveness of the enterprise
Optimisation of tax burden	Using strategies to minimise tax costs, such as financial transaction planning, using tax breaks and incentives	The tax burden is reduced, allowing more financial resources to be retained for investment and development
International agreements on the avoidance of double taxation	Signing agreements between countries to avoid double taxation, which allows businesses to reduce tax costs when conducting international business	Helps reduce tax risks and costs, which increases competitiveness in international markets
Tax policy flexibility	The company's ability to adapt tax strategies to changes in legislation and international tax initiatives, such as the global minimum tax	Increases business stability and allows adapting to changes in the global tax environment
Tax tools for international transactions	Using tools such as transfer pricing and financing through offshore zones to optimise tax costs	Improves financial management efficiency, reduces costs and increases opportunities for company growth
Transparency and reporting	Creating transparent tax reporting systems that reduce legal and financial risks	Increases trust from investors, partners and regulators, which positively affects the company's reputation
Tax risks and their management	Identification of potential tax risks, such as changes in national legislation or international tax treaties, and their strategic management	Reduces the likelihood of legal and financial sanctions, which allows avoiding the costs of resolving legal issues
Increasing investment attractiveness	Using tax strategies to increase the attractiveness of a company among investors, in particular by reducing tax costs and increasing efficiency	Increases the level of investment attraction, which contributes to the development of the company and an increase in its market share
Competitiveness in the international environment	Applying tax strategies to ensure competitive advantages in the international market, for example, by reducing production or distribution costs	Increases the ability to compete with other businesses in global markets, contributing to long-term growth
Integration with international tax systems	Adaptation to international tax systems and standards, such as the Organisation for Economic Co-operation and Development or the EU, to facilitate doing business internationally	Provides ease in conducting international transactions, improves cooperation with foreign partners and regulators

Table 2, Continued

Aspect	Description	Impact on the competitiveness of the enterprise
Strategic planning and innovation in the tax environment	Using tax planning as part of an overall company strategy that includes innovations in tax and financial management	Enables companies to maintain industry leadership, develop new markets, and expand their businesses through strategic investments

Source: created by the authors based on Organisation for Economic Co-operation and Development (2024a; 2024b; 2024c)

The role of tax planning is particularly important for companies in emerging economies such as India and China, where they must take into account not only international competition but also domestic economic factors and tax systems. For example, companies such as Tata Group and Reliance Industries in India are actively using international tax planning strategies to optimise their tax costs in light of different economic and tax systems. In analysing the effectiveness of tax planning, a number of key indicators were considered: financial results, tax payments, profitability, tax expenditures and their ratio to total revenues. These indicators allow us to assess how companies use tax strategies to reduce tax costs and maximise profits. For example, companies operating in low-tax countries may use transfer pricing to allocate income to their subsidiaries, which reduces their overall tax liability. The investment activity of enterprises, the level of infrastructure development, the volume of export and import operations, and the ratio of external and internal finances were also assessed. This data helps to understand how tax planning affects the ability of companies to attract investment and develop their operations in the international market. For example, companies that optimise their tax expenditures may have greater opportunities to finance new projects and expand production capacity, which contributes to their development and competitiveness (Musayeva *et al.*, 2024).

Another important aspect is to study the level of customer satisfaction and the efficiency of organising tax liabilities. Comprehensive tax planning allows companies not only to optimise tax costs but also to improve customer service, which is a key factor in maintaining a competitive position in the market. Accordingly, businesses that apply effective tax planning strategies can use the freed-up funds to improve the quality of products and services, which increases customer satisfaction and contributes to the company's long-term growth. In the context of using tax strategies internationally, it is important to note that effective tax planning also helps to reduce the financial and regulatory risks associated with transactions between countries with different tax regimes. For example, businesses from countries with high tax rates can use transfer pricing to optimise their tax costs, allowing them to remain competitive despite high tax rates in their home country. Assessing the effectiveness of tax planning, it can be noted that companies with low tax costs that actively use tax planning strategies demonstrate better financial results. For example, companies that use transfer pricing can significantly reduce their tax liabilities while maintaining high profitability. According to research by A. Johansson *et al.* (2017), international tax planning allows companies to reduce their effective tax rates by 5-15%, which can lead to significant financial benefits.

The tax systems in the US, Germany, France, and Ukraine have significant differences, which is reflected in the level of tax burden on businesses and their ability to adapt to changes at the international level. The US tax system is one of the most complex, with numerous taxes at the federal, state, and local levels. The federal corporate tax, although reduced after Trump's reforms (from 35% to 21% in 2018), remains a high tax burden on international companies (Hendricks *et al.*, 2019). At the same time, the United States actively uses the concept of "tax havens" where companies can optimise their tax liabilities. This allows companies to significantly reduce their tax burden by using various transactions between subsidiaries in different jurisdictions. The United States is also actively integrating into the international tax system by supporting the Base Erosion and Profit Shifting standard, which aims to minimise tax evasion.

Germany's tax system is based on the principles of progressive taxation and is one of the most transparent in Europe. The corporate tax rate is 15%, but companies have additional social security and other obligations. Germany is actively implementing international tax standards and participates in the EU's reform to harmonise tax rules (PwC, 2024). However, the high level of bureaucracy can be an obstacle to the development of small and medium-sized businesses, especially in comparison with more flexible tax systems. France, in turn, has a tax system with a high level of government intervention in the economy. The tax rate for corporations here is significantly higher than in Germany – 33.33% (in 2022, it is planned to reduce to 25%) (Tax Foundation, 2024). Nevertheless, the French government is actively pursuing reforms aimed at reducing the tax burden on small and medium-sized businesses and stimulating innovation through research tax incentives. However, the high tax burden and complexity of administrative procedures sometimes become a barrier to investment. Ukraine has significantly lower tax rates compared to these countries, but its tax system is subject to numerous reforms and changes, which often leads to instability. The corporate tax rate is 18%, which is quite competitive compared to Europe, but in practice the system is often characterised by high levels of tax evasion and significant tax administration costs. There are also numerous incentives for foreign investors, but due to the instability of the legislation, businesses may face problems at the local level.

Adapting tax systems to international standards is an important factor in ensuring the stability of national economies and attracting investment. The United States and

Germany are active participants in international initiatives to combat tax evasion and promote the development of global standards for business-to-business transactions. Germany, in particular, actively supports the initiatives of the Organisation for Economic Co-operation and Development (2024a), such as Base Erosion and Profit Shifting, aimed at combating tax evasion. France, with its high level of bureaucracy, has been somewhat slower to adapt to these standards, although it is actively reforming its tax system. Ukraine has taken some steps towards integrating international standards in recent years, but political instability and frequent changes in legislation have made this process much more difficult. However, simplification of procedures for international companies is an important factor for foreign investors, which requires further changes in the tax administration.

The investment attractiveness of a tax system depends not only on tax rates but also on the tax climate, including stability, predictability, and efficiency of administration. The United States has traditionally been one of the most attractive countries for investment due to its large market, technological advances, and flexible financing mechanisms. However, high taxes, especially on corporations, can reduce investment attractiveness for some sectors. Germany has a high level of investment, as it is an economic leader in Europe with a strong infrastructure, favourable investor legislation and a stable economic situation. France, although it has high tax rates, actively encourages investment through tax incentives for innovative businesses and start-ups, making it attractive to investors in the high-tech and science sectors. Although Ukraine has potential due to its natural resources and strategic location, it faces challenges in ensuring the stability of the tax climate (Tiutiunyk *et al*., 2023). Frequent legislative changes and high levels of corruption make the country less attractive for foreign investment compared to other countries, despite its competitive tax rates.

Effective tax control is an important condition for ensuring fair competition in the market and preventing tax evasion. The United States has one of the most effective tax control systems due to the development of technology and constant reforms (Vermeer *et al*., 2023). The tax authorities are able to track international transactions and prevent the use of tax schemes for tax evasion. Germany also has an effective tax control system based on process automation and thorough analysis of corporate finances. France, although it has a strong tax service, faces certain challenges due to its high level of bureaucracy. In Ukraine, the effectiveness of tax control remains one of the main challenges, given the problems with corruption and insufficient automation of the system.

The comparative analysis shows that the tax systems of the US, Germany, France, and Ukraine have significant differences, which directly affect the level of tax burden on businesses and their ability to adapt to international standards. The US and Germany have developed tax systems that are actively adapting to changes at the international level, while France, despite its high rates, has positive investment incentives for innovation. Ukraine, although it has competitive tax rates, faces problems of instability and ineffective tax control, which limits its investment attractiveness.

The study identifies a number of key risks and opportunities that significantly affect the effectiveness of tax planning in different countries. These factors are important for strategic management and can increase the competitiveness of companies in the international market if properly considered. The analysis of the identified risks and opportunities allowed us to develop recommendations for improving approaches to tax planning and adapting companies to a rapidly changing external environment. One of the main risks is changes in national legislation and international tax treaties. All the above countries, including the US, Germany, France and Ukraine, periodically introduce new rules to combat tax evasion, for example, through the Base Erosion and Profit Shifting initiatives of the Organisation for Economic Co-operation and Development. These changes may lead to increased tax liabilities for businesses that are not prepared for them and create additional costs for reviewing and adapting internal processes. In this case, companies should have a flexible tax planning system that allows them to respond quickly to changes in order to avoid a negative impact on their financial stability. In addition, changes in international tax treaties may increase the complexity of managing transactions between subsidiaries operating in different jurisdictions.

Another important risk is the dependence on low-tax jurisdictions (so-called tax havens), which may be subject to stricter control by international organisations. Countries such as the Netherlands, Luxembourg, and Singapore have traditionally been popular for optimising tax liabilities due to their low tax rates (Farah *et al*., 2021). However, pressure on these jurisdictions from organisations such as the EU and the Organisation for Economic Co-operation and Development to combat tax evasion may force businesses to look for new, less obvious ways to optimise tax liabilities. This will require significant efforts on the part of companies to adapt to the new environment. On the other hand, international initiatives to harmonise tax standards and reduce tax barriers for investors are creating opportunities for effective tax planning. For example, countries that actively support the reforms of the Organisation for Economic Co-operation and Development can ensure transparency and predictability of their tax systems, which increases investor confidence and makes them more attractive to international business. Such opportunities give companies a chance to minimise tax costs through the use of international agreements and reduce the risk of unexpected changes in tax policy.

Another crucial opportunity is the use of instruments to reduce the tax burden on innovation projects, which is actively supported in many countries, such as Germany and France. These countries provide tax incentives for companies that invest in R&D, which allows them to reduce tax costs in the long run and maintain high rates of innovation (Organisation for Economic Co-operation and

Development, 2024c). This, in turn, can become a competitive advantage for enterprises in the international market, as technological innovation is an important factor in strengthening the position of companies in global supply chains. The development of information technology also creates new opportunities for automating tax planning processes and reducing administrative costs. In the context of business globalisation and the increasing number of international transactions, companies can use modern software solutions to effectively manage their tax liabilities. Integration of such solutions allows for a faster response to changes in legislation and greater transparency and compliance with international standards.

Given these risks and opportunities, several recommendations can be made to improve tax planning. Businesses should ensure flexibility in their tax planning systems to quickly adapt to changes in legislation and international standards. It is important to actively engage with tax advisors and legal counsel to continuously monitor new initiatives and standards at the international level. Businesses should invest in the automation of tax liability management processes and actively implement innovative solutions to reduce tax costs. Overall, successful tax planning is a key factor in ensuring the competitiveness of companies in the international market. Taking into account the identified risks and opportunities will help companies maintain financial stability and respond effectively to changes in the global economic environment.

Discussion

The study confirmed the importance of effective tax planning and international tax competition for increasing the competitiveness of enterprises in the global economy. These results were consistent with the findings of other researchers, such as M. Afzali & T. Thor (2024), who emphasised the importance of corporate culture for effective tax planning. They noted that companies with strong corporate culture are able to better manage tax costs and adapt to changes in the tax environment, which provides them with a competitive advantage.

The considered results of the study confirmed the conclusions of Z. Asadzade (2024), who highlighted the importance of a competitive environment for business development. He noted that countries with effective tax strategies create favourable conditions for attracting investment and stimulate economic growth. This is particularly true of tax reforms that can reduce tax rates, which encourages international companies to invest in these countries. However, as the scientist emphasised, it is important not only to reduce tax rates but also to create general conditions for stable economic development, including improving infrastructure, increasing financial stability and stimulating entrepreneurial activity. Therefore, tax strategies aimed at creating a favourable competitive environment are key to attracting investment, especially in the context of globalisation and rapidly changing economic conditions. In this regard, the results of the study are also consistent with the work of E. Pan (2024), who raised the issue of the limited competitive advantage that can be gained through tax planning. The scholar noted that although tax planning can help companies reduce taxation costs, it is not always a determining factor in achieving competitive advantage in the international market. He pointed out that tax strategies can be useful for improving business efficiency, in particular through cost optimisation, but in a global context, their impact on competitiveness is limited. This can be explained by the fact that other factors, such as technological innovation, access to resources and markets, and the skill level of the workforce, are equally important in determining competitive advantage in global markets.

On the other hand, the study by R. Avi-Yonah & Y. Kim (2022) also considered the prospects of a global minimum tax, which was aimed at reducing tax competition between countries. They noted that the introduction of a global minimum tax could contribute to a more equitable distribution of tax revenues between countries, reducing the incentives for multinational corporations to evade taxes by shifting their income to countries with low tax rates. However, according to the authors, while such a minimum tax could have positive implications for global tax equity, it also has the potential to have a negative impact on countries with already low tax rates, as it could limit their ability to attract investment. This approach is consistent with the findings of D. Elkins (2019), who emphasised the importance of neutrality in international taxation and noted that neutral tax systems, in which tax rates are similar across countries, reduce barriers to international trade and business by ensuring a level playing field for all market participants. However, as the researcher noted, neutrality can cause certain problems, such as uneven distribution of tax revenues between countries. This is particularly true for small and medium-sized economies, for which tax revenues are an important source of financing. Therefore, while neutrality in international taxation can reduce tax barriers, it can also lead to unfair consequences for less developed countries that may not receive adequate tax revenues due to high tax rates or other factors.

A study by M. Herzfeld (2021) showed that tax competition was not limited to lowering tax rates alone but also included other factors such as the availability of resources and markets. The authors pointed out that countries not only reduce tax rates to attract international investment but also actively create favourable conditions for business by facilitating access to important resources such as labour, infrastructure, and market access. They emphasised that these aspects are important components of tax competition, as they allow countries to attract investors and create competitive advantages. These results were also confirmed in the study by S. Hager & J. Baines (2020), which indicated that a large concentration of economic resources in large companies can contribute to the growth of economic inequality. The authors noted that large corporations have significant resources to manipulate tax systems, which allows them to gain additional benefits, in particular through

the use of tax breaks and other strategies that reduce the tax burden. These factors can lead to an even greater concentration of capital in the hands of large players, which contributes to the growing economic inequality between large and small companies. In turn, it is difficult for small and medium-sized enterprises to compete under such conditions, making tax competition an important factor that requires careful analysis and proper regulation.

The results of the research by C. Azémar *et al.* (2020) and S. Hager & J. Baines (2020) also confirmed the importance of developing effective mechanisms to ensure a fair tax environment. This environment should be such that it does not contribute to the excessive enrichment of the largest enterprises at the expense of small and medium-sized companies. The importance of this aspect is emphasised in the work by V. Flagmeier *et al.* (2021) and P. Saptono & I. Khozen (2021), which discussed tax strategies that focus on effective reporting of tax liabilities. They noted that transparency in tax matters can contribute to capital growth, as investors prefer companies that follow clear and understandable tax strategies. According to their research, increased transparency in reporting tax liabilities can build investor confidence, which in turn helps to strengthen a company's market position. These ideas were also supported by the results of the study by I. Tiutiunyk *et al.* (2023), which showed that transparency in tax matters is crucial for attracting investment and maintaining competitiveness. They pointed out that countries that implement transparent tax systems can create an attractive business environment, attracting investors and increasing their international competitiveness. This approach not only reduces tax barriers but also ensures a level playing field for all market participants, which has a positive impact on the overall economic situation in the country. In addition, the study by G. Schjelderup & F. Stähler (2024) focused on global tax reforms, such as the global minimum tax, which had a significant impact on tax competition between countries. They noted that the introduction of the minimum tax had the potential to significantly change approaches to international taxation. It reduced the incentive for countries with low tax rates to use tax competition as a means of attracting investment (Oleksy-Gebczyk, 2024). They noted that global tax reforms could contribute to a more equitable distribution of tax revenues and help reduce tax gaps between countries. This is in line with the work of S. Tandon (2022), who explored the need for a minimum tax to ensure fairness in international taxation. Tandon pointed out that the introduction of such a tax could be an important step to ensure a level playing field and reduce the negative effects of tax competition, which could lead to disproportionate enrichment of the richest countries.

The study of A. Kalra & M. Ibne Afzal (2023) focused on transfer pricing practices in multinational corporations and their impact on tax revenues of countries, especially in developing countries. This was consistent with the findings of F. Scarpa & S. Signori (2023), who emphasised the importance of corporate tax responsibility for ensuring transparency and fairness in the tax system. The work of K. Meyer *et al.* (2023) looked at international business in the digital age and identified global strategies that could help businesses adapt to changes in national tax systems. This was confirmed by H. Wen *et al.* (2023), who pointed out the importance of developing small and medium-sized enterprises through e-commerce and reducing tax barriers for such enterprises. The results of this study also correlated with the study by R. Morano *et al.* (2023), who investigated the relationship between ease of doing business, innovation, and competitiveness of national economies. As noted by Z. Yue *et al.* (2023), a reduction in tax rates could motivate enterprises to introduce innovative technologies, which in turn would contribute to the growth of economic competitiveness. According to a study by X. Zhang *et al.* (2022), gender diversity in companies could have a significant impact on tax policy and tax avoidance, as diversity in the composition of the company's governing bodies could change the approach to strategic planning, including tax issues. This reflected a more general trend that tax planning strategies are complex and need to take into account a wide range of social and economic factors.

Conclusions

The study identified the key factors that determine the effectiveness of tax planning in companies in different countries, including the United States, Germany, the United Kingdom, France, China, India, and Ukraine. The focus was on companies that have a major impact on the global economy, including Apple, Google, Microsoft, Volkswagen, BMW, Siemens, Unilever, BP, Rolls-Royce, L'Oréal, Renault, Airbus, Alibaba, Huawei, Tencent, Tata Group, Reliance Industries, Infosys, Kyivstar, Ukrtelecom, and DTEK. The analysis of these companies allowed us not only to assess the tax planning strategies they use to optimise their tax liabilities but also to identify the link between tax planning efficiency and international competitiveness. One of the main findings of the study is that companies that actively use tax planning strategies can significantly reduce their tax costs, which allows them to be more competitive in global markets. This increases their ability to attract investment and optimise their financial resources. It has also been found that for most companies operating in international markets, an important factor is the ability to adapt to the changing conditions of tax systems in different countries, which necessitates the availability of flexible and effective tax planning mechanisms. In particular, it was found that companies from the United States, Germany, and the United Kingdom operating in countries with high tax rates tend to have more developed tax planning strategies that allow them to reduce their tax burden through international tax structures, such as offshore zones and tax treaties between states. On the other hand, Ukrainian companies have more limitations in using such strategies due to an underdeveloped tax system and a high dependence on national tax rules, which creates additional difficulties in optimising tax costs.

Another equally important result is that the effectiveness of tax planning directly affects the level of investment attractiveness of companies. The study shows that companies that demonstrate high transparency in their tax policy and comply with international tax standards enjoy greater investor confidence and are able to attract more investment. This, in turn, contributes to their development and strengthening of competitiveness in the global market. In terms of quantitative results, the study confirmed that companies that actively use tax strategies tend to have higher profitability and use their financial resources more efficiently. However, the effectiveness of these strategies depends on the level of development of the tax system of the country in which the company operates, as well as on adaptation to international tax standards. The practical results of the study are to identify the main recommendations for improving tax planning at enterprises. In particular, it is necessary to improve the mechanisms for adapting to changes in international tax rules and reduce the risks associated with tax audits and fines. Consideration should also be given to creating more transparent tax systems at the national level, which would reduce tax barriers for small and medium-sized businesses, ensuring a level playing field for all market participants.

In the future, an important area for research is the development of new approaches to tax planning in the context of globalisation and integration of countries into international tax systems. This includes considering the possibility of introducing global minimum taxes and assessing their impact on tax competition between countries. It is also necessary to investigate the effectiveness of new technologies in the field of tax process automation, such as blockchain and other innovative methods, that can improve transparency and reduce the risks of tax manipulation.

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Conflict of Interest

None.

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Роль міжнародного податкового планування у забезпеченні конкурентоспроможності підприємства на міжнародному ринку

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Анотація. Метою дослідження було визначення можливостей та ризиків міжнародного податкового планування у забезпеченні конкурентоспроможності підприємств на міжнародному ринку. Методологія базувалася на порівняльному аналізі податкових систем, трансфертного ціноутворення та угод про уникнення подвійного оподаткування в різних країнах, а саме Німеччина, Франція, США, Україна. Визначено, що ключові можливості міжнародного податкового планування, серед яких оптимізація податкового навантаження, використання

угод про уникнення подвійного оподаткування та трансфертного ціноутворення. Виявлено ризики, пов'язані з податковими санкціями, нестабільністю законодавства та репутаційними втратами, які можуть впливати на конкурентоспроможність підприємств у глобальному середовищі. У результатах дослідження визначено, що в країнах із прозорим і стабільним податковим законодавством, таких як Німеччина та Канада, підприємства мають більше можливостей для ефективного податкового планування, що сприяє підвищенню їхньої конкурентоспроможності. Зокрема, у Німеччині широко використовуються холдингові структури для оптимізації податкового навантаження, тоді як у США особливу увагу приділяють дотриманню правил трансфертного ціноутворення, що дозволяє уникати подвійного оподаткування та знижувати ризики санкцій. У Ірландії податкове планування спрямоване на використання низькоподаткових режимів, що приваблює міжнародні корпорації. У країнах, що розвиваються, таких як Україна основними викликами залишаються нестабільність податкових норм і складність адміністрування, що ускладнює впровадження ефективних стратегій. Практична цінність дослідження полягає у можливості застосування отриманих результатів для розробки оптимальних стратегій податкового планування, які сприятимуть зменшенню податкового навантаження, підвищенню фінансової стійкості та конкурентних переваг підприємств у різних юрисдикціях

Ключові слова: фінансове регулювання; трансфертне ціноутворення; глобалізація економіки; процес оптимізації; можливості та загрози

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Cryptocurrency regulation in post-Soviet countries: Balancing global practices and local specifics

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Abstract. This study examined cryptocurrency regulation in post-Soviet countries and identifies potential areas for improvement. It was analysed the varying regulatory approaches among these countries, ranging from restrictive policies (Ukraine and Georgia) to more liberal ones (Moldova). Armenia and Azerbaijan, while not implementing specific regulatory measures, had expressed concerns regarding cryptocurrency adoption, positioning them in an intermediate stance. It was

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found that the technological and political foundations of the cryptocurrency markets in five post-Soviet countries are similar, forming the most comparable group. However, they lag significantly behind the European Union and the United States. Although political freedom in these countries remained within the range of 55-72 points in 2024, the trend from 2020 to 2024 showed a decline. The disparity in information and communication technology (ICT) development among post-Soviet countries ranged from 70 to 88 points, whereas in the United States, Germany, and France, this indicator varied between 87 and 97 points. However, the overall trend for ICT development in post-Soviet countries remains positive. The study concluded that adopting regulatory practices from the United States, Germany, and France – by analysing their experiences, challenges, and mistakes – would be beneficial for Georgia and Ukraine. Specifically, Georgia should enhance its legislation and the legal status of cryptocurrencies based on the European Union and U.S. experience, while Ukraine should focus on improving tax policy, drawing from Germany's approach. Furthermore, both countries need to strengthen measures to combat financial crimes involving cryptocurrencies, following France's example. For Moldova, Armenia, and Azerbaijan, rather than addressing cryptocurrency-related challenges directly, an alternative approach was recommended: the development and implementation of central bank digital currencies

Keywords: security; double spending; digital currency; virtual currency; central bank

Introduction

The scale of the modern global economy continues to reach new heights, fostering intensified competition. Competition between countries is intensifying. In this competition, those countries that more actively use new financial instruments are achieving success. Against this background various types of cryptocurrencies are widely discussed by researchers, entrepreneurs, investors, governments, and the general public on an international scale, attracting increasing attention. As of 2024, the global number of cryptocurrency users exceeded 425 million, with 0.02% of them (88,200 individuals) being crypto millionaires and 22 classified as crypto billionaires. The total market value of cryptocurrencies reached USD 1.2 trillion in 2024, while the number of different cryptocurrencies approached 5,000 (Feinstein & Werbach, 2021; Henley & Partners Holdings Ltd, 2023).

The scale of the modern global economy continues to reach new heights, fostering intensified competition among countries. In this competition, those countries that proactively adopt innovative financial instruments are achieving notable success (Silagadze, 2022). Amid such dynamics, cryptocurrencies have become a focal point of discussion on an international scale, engaging researches, entrepreneurs, investors, governments, and general public alike. As of 2024, the global number of cryptocurrency users had surpassed 425 million, with a remarkable 0.02% (88,200 individuals) identified as crypto millionaires and 22 classified as crypto billionaires. The total market value of cryptocurrencies reached USD 1.2 trillion in 2024, while the number of distinct cryptocurrencies approached 5,000 (Feinstein & Werbach, 2021; Henley & Partners Holdings Ltd, 2023).

Given the growing global popularity of cryptocurrencies, numerous international researchers have examined the regulatory aspects of these digital assets across different regions. In analysing the characteristics of cryptocurrencies, J. Lee & F. L'Heureux (2020) argued that their primary feature is decentralisation, which allows them to bypass government regulation. The regulation of cryptocurrencies remains one of the major challenges in the current crypto market. Examining the control and management of cryptocurrencies by national governments, B. Feinstein & K. Werbach (2021) stated that the rapid expansion of this market, combined with the absence of global regulatory improvements, has led to issues such as money laundering, fraud, and capital outflow. However, national approaches to cryptocurrency regulation vary significantly. Studying cryptocurrency policies in over 200 countries, D. Weaver (2022) concluded that the adoption and regulation of cryptocurrencies depend on factors such as civil liberties, political rights, gross domestic product (GDP) per capita, investment levels, and regional location. According to D. Weaver, cryptocurrency adoption is notably higher in the Western Hemisphere than in the Eastern Hemisphere. Conversely, some researchers, such as C. Sonksen (2021), argued that the best regulatory models as of 2021 were found in the Asian region. Cryptocurrency regulation in the European Union (EU) is not without flaws.

S. Daskalova & D. Kumanov (2024), after analysing the EU legal framework, concluded that while European countries aim for regulatory harmonisation, the system is not yet fully effective. Separately, C. Wronka (2024) conducted a comparative analysis of cryptocurrency regulation in Germany and the UK. The study found that regulatory approaches differ significantly: the UK promotes innovation and the growth of the industry by fostering favourable regulatory conditions, whereas Germany prioritises investor protection and market stability. However, both regulatory systems face challenges, including ambiguity in cryptocurrency classification and taxation-related issues. Comparing the influence of central banks in Asian, Oceanian, and African countries on cryptocurrencies, M. Yaneva (2020) determined that there is no unified stance among central banks regarding cryptocurrencies as a legitimate means of payment alongside fiat currencies. The lack of communication between regulators and central banks in each country is identified as a major issue in the cryptocurrency regulation system. K. Turyan (2024) examined the role of financial institutions in former

Soviet Union (USSR) member states. The analysis found that in Central Asia and the Caucasus region, cryptocurrency usage poses significant legal challenges, as the legal status of these assets remains undefined. As a result, there are no legal protections for cryptocurrency users, potentially leading to substantial financial losses. Building on the findings of previous studies, it can be concluded that former USSR member states have often not been the primary focus of cryptocurrency regulation research, and the local characteristics of post-Soviet countries have frequently been overlooked. This gap in the literature underscores the relevance of the present study.

The aim of this study was to examine cryptocurrency market regulation on a global scale, with a particular focus on the local characteristics of post-Soviet countries. To achieve this objective, the study set out the following tasks: analyse the concept of "cryptocurrency" in relation to other means of payment and financial assets; investigate the advantages and disadvantages of cryptocurrency regulation; examine the regulatory frameworks governing crypto assets in Azerbaijan, Armenia, Georgia, Ukraine, and Moldova, comparing them with the regulatory approaches of the United States, Germany, and France; and identify potential ways to enhance cryptocurrency regulation in post-Soviet countries, taking local characteristics into account.

Materials and Methods

During the analysis, the key categorical concepts of this study – "digital currency", "virtual currency", and "cryptocurrency" – were defined based on the following parameters: issuer, regulation, form, costs, and international usage. Additionally, the advantages and risks associated with cryptocurrencies for users and governments in different countries were examined. Following the identification of cryptocurrency features and their impact on the global financial system, the 2024 Global Adoption Index (2024) was analysed to quantitatively assess cryptocurrency adoption levels. This index facilitated the identification of the leading countries in cryptocurrency adoption in 2024. Furthermore, the index was specifically examined for post-Soviet countries as a local indicator of the unique characteristics of cryptocurrency development in each nation. Based on this indicator, a selection of countries was made for further research into cryptocurrency regulation within the post-Soviet space. The selected countries fall into three distinct categories: countries actively implementing changes and fostering cryptocurrency market development – Ukraine and Georgia; countries with a transitional adoption regime (i.e., those that do not integrate cryptocurrencies into their financial systems but acknowledge potential risks) – Armenia and Azerbaijan; and a country with a liberal stance towards cryptocurrency adoption – Moldova. This selection was based on the governmental acceptance criterion, ensuring that recommendations for cryptocurrency regulation could be developed for countries with positive, neutral, and negative stances towards cryptocurrency adoption.

Since this study also focused on the local characteristics of countries, the foundational factors influencing cryptocurrency development – namely, the political and technological environments – were analysed. The political environment was examined using the Index of Economic Freedom (EFW) for the period 2020-2024. This index, calculated based on 12 criteria, is scored on a scale from 0 to 100 points (Heritage Foundation, 2024). Additionally, the Democracy Index for 2020-2024 was analysed, which assesses five key criteria and is rated on a scale from 1 to 10 points (Economist Intelligence Unit Limited, 2024a; 2024b).

The technological environment was assessed through the Information and Communications Technology Development Index (IDI) for 2024, which measures infrastructure development. This index, calculated based on 11 criteria, is also scored on a scale from 0 to 100 points (World Population Review, n.d.). The analysis of these indices was essential for identifying the similarities and differences in the local characteristics of post-Soviet countries in their path towards cryptocurrency market development.

Following the assessment of each country's capacity for cryptocurrency adoption, the key distinguishing aspects of cryptocurrency regulation in Ukraine, Georgia, Moldova, Armenia, and Azerbaijan were identified. To improve cryptocurrency regulation in post-Soviet countries, the study examined the regulatory approaches of the United States, Germany, and France. The analysis focused on three key parameters: legislation (existence of regulatory laws and the legal status of cryptocurrencies), tax policy, protection against fraud and market manipulation. The legislative- normative acts reviewed in this analysis included: Order of the President of the National Bank of Georgia No. 94/04 "On Approval of the Rules for Registration, Deregistration and Regulation of Virtual Asset Service Providers in the National Bank of Georgia" (2023), Law of Ukraine No. 2074-IX "On Virtual Assets" (2024), Directive (EU) No. 2018/843 of the European Parliament and of the Council "Amending Directive (EU) 2015/849 on the prevention of the use of the financial system for the purposes of money laundering or terrorist financing, and amending Directives 2009/138/EC and 2013/36/EU" (2018), Regulation (EU) No. 2023/1114 of the European Parliament and of the Council "On Markets in Crypto-Assets, and Amending Regulations (EU) No 1093/2010 and (EU) No 1095/2010 and Directives 2013/36/EU and (EU) 2019/1937" (2023), Law of France No. 2019-486 "Relating to the Growth and Transformation of Businesses" (2019).

At the final stage of the study, the challenges associated with different approaches to cryptocurrency regulation in the financial systems of the United States, Germany, and France were identified. Additionally, the feasibility of applying similar regulatory frameworks in post-Soviet countries in 2025 was examined. As a result, the study assessed the possibility and practicality of adopting American and European regulatory experiences in the five analysed post-Soviet countries. Based on this analysis, specific recommendations for regulatory improvements were developed.

Results

Since the 1970s, fiat money – a form of currency with no intrinsic value that is used as legal tender by government decree – has become dominant in the international financial system. Fiat money includes printed banknotes, minted coins, and non-cash funds, all of which derive their value from government recognition as legal tender. It is fully regulated by the state and functions as a centralised currency (Dapp, 2021). In this system, banks act as intermediaries between the central bank and currency users, charging fees for processing fiat currency transactions. By doing so, banks remain integral to the financial cycle and contribute to the security and stability of the currency (Khan *et al*., 2020).

Economic conditions in the 21st century have evolved in parallel with the digitalisation of the global financial system. As a result, digital currency has emerged – a digital asset recognised as a means of payment, which includes digital fiat currency (Khan *et al.,* 2020; Xiong & Luo, 2024). While money throughout the 20th century existed primarily in physical form, it has now transitioned into a virtual format, though it remains under the control of each country's central bank. One of the primary issues with the digital format of fiat money is the double cost incurred by the end user. This refers to additional expenses that exceed a user's actual balance, including transaction fees for fund transfers, payment processing, and currency exchange. This drawback negatively impacts user trust in commercial banks, which act as intermediaries between individuals and the central bank (Sixt, 2017).

Cryptocurrency is gaining popularity as it eliminates the double-spending issue commonly associated with digital fiat currency (Khan *et al.,* 2020). It is a form of virtual currency that operates on a decentralised system (Xiong & Luo, 2024). Virtual currency refers to a digitally expressed value that functions as a medium of exchange, a store of value, and/or a unit of account. However, it does not hold the status of legal tender, as it is not backed by any legal jurisdiction (Gupta, 2021). Cryptocurrency exists exclusively in digital format and is secured through cryptography. Its foundation is blockchain technology – a decentralised ledger system that records transactions across multiple nodes. Blockchain structures data into sequentially linked blocks that are cryptographically secured and cannot be altered. In other words, blockchain ensures data integrity, security, and a verifiable transaction history, making it the backbone of cryptocurrency.

The development of blockchain technology has paved the way for alternative digital currencies beyond cryptocurrencies. Recognising the advantages of blockchain, central banks and national governments have explored the digitalisation of fiat currency to enhance the efficiency and security of financial systems. This has led to the emergence of Central Bank Digital Currencies (CBDCs). CBDCs offer several advantages, including faster and more cost-effective payment processing and the ability to store money exclusively in digital format. However, they also allow governments to monitor all user transactions, potentially enabling personalised fiscal policies, such as automated taxation (Dapp, 2021). It can be concluded that, in comparison to cryptocurrency and fiat money, CBDCs have not yet gained significant popularity on a global scale. While fiat money operates under a centralised management system, it is affected by the double-spending problem. In contrast, cryptocurrency serves as an alternative for users, addressing the shortcomings of both CBDCs and fiat currency through decentralised management, a fully digital format, and the elimination of double-spending. In other words, cryptocurrency offers significant advantages to users. Cryptocurrency transaction systems are rapidly gaining popularity worldwide due to a trust framework involving individuals, organisations, computers, and decentralised organisations. By leveraging cryptocurrency, it is possible to minimise the costs traditionally imposed by banking systems on national economies. To address the issue of transaction security and verification, blockchain-based cryptocurrencies rely on a consensus mechanism, specifically Proof of Work (PoW). PoW is executed by a decentralised network of miners, who validate transactions and maintain the accuracy of the blockchain ledger. This means that, unlike fiat currency and CBDCs, cryptocurrencies are "mined" and exchanged within the economy without incurring transaction costs (Khan *et al*., 2020).

Cryptocurrency presents regulatory challenges for governments worldwide. Several key issues in this process stem from the underlying blockchain technology, as various cryptocurrencies are built upon it. Firstly, cryptocurrencies provide alternative access to financial services, posing a challenge to the traditional decentralised banking system. While all transactions are recorded in a public ledger, the use of pseudonyms complicates regulation. This is because transactions are linked to a cryptographic address rather than the personal identity of the user. Another major issue is the decentralised nature of blockchain technology. On the one hand, decentralisation enhances the security of cryptocurrency. On the other hand, it creates challenges in legal liability (Xiong & Luo, 2024). Unlike conventional financial systems, cryptocurrencies operate without a central governing body, making it difficult to establish legal responsibility in cases of fraud (Gonzálvez-Gallego & Pérez-Cárceles, 2021). Additionally, the international scope of blockchain complicates government efforts to regulate it. As a result, each government has adopted its own approach to cryptocurrency regulation. For example: Total bans on cryptocurrency exist in China. Partial bans on certain cryptocurrency-related activities are in place in Pakistan and Saudi Arabia. Restrictive regulations with strict risk-mitigation measures exist in the United States and Canada. Supportive regulations that encourage cryptocurrency market development exist in Kazakhstan and Germany. No official regulation, but concerns about risks, exist in Armenia and Azerbaijan. No regulation at all exists in Yemen and Turkmenistan. Legal tender status is granted to cryptocurrencies in the Central African Republic and El Salvador. On an international scale, only around 27% of countries have

adopted a supportive stance towards cryptocurrency regulation. This reflects widespread concerns about the potential risks of financial crime, monetary policy violations, and threats to economic stability (Xiong & Luo, 2024).

One of the key indicators for assessing cryptocurrency adoption in a country is a quantitative measure of its adoption level on a global scale, represented by the Cryptocurrency Adoption Index. This global index comprises four sub-indices, which take into account factors such as population size and purchasing power. The ranking is determined using the geometric mean, with normalised final values ranging from 0 to 1. A higher score, closer to 1, indicates a greater level of adoption. In 2024, the leading countries in cryptocurrency adoption were: India – 1.0 points (1st place), Nigeria – 0.693 points (2nd place), Indonesia – 0.680 points (3rd place), United States – 0.540 points (4th place). Among post-Soviet countries, Ukraine had the highest level of cryptocurrency adoption in 2024, with a score of 0.407 points, ranking 6th out of 151 countries in the international ranking. By comparison, in 2020, the United States ranked 6th out of 154 countries with a score of 0.327 points (2024 Global Adoption Index, 2024). Notably, in 2020, Ukraine was the global leader in cryptocurrency adoption, achieving a Cryptocurrency Adoption Index score of 1.0 points, the highest recorded level. Other post-Soviet countries, however, exhibited low levels of cryptocurrency adoption.

One of the key challenges for post-Soviet countries is the decision between adapting existing cryptocurrency regulations based on the successful experiences of other nations or developing an entirely new regulatory framework (Ishchuk & Ishchuk, 2023). To examine international regulatory approaches and identify aspects that could be applied to post-Soviet countries, this study selected nations that ranked highly in the Cryptocurrency Adoption Index in 2024: North America: United States (0.540 points, 4th place), European Union: Germany (0.110 points, 21st place) and France (0.106 points, 22nd place). Additionally, post-Soviet countries with varying levels of cryptocurrency adoption were selected for analysis: Ukraine (0.407 points, 6th place), Georgia (0.030 points, 54th place), Moldova (0.027 points, 59th place), Armenia (0.019 points, 77th place), Azerbaijan (0.014 points, 92nd place) (2024 Global Adoption Index, 2024). The extent to which cryptocurrency is adopted in each country is reflected in its regulatory approach. Currently, there is no unified international regulatory framework for cryptocurrencies (Seok, 2024). While complete bans on cryptocurrency usage exist in some countries across South America, Africa, and Asia, such prohibitions remain relatively rare, affecting only 10.8% of countries globally (Thomson Reuters, 2022). As of 2024, 71 countries have yet to implement regulations for the cryptocurrency market (Xiong & Luo, 2024).

Among the post-Soviet countries analysed, only Ukraine and Georgia have legalised and regulated cryptocurrency at the state level. In both nations, the government actively promotes the development of the crypto market. In contrast, Moldova has partially restricted cryptocurrency usage, while Azerbaijan and Armenia have not developed specific regulatory frameworks but have expressed concerns about potential risks. These variations in regulatory approaches highlight the need for a more detailed analysis of the current situation in post-Soviet countries (Xiong & Luo, 2024).

Cryptocurrency regulation in the analysed countries varies significantly in terms of legislation, tax policy, and investor protection. From a regulatory perspective, it is crucial to examine the legal framework governing cryptocurrencies. Since March 2022, the foundation for cryptocurrency regulation in Ukraine has been the Law of Ukraine No. 2074-IX (2024). Under this law, the legal status of cryptocurrency in Ukraine is defined as a virtual asset within civil law. It is described as a set of electronic data that holds value and cost. However, cryptocurrency is not recognised as a means of payment, meaning it cannot be used for purchasing goods or services (Thomson Reuters, 2022). In Ukraine, virtual assets are categorised into two types: secured by fiat currency, such as stable coins and unsecured, such as Bitcoin. Virtual currencies can be stored, exchanged, transferred, bought, and sold. However, a key issue in Ukraine's cryptocurrency regulation is its tax policy. The lack of comprehensive regulation has led to concerns regarding money laundering and tax evasion (Martinčević *et al.*, 2022). The Law of Ukraine No. 2074-IX (2024) states that compliance and oversight of virtual assets will be carried out by the National Securities and Stock Market Commission.

Cryptocurrency-related activity is growing worldwide, including in Georgia. Cryptocurrency is not recognized a legal form of payment in Georgia. In 2014, the National Bank of Georgia classified cryptocurrencies as digital assets with an uncertain legal status, highlighting their potential use in money laundering and criminal activities. As a result, cryptocurrencies in Georgia are not recognised as virtual currencies, but rather as digital assets, which has prevented their legalisation in the country. Cryptocurrency regulation in Georgia is influenced by the positions of multiple government institutions, including the Central Bank, the Ministry of Finance, the Ministry of Economic Development, and the Prosecutor General's Office. However, these institutions do not hold a unified stance on the definition and regulation of cryptocurrencies. Furthermore, Georgia lacks specific legislation that defines the legal status of cryptocurrencies or provides regulatory measures. Cryptocurrencies are not recognised as a means of payment, and there are no legal protections against fraud and market manipulation.

Up until 2016, the Georgian government had imposed restrictions on cryptocurrency-related activities. However, it later legalised these digital assets, acknowledging the risks associated with them. In subsequent years, the Georgian government expressed interest in improving cryptocurrency regulation as part of an effort to develop a national cryptocurrency (Topuria, 2024). Order of the President of the National Bank of Georgia No. 94/04 (2023) came into force

in Georgia, mandating the registration of the so-called "virtual asset service providers" with the National Bank of Georgia and outlining their subsequent obligations. In 2019 the National Bank of Georgia introduced digital bank licensing principles to lower entry barriers for new market participants. In 2022, the first digital bank was licensed, followed by three more in 2023. The digital lari pilot program was also launched in 2024 (AccountAnts, n.d.). In parallel with progress in this direction, it is anticipated that this advancement will contribute to reducing cartel transactions within Georgian banking system.

In Azerbaijan, cryptocurrencies do not fit within the traditional classification of assets. They are not recognised as legal tender, as only national and foreign state-backed currencies are considered valid forms of money. Additionally, cryptocurrency is not classified as intangible property, since it is considered an alienable right with economic value. Consequently, Azerbaijan does not have specific legislative or tax regulations governing cryptocurrency, nor does it have fraud prevention mechanisms (Safarli, 2023). The country's regulatory approach to cryptocurrency remains conservative. Similarly, Moldova and Armenia do not have clearly defined legislative or tax regulations for cryptocurrency, and there are no legal mechanisms for fraud prevention or market protection. The Moldovan government has adopted a liberal stance towards cryptocurrency circulation, while in Armenia, cryptocurrencies are not subject to prohibitive measures, except for criminal procedural regulations (Lohoyda, 2021).

It can be concluded that while Ukraine has established legislation regulating cryptocurrency and defining its legal status, it lacks a clear tax policy regarding cryptocurrencies. In contrast, Georgia has implemented a tax policy for cryptocurrencies but does not have specific legislation defining their legal status or regulatory framework. In Azerbaijan, Moldova, and Armenia, there are no established laws, tax policies, or mechanisms for fraud prevention in the cryptocurrency sector. As a result, while Ukraine and Georgia have taken initial steps towards legal regulation, their regulatory frameworks remain underdeveloped, positioning them as emerging markets for cryptocurrency. Therefore, it is crucial for these countries to incorporate best international practices regarding the legal status and regulation of cryptocurrency into their legislative frameworks. For Moldova, Armenia, and Azerbaijan, alternative approaches must be explored to address cryptocurrency-related challenges effectively. To develop country-specific measures, it is essential to consider each nation's local characteristics, which play a vital role in determining the feasibility and acceptance of cryptocurrency regulation. Two key local factors influencing cryptocurrency adoption are political and technological capabilities. Political conditions are assessed using indicators such as the EFW and the Democracy Index (Heritage Foundation, 2024; Economist Intelligence Unit Limited, 2024a; 2024b). Currently, the EFW is calculated for 184 countries by Heritage Foundation (2024). Table 1 provides a comparative analysis of EFW trends over time in the analysed countries.

Table 1. Dynamics of EFW in the countries under study in comparison for 2020-2024

Year \ Country	Azerbaijan	Armenia	Germany	Georgia	Moldova	USA	Ukraine	France
2020	69.3	70.6	73.5	77.1	62.0	76.6	54.9	66.0
2021	70.1	71.9	72.5	77.2	62.5	74.8	56.2	65.7
2022	61.6	65.3	76.1	71.8	61.3	72.1	54.1	65.9
2023	61.4	65.1	73.7	68.7	58.5	70.6	–	63.6
2024	61.6	64.9	72.1	68.4	57.1	70.1	–	62.5
Absolute change during 2020-2024	−7.7	−5.7	−1.4	−8.7	−4.9	−6.5	–	−3.5

Note: due to the ongoing military actions in Ukraine, the primary data required for the calculation of the EFW has ceased to be published. As a result, the most recent available EFW value for Ukraine is from 2022
Source: compiled by the authors based on Heritage Foundation (2024)

The dynamics of EFW changes from 2020 to 2024 have been negative for all the analysed countries. However, it is important to note that the rate of decline in post-Soviet countries has been significantly greater than in EU countries. For instance, while Georgia surpassed the United States in this indicator in 2020, economic conditions in post-Soviet countries have deteriorated significantly over the years. As a result, all five post-Soviet countries examined in this study now exhibit lower levels of economic freedom compared to the United States and EU nations. As of 2024, according to the EFW indicator: Moldova and Ukraine are classified as "unfree" countries, scoring within the 50-59.9 range. Armenia, Azerbaijan, and Georgia are classified as "moderately free", similar to France. The United States and Germany are classified as "mostly free", scoring within the 70-79.9 range (Heritage Foundation, 2024). It is also essential to consider the dynamics of political freedom, as measured by the Democracy Index (Table 2).

Table 2. Dynamics of the Democracy Index in the countries under study in comparison for 2020-2024

Year \ Country	Azerbaijan	Armenia	Germany	Georgia	Moldova	USA	Ukraine	France
2020	2.68	5.35	8.67	5.31	5.78	7.92	5.81	7.99
2021	2.68	5.49	8.67	5.12	6.10	7.85	5.57	7.99
2022	2.87	5.63	8.80	5.20	6.23	7.85	5.42	8.07
2023	2.80	5.42	8.80	5.20	6.23	7.85	5.06	8.07
2024	2.80	5.35	8.73	4.70	6.04	7.85	4.90	7.99
Absolute change during 2020-2023	+0.12	0.0	+0.06	−0.61	+0.26	−0.07	−0.91	0.0

Source: compiled by the authors based on Economist Intelligence Unit Limited (2024a; 2024b)

Between 2020 and 2024, the Democracy Index increased in all post-Soviet countries, with the exception of Georgia and Ukraine, where it showed a declining trend, and Armenia, where it returned to its 2020 value. In 2024, according to the Democracy Index classification: Germany was categorised as a full democracy, falling within the 10.00-8.01 range. The United States, France, and Moldova were classified as flawed democracies, with scores in the 8.00-6.01 range. Ukraine, Georgia, and Armenia were categorised as hybrid regimes, with Democracy Index values between 6.00 and 4.01. Azerbaijan, with a Democracy Index of 2.80 in 2023, fell within the 4.00-1.00 range and was therefore classified as an authoritarian regime (Economist Intelligence Unit Limited, 2024a; 2024b). Considering the Democracy Index alongside the EFW, it can be concluded that all five analysed post-Soviet countries face a political environment that hinders the full-scale adoption and regulation of cryptocurrencies, due to limitations in political and economic freedom.

Additionally, when assessing the local characteristics of post-Soviet countries, it is essential to examine the development of information and communication technologies (ICTs), which provide the technological foundation for cryptocurrency market growth. This factor is measured by the IDI. Currently, the IDI is calculated by the United Nations (UN) for 170 countries. The IDI dynamics for 2023-2024 in the analysed countries are presented in Figure 1.

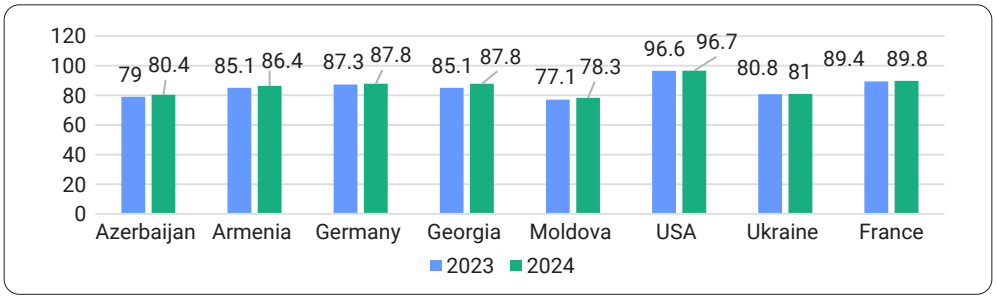

Figure 1. IDI dynamics in the countries under study compared for 2023-2024
Source: compiled by the authors based on World Population Review (n.d.)

As of 2024, the IDI in Ukraine increased by 0.2% compared to 2023, while in Armenia, it rose by 1.3%. In Azerbaijan, Moldova, and Georgia, the IDI increased by 1.4%, 1.2%, and 2.7%, respectively, compared to the previous year. The positive growth in IDI levels across post-Soviet countries, in comparison to EU nations and the United States, highlights a solid technological foundation for cryptocurrency market development (World Population Review, n.d.). Furthermore, as of 2024, the IDI and EFW indicators in the five post-Soviet countries exhibited similar trends, placing them within the same or closely related groups in terms of technological and economic conditions for cryptocurrency adoption.

Having analysed cryptocurrency regulation in the post-Soviet countries, as well as the local characteristics of Georgia, Ukraine, Moldova, Armenia, and Azerbaijan, it is crucial to examine the experiences of other countries and identify key regulatory challenges. Learning from these experiences can serve as a foundation for improving cryptocurrency regulation in the post-Soviet region.

The United States hosts the largest number of crypto investors, exchanges, and mining funds. As of 2024, the IDI in the United States stood at 96.7% out of 100%. The EFW, IDI, and Democracy Index collectively provide a strong foundation for the functioning and expansion of the cryptocurrency market. The regulation of crypto assets in the United States is integrated into the existing regulatory framework (Burgess, 2024). While the cryptocurrency regulatory landscape continues to evolve annually, the perspectives of different regulatory agencies remain divergent. For example: The Securities and Exchange Commission (SEC) classifies cryptocurrency as a security. The Commodity Futures Trading Commission (CFTC) considers it a commodity. The Treasury Department (Treasury) defines

it as a currency. The Internal Revenue Service (IRS) treats cryptocurrency as a digital asset that functions as a medium of exchange, store of value, and/or means of settlement, requiring annual disclosure in tax returns (Thomson Reuters, 2022). Despite a White House directive to coordinate regulatory efforts among these agencies, there is no single federal law governing cryptocurrency. This fragmented regulatory framework results in inconsistent guidelines and gaps in consumer protection.

However, efforts are underway to establish a unified regulatory framework that classifies different types of cryptocurrencies as securities, commodities, or property, with the aim of enhancing consumer protection against financial crimes (Xiong & Luo, 2024). For Ukraine and Georgia, the U.S. experience highlights the importance of avoiding similar regulatory pitfalls. To enhance cryptocurrency regulation, it is crucial for these countries to: develop a coordinated regulatory system that ensures effective communication and collaboration between government agencies; establish a comprehensive tax policy to mitigate risks for investors and reduce opportunities for tax evasion; strengthen fraud prevention and financial crime measures, drawing lessons from U.S. regulatory practices. Given that Georgia and Ukraine currently have limited mechanisms to prevent fraud and financial crimes in the cryptocurrency sector, their governments can improve regulatory safeguards by adopting best practices from the U.S. model while addressing its shortcomings.

In addition to the United States, it is also essential to examine adaptive regulatory measures from EU countries that could be applied to post-Soviet nations to improve cryptocurrency regulation. The primary objective of cryptocurrency regulation in the EU is to harmonise regulatory and legal frameworks across all member states by integrating cryptocurrency into national regulatory structures. The EU introduced the Directive (EU) No. 2018/843 of the European Parliament and of the Council (2018), which partially addresses cryptocurrency regulation, particularly in the context of fraud prevention and financial crime mitigation. However, EU member states retain the right to adapt the Directive at their own discretion, leading to inconsistencies in regulation across the EU (Burgess, 2024).

To better understand these regulatory differences, it is useful to compare Germany and France, two countries with distinct cryptocurrency regulatory frameworks. Despite their similar IDI and EFW scores, as well as high Democracy Index values – which provide favourable local conditions for the cryptocurrency market – Germany and France have taken different approaches to cryptocurrency regulation (Heritage Foundation, 2024; World Population Review, n.d.). Germany was among the first countries to authorise financial institutions and the general public to store cryptocurrency legally (Thomson Reuters, 2022). As a result, the regulation of crypto assets in Germany and France differs significantly, despite their comparable economic and political environments.

The French government actively supports the development of the cryptocurrency market within the country (2024 Global Adoption Index, 2024). From a legislative perspective, France adopted the Law of France No. 2019-486 (2019), which, in addition to regulating business expansion and transformation, also governs cryptocurrency regulation. The Law of France No. 2019-486 establishes the legal status of cryptocurrency as a digital asset, rather than a currency, as cryptocurrency is not recognised as a medium of exchange and is considered ineffective as a store of value in France. Additionally, Law of France No. 2019-486 sets rules for cryptocurrency investors, requiring them to either register or obtain a licence, depending on their intended use of cryptocurrencies. These registration and licensing requirements serve as key measures to prevent money laundering and fraud (AbdelAziz & Shalaby, 2023).

Since 2019, anonymous cryptocurrency accounts have been prohibited in France under the Law of France No. 2019-486 (2019). The Financial Markets Authority (AMF) is responsible for overseeing the sector. In terms of taxation, cryptocurrencies in France are classified similarly to movable property: casual traders are subject to a 30% tax; miners and regular traders pay a 45% tax (Thomson Reuters, 2022). France's cryptocurrency regulation differs from that of the EU and other countries, including the United States, as it implements an unrestricted incentive plan that deviates from the traditional financial instruments' regulatory framework. A distinctive feature of AMF oversight in France is its comprehensive responsibility for regulating cryptocurrencies and digital assets, ensuring investor protection and market stability as the sector rapidly evolves. In contrast, cryptocurrency regulation in the United States remains fragmented, with multiple agencies – including the SEC, the CFTC, and the IRS – sharing regulatory authority. The absence of a unified federal law further complicates the regulatory landscape in the U.S.

In Germany, both individuals and legal entities can use and trade cryptocurrency through official exchanges. However, a licence from the German Federal Financial Supervisory Authority (BaFin) is required for such activities. Regarding the legal status of cryptocurrency in Germany: Cryptocurrency is considered an illegal means of payment but is recognised as a legal asset in the form of a financial instrument. Crypto assets are accepted as a means of exchange, payment, and investment, meaning they can be transferred, stored, and sold. From a taxation perspective, cryptocurrencies in Germany are classified as private money and are therefore taxed accordingly: Profits of less than EUR 600, held for less than a year, are not taxable. Sales of cryptocurrencies stored for more than a year are tax-exempt. If neither of the above conditions is met, profits are taxed at the standard income tax rate (Thomson Reuters, 2022).

To address regulatory gaps in the harmonisation of cryptocurrency laws across the EU, the Regulation (EU) No. 2023/1114 of the European Parliament and of the

Council (2023) aims to regulate crypto assets that are not covered under existing financial legislation. The Regulation (EU) No. 2023/1114 of the European Parliament and of the Council provisions apply to three categories of crypto assets: Asset-referenced tokens (ARTs) – Tokens that stabilise their value by linking to a basket of assets, such as stable coins. E-money tokens (EMTs) – Tokens that stabilise their value by pegging to a fiat currency, such as the USD-pegged cryptocurrency USD Coin (USDC) (Burgess, 2024). Utility tokens – Tokens used to access goods and services within a specific network. However, Regulation (EU) No. 2023/1114 of the European Parliament and of the Council does not apply to decentralised finance (DeFi), as DeFi operates without intermediaries and falls outside the scope of traditional financial regulation (Xiong & Luo, 2024).

Analysing the EU and US approaches to cryptocurrency regulation, alongside the local characteristics of post-Soviet countries, it becomes evident that adopting these regulatory models is advisable only for Ukraine and Georgia, rather than for all post-Soviet nations. This is primarily because Ukraine and Georgia already have a restrictive regulatory framework and possess the necessary political and technological conditions to foster cryptocurrency market development. Although both Ukraine and Georgia have taken initial steps towards cryptocurrency regulation, their regulatory systems remain incomplete, particularly in terms of legislation, tax policy, and measures to prevent fraud and financial crimes. For regulation to be effective, it is crucial to identify and address the existing gaps and risks specific to each country. Additionally, learning from the experiences of other nations – those that have advanced further in cryptocurrency regulation – can help avoid past regulatory mistakes.

The EU approach to cryptocurrency integration is cautious and gradual, meaning that the financial system is introduced to cryptocurrencies in a controlled and phased manner. This slow integration strategy is particularly relevant for Ukraine and Georgia, considering their local economic and regulatory environments and their long-term cryptocurrency market development goals (Burgess, 2024). Over time, this approach has become more tailored to individual national markets, contributing to a more harmonised regulatory framework. However, such harmonisation must still account for market dynamics and the unique characteristics of each country (Xiong & Luo, 2024). The legal regulatory model chosen by a country has a direct impact on the growth and stability of its cryptocurrency market within its financial system (Topuria, 2024). Therefore, a gradual and systematic integration of cryptocurrencies, combined with a comprehensive legal, tax, and protective regulatory framework, represents the most effective approach for both Ukraine and Georgia.

In Georgia, the first priority in improving cryptocurrency regulation is to establish a clear legal framework. A key difference between Georgia and other countries lies in the classification of cryptocurrency. When defining its legal status, Georgia should consider international experiences, where cryptocurrency is classified as property, a security, or a commodity. In developing its cryptocurrency regulations, Georgia must also address the regulatory shortcomings observed in the United States, where fragmented oversight has led to inconsistent policies (Burgess, 2024). A similar issue exists in Georgia: the unclear legal status of cryptocurrency creates management challenges and fails to provide adequate security guarantees for users (Topuria, 2024).

To resolve this issue, Georgia must establish clear legal definitions for cryptocurrency and assign specific responsibilities to regulatory bodies. This would prevent regulatory duplication and ensure a more effective oversight system (Xiong & Luo, 2024). Additionally, improving the classification of cryptocurrencies and mandating all service providers to become self-regulatory organisations could enhance user data protection and reduce the risk of financial crimes (Burgess, 2024). These measures represent the second most critical step for Georgia in improving cryptocurrency market regulation. For Ukraine, given its existing legislation, the primary challenge lies in its tax policy. It is crucial to eliminate ambiguities in taxation and establish a transparent and flexible tax system, similar to Germany's approach. Implementing such a taxation model would be the second key measure for Ukraine in enhancing its regulatory framework and advancing the development of its cryptocurrency market.

The third most important measure, jointly essential for Ukraine and Georgia in improving cryptocurrency regulation, is the implementation of financial fraud and money laundering prevention measures, drawing from France's experience. Specifically, the registration and licensing of cryptocurrency exchanges, along with expanding the functions of a central regulatory body, could significantly reduce risks associated with financial fraud and money laundering through crypto assets. In contrast, the regulatory approaches adopted in the United States and the European Union are not suitable for Moldova, Armenia, and Azerbaijan, given these countries' neutral or negative stance towards integrating cryptocurrencies into their financial systems. Additionally, challenges such as a weaker technological infrastructure and political instability make these approaches impractical. For these three post-Soviet nations, a more viable strategy would be the consideration and implementation of CBDCs. As cryptocurrencies gain global popularity, an increasing number of central banks are developing CBDCs, which offer the advantage of linking digital assets to national currencies. This strategy is the most suitable and pragmatic approach for post-Soviet countries (Makarchuk *et al.*, 2023; Burgess, 2024).

In cash-based economies, where traditional banking and digital payment systems do not pose significant competition to physical currency, CBDCs offer an optimal solution (Mancini-Griffoli *et al.*, 2018). For instance, digital currencies have already been introduced in the UK and the United States. Through CBDCs, central banks can simultaneously protect users' financial rights and prevent financial crimes, offering a secure and reliable means of

payment. This contrasts with the increasing influence of cryptocurrencies, which pose regulatory and financial stability challenges in many countries. Thus, CBDCs present a viable alternative for post-Soviet countries that perceive cryptocurrency legalisation as too risky and existing regulatory mechanisms as insufficient for ensuring the stability and efficiency of their financial systems (Burgess, 2024).

Cryptocurrency has yet to achieve full success as a medium of exchange, a store of value, or a stable unit of account, whereas CBDCs are designed to address these shortcomings (Gupta, 2021). While cryptocurrency, fiat money, and bank deposits coexist, CBDCs offer the advantage of minimal transaction costs, a feature that is also a key benefit of cryptocurrency over fiat money (Mancini-Griffoli *et al.*, 2018). One of the main advantages of cryptocurrency is its ability to operate without intermediaries, thereby minimising third-party risk. In contrast, CBDCs can only partially mitigate this risk by reducing transaction layering, while at the same time granting central banks greater control over transactions.

Another advantage of cryptocurrency is its decentralised nature and complete transaction anonymity, which limits government oversight. In this regard, cryptocurrencies and CBDCs represent opposing financial models, as CBDCs are fully centralised and enable government control over transactions. However, given the rapid digitalisation of financial systems, post-Soviet countries that are strongly opposed to cryptocurrencies should not immediately reject financial system innovations. Instead, they should consider more controlled alternatives, such as CBDCs (Gupta, 2021). As the analysis has shown, fiat currency poses risks to users, and the primary reason for cryptocurrency's popularity is its ability to eliminate such risks. However, CBDCs do not fully resolve this issue, as they remove intermediaries between the central bank and the end user (Cukierman, 2020). In this system, the central bank benefits from transaction control, while users benefit from a simplified and more secure financial process. Such a regulatory structure significantly reduces the risk of financial fraud (Ballaschk & Paulick, 2021).

For Moldova, Armenia, and Azerbaijan, these factors provide strong justification for opting out of cryptocurrency adoption in favour of CBDCs. The recommended strategy for these countries should include: developing a legislative framework for digital currencies; improving technological infrastructure to support digital financial transactions; conducting public awareness campaigns to educate citizens on CBDCs; gradually integrating CBDCs into the financial system while monitoring their impact on the broader economy. CBDCs eliminate many of cryptocurrency's disadvantages while offering the benefits of digital currency adoption. Although CBDCs may not rely on blockchain technology or cryptographic systems, they remain a critical benchmark for cost efficiency, privacy, and financial innovation in the years ahead. Given the neutral stance of the Armenian and Azerbaijani governments, the liberal approach of Moldova, and the political and technological feasibility of CBDC adoption, this represents the most viable alternative for these three countries.

Discussion

The study found that, in general, cryptocurrency is a cryptographically protected virtual currency that is gaining global popularity. However, the primary challenge faced by different countries is the imperfect regulatory framework for this type of digital asset. The main issues relate to legislation and the legal status of cryptocurrency. None of the analysed post-Soviet countries has adopted a unified classification for cryptocurrencies. For instance: In Ukraine, cryptocurrency is classified as a virtual asset, but not a means of payment (Spytska, 2023). In Georgia, it is considered a digital asset, rather than a virtual currency. In Azerbaijan, cryptocurrency does not align with the traditional asset classification system. In Armenia and Moldova, there is no official definition or legal interpretation of cryptocurrency at the national level. This lack of legal clarity presents a significant barrier to the development of an effective regulatory system, which, in turn, impacts cryptocurrency adoption. While all analysed countries acknowledge the risks of money laundering and financial fraud, there is no consensus on the legal status of crypto assets. These findings align with the research of L. Öztürk & E. Sülüngür (2021), who concluded that most national governments seeking to develop cryptocurrency markets recognise associated risks but take minimal legislative action to define the legal status of cryptocurrencies. To establish effective regulation, it is essential to provide a clear legal definition of cryptocurrencies. Standardising and harmonising regulatory frameworks would facilitate greater consistency and internalisation of rules governing cryptocurrency use and oversight.

Through an analysis of local characteristics and the potential for cryptocurrency adoption within the financial systems of post-Soviet countries, it was determined that all analysed nations have a less developed political landscape. Specifically: Moldova and Ukraine are categorised as unfree countries. Armenia, Azerbaijan, and Georgia are classified as moderately free countries. In terms of information technology infrastructure, the five analysed countries exhibit similar levels of development within the post-Soviet space, yet remain significantly behind the United States and the European Union. This technological gap has a direct impact on cryptocurrency adoption in each country. It was observed that: Azerbaijan and Armenia do not take specific regulatory actions regarding cryptocurrency. Moldova maintains a liberal policy towards cryptocurrency. Ukraine and Georgia have implemented the most structured and strictly regulated approaches among the analysed post-Soviet countries. This distinction arises from the fact that Ukraine and Georgia recognise the opportunities that cryptocurrencies offer to users, which contributes to their global popularity (Kuzheliev, 2023). Conversely, Moldova, Azerbaijan, and Armenia focus primarily on the risks associated with cryptocurrencies, such as minimal regulatory control and a decentralised system. These

findings align with the research of Y. Mezquita *et al.* (2023), who concluded that governments in many countries reject financial assets that are voluntarily created and lack security control within the financial system. Similarly, L. Öztürk & E. Sülüngür (2021) emphasised the importance of evaluating both the benefits and risks when determining a country's approach to cryptocurrency adoption.

To examine various approaches to cryptocurrency regulation on a global scale and identify best practices that could be adopted by post-Soviet countries, the regulatory systems of the United States, Germany, and France were analysed. The findings revealed that classification issues regarding cryptocurrency also persist in these countries.

In the EU, despite efforts to harmonise cryptocurrency legislation across member states, differences in adaptation remain at the national level. Similar conclusions were drawn by V. Benson *et al.*, (2024), who studied the challenges of regulatory harmonisation in the cryptocurrency sector. Their research found that the EU lacks a unified national regulatory framework, and existing legislation is primarily focused on implementing AML measures rather than establishing comprehensive cryptocurrency regulation.

In the United States, cryptocurrency is classified as a security, commodity, or property, depending on the regulatory agency (Llazo *et al.*, 2024). Both the United States and EU countries have attempted to create a unified regulatory system for cryptocurrencies, but inconsistencies remain. This regulatory experience is valuable for Ukraine and Georgia, as both nations are actively integrating cryptocurrencies into their financial systems. However, it is crucial for them to learn from the regulatory challenges faced by the US and EU and to avoid similar pitfalls when developing their own frameworks. Despite ongoing improvements, the regulatory systems in the United States, Germany, and France are still far from perfect. The notion that countries should adopt external regulatory models differs from the conclusions of M.G. Lindsay (2023), who compared cryptocurrency regulations in Western and Asian countries. Their research found that domestic cryptocurrency regulations are becoming obsolete, given the rapid rise in cryptocurrency adoption. According to their findings, the only viable solution is international regulatory coordination rather than country-specific legislation.

The analysis revealed that Armenia and Azerbaijan have not taken concrete steps to regulate cryptocurrencies, while Moldova remains critical of their introduction into the financial market. The primary concerns for these countries stem from the risks posed by cryptocurrencies to government control, including: a challenge to the traditional banking system due to transaction anonymity; the absence of double costs, which affects financial oversight; a decentralised system, which weakens the control of each country's central bank (Karimli *et al.*, 2024). Given the lack of interest from Armenia, Azerbaijan, and Moldova in integrating cryptocurrencies into their financial systems, it would not be advisable to apply the regulatory models of the United States and the European Union, as suggested for Georgia and Ukraine. Instead, these three countries should focus on an alternative strategy: the development and implementation of CBDCs. CBDCs offer similar advantages to users as cryptocurrencies while eliminating risks for governments. As digitalisation becomes essential for improving financial systems, CBDCs present a viable opportunity to achieve this goal (Dmytrenko, 2024). Similar conclusions were drawn by M. Bordo & A. Levin (2017), who found that CBDCs function as a stable store of value, a unit of account, and a medium of exchange with minimal transaction costs for users. This stands in contrast to the operational characteristics of cryptocurrencies. These findings are consistent with the results of this study and have been confirmed by other researchers, including W. Engert & B.S.C. Fung (2017), who analysed central banks' motives and the potential consequences of CBDC implementation. The design and functionality of CBDCs have been extensively examined by D. Chaum *et al.* (2021) and E. Prasad (2021), who identified two main types of CBDCs: General-purpose CBDC – This serves as a digital complement to physical currency. It allows direct transfers between users without requiring commercial banks, while still enabling central banks to monitor and process transactions (Chaum *et al.*, 2021). Wholesale CBDC – Designed for large-scale transactions between financial institutions, serving as a digital analogue of traditional currency (Prasad, 2021). Given the political and economic conditions in Armenia, Azerbaijan, and Moldova, the implementation of CBDCs presents the most practical alternative to cryptocurrency adoption, ensuring a controlled and secure financial system while facilitating technological progress.

Given the risks associated with minimal control over cryptocurrencies due to their cryptographic nature, Armenia, Azerbaijan, and Moldova may choose to develop a CBDC design that does not rely on blockchain technology. This aligns with the findings of U. Bindseil (2019), who examined potential digital currency models for central banks. His analysis concluded that the design choice between a CBDC based on accounts or tokens plays a crucial role in shaping a country's future economic policy. The debate over CBDC design remains ongoing among researchers. While some scholars, such as D. Chaum *et al.* (2021), completely reject the idea of blockchain-based CBDCs, others, including T. Zhang & Z. Huang (2021), argued that blockchain technology can be effectively integrated into CBDC systems. However, these contrasting perspectives reinforce the notion that blockchain-based CBDC models are not a necessity for Moldova, Armenia, and Azerbaijan, making their exclusion from CBDC development strategies a valid approach in line with their existing policies. It is also important to consider the challenges associated with CBDC implementation. Both T. Zhang & Z. Huang (2021) and D. Chaum *et al.* (2021) highlighted several potential drawbacks, including: increased transaction costs compared to traditional payment systems and limited scalability, which could impact efficiency and widespread adoption. However, in this study, the potential disadvantages of CBDCs for

Moldova, Armenia, and Azerbaijan were not examined, with the focus placed solely on their benefits and advantages. Future research should explore both the strengths and limitations of CBDC implementation to provide a comprehensive assessment of its viability for these countries.

Conclusions

The study determined that the EFW dynamics for all post-Soviet countries have been negative, ranging from 4.9% to 8.7% during 2020-2024, indicating political barriers to cryptocurrency regulation. Meanwhile, the IDI dynamics for the same period showed an increase of 0.2%-2.7% in all post-Soviet countries, reflecting a strong technological foundation. Despite similar local characteristics supporting the development of cryptocurrencies, a single regulatory strategy is not suitable for all five analysed countries. The experiences of the United States, Germany, and France are particularly relevant for Ukraine and Georgia. In the United States, fragmented cryptocurrency regulation has resulted in regulatory challenges, whereas in EU countries, efforts to harmonise regulations among member states have led to variation in national implementation. The main issues in both the US and the EU include: the absence of a clear definition and classification of cryptocurrencies as well as the lack of a unified regulatory framework These problems should be taken into account by post-Soviet countries to prevent similar issues from arising in their own regulatory frameworks. Ukraine and Georgia have already adopted restrictive policies regarding cryptocurrency. Considering their local characteristics, further refinement of cryptocurrency regulation should incorporate lessons from the United States, Germany, and France. General measures for improvement in Ukraine and Georgia include: slow and structured integration of cryptocurrencies into the financial system and enhancement of control measures to strengthen regulatory oversight. Additionally: Ukraine should focus on improving its tax policies to ensure greater transparency. Georgia should establish clear legislation and define the legal status of cryptocurrencies.

Many countries remain reluctant to introduce blockchain technology into their financial systems, with integration challenges particularly evident in Moldova, Armenia, and Azerbaijan. The adoption and regulation of cryptocurrencies in post-Soviet countries varies significantly, primarily due to local conditions, which remain far less developed compared to the United States and EU countries. Armenia and Azerbaijan have no cryptocurrency regulation in place Moldova, despite maintaining a liberal stance, has not developed a clear regulatory framework. Given these circumstances, Moldova, Armenia, and Azerbaijan should consider an alternative approach – the development and implementation of CBDCs. Unlike cryptocurrencies, CBDCs present minimal risks while offering opportunities for both users and governments, providing a structured and controlled integration of digital currency into the financial system.

Including countries from other regions, beyond Central Europe and North America, in the analysis could provide broader insights and a greater variety of successful approaches to cryptocurrency regulation. This would allow post-Soviet countries to explore diverse regulatory models and better understand which measures should be implemented to enhance their own regulatory frameworks. However, a limitation of this study is that it only examined three countries, restricting the scope of comparative analysis.

For Ukraine and Georgia, it is essential to improve the classification of cryptocurrencies as a first step in refining regulation. Once a clear legal definition of cryptocurrency is established for each country, it will be possible to develop more detailed regulatory measures. For Moldova, Armenia, and Azerbaijan, further independent research is required to explore the development and implementation of digital currencies, assessing both the opportunities and risks associated with their introduction. These studies should take into account the specific developmental characteristics, as well as the strengths and weaknesses of each country's financial and technological infrastructure. Future research should also focus on the potential establishment of an international cryptocurrency regulation system, aimed at preventing financial crimes related to cryptocurrencies. This would be relevant for both countries that actively promote cryptocurrency adoption and those that completely reject its integration into their financial systems.

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Conflict of Interest

None.

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Регулювання криптовалют у пострадянських країнах: баланс між глобальними практиками та місцевою специфікою

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Анотація. У цьому дослідженні розглядалося регулювання криптовалют у пострадянських країнах та визначаються потенційні сфери для вдосконалення. Аналізувалися різні регуляторні підходи в цих країна – від обмежувальної політики (Україна і Грузія) до більш ліберальної (Молдова). Вірменія та Азербайджан, не застосовуючи конкретних регуляторних заходів, висловили занепокоєння щодо прийняття криптовалют, що дозволило їм зайняти проміжну позицію. Виявило, що технологічні та політичні основи криптовалютних ринків у п'яти пострадянських країнах схожі, утворюючи найбільш порівнянну групу. Однак вони значно відстають від Європейського Союзу та Сполучених Штатів. Хоча політична свобода в цих країнах залишилася в межах 55-72 балів у 2024 році, тренд з 2020 по 2024 рік демонстрував зниження. Нерівність у розвитку інформаційно-комунікаційних технологій (ІКТ) між пострадянськими країнами коливалася від 70 до 88 балів, тоді як у США, Німеччині та Франції цей показник коливається від 87 до 97 балів. Однак загальна тенденція розвитку ІКТ у пострадянських країнах залишається позитивною. У дослідженні зроблено висновок, що для Грузії та України було б корисно перейняти регуляторну практику США, Німеччини та Франції, проаналізувавши їхній досвід, виклики та помилки. Зокрема, Грузія повинна вдосконалити своє законодавство та правовий статус криптовалют, спираючись на досвід Європейського Союзу та США, тоді як Україна повинна зосередитися на вдосконаленні податкової політики, спираючись на підхід Німеччини. Крім того, обом країнам необхідно посилити заходи щодо боротьби з фінансовими злочинами, пов'язаними з криптовалютами, за прикладом Франції. Для Молдови, Вірменії та Азербайджану замість безпосереднього вирішення проблем, пов'язаних з криптовалютами, рекомендовано альтернативний підхід: розробка та впровадження цифрових валют центральних банків

Ключові слова: безпека; подвійні витрати; цифрова валюта; віртуальна валюта; центральний банк

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Energy security as a key factor in Ukrainian economic resilience in the time of war

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Abstract. The research aimed to evaluate the condition of the Ukrainian energy system amid the war, ascertain the degree of infrastructure damage, and estimate the potential for restoration and maintenance of a steady energy supply. The study during 2022-2024 was based on the analysis of official reports, satellite images and analytical materials on the damage and restoration of Ukrainian energy infrastructure. The financing of recovery and regulatory reforms in the energy sector was highlighted. The study established that the total financial losses of the energy sector amount to more than USD 33.8 billion. Of these, USD 11.4 billion were direct losses in the electricity sector. The analysis showed a significant debt burden on district heating companies (USD 2.6 billion) and the need for debt restructuring. The study characterised the indicators of the level of damage to the energy infrastructure, which is a critical stage in the analysis of Ukraine's energy security as a fundamental factor of national economic stability. The assessment of possible sources of financing for the industry's recovery, including international assistance, grant programmes and private sector investment, was emphasised. It was examined the role of international financial institutions, such as the European Bank for Reconstruction and Development, the World Bank and the European Investment Bank, which have already allocated more than USD 1.1 billion for emergency measures to restore Ukraine's energy infrastructure. Given the financial challenges, recommendations were developed to attract additional resources through investment insurance mechanisms, green bonds, and public-private partnerships. The study also addressed the issue of adapting tariff policy and introducing differentiated tariffs to cover the costs of infrastructure rehabilitation and encourage energy saving. This model integrates technical, financial and managerial solutions to ensure economic stability and attract the capital needed to modernise Ukraine's energy sector

Keywords: infrastructure challenges; decentralised generation; renewables; grid integration; innovative development

Introduction

Securing energy stability is a crucial aspect of national security, particularly in the context of violent conflicts that jeopardise governance and economic progress. The ongoing hostilities in Ukraine since 2014, which escalated significantly in 2022, have caused large-scale destruction of energy infrastructure, interruptions in supply and destabilisation of the energy system. In addition to physical losses, the country faced dependence on imported energy supplies, threats of energy blackmail, financial pressure on the industry and the need to urgently restore facilities. Systematic attacks on critical infrastructure, disruption of logistics chains and loss of control over energy-generating facilities have significantly complicated the country's stable energy supply. The destabilisation of the energy sector directly affects industry, agriculture, business and the daily lives of citizens, making energy security analysis essential to assess risks and develop stabilisation strategies. Ensuring energy security is the foundation for economic resilience, as a stable energy supply ensures the continuity of industrial production, the operation of small and medium-sized enterprises, and social facilities. Existing research in the context of armed conflict has largely focused on energy diversification, infrastructure rehabilitation, and adaptation of governance systems.

Author A. Lisovyi (2024) examined the issue of Ukrainian energy security in light of contemporary concerns stemming from geopolitical causes and the ramifications of the armed conflict. The author emphasizes the nation's reliance on imported resources, technological constraints, inadequate energy efficiency, and infrastructural degradation resulting from war actions. The document underscores the significance of diversifying energy suppliers, advancing renewable energy sources, and enhancing energy efficiency to bolster energy independence. Y. Kovalenko *et al.* (2024) examined the evolution of energy security measures, transitioning from conventional fuel supply to contemporary challenges arising from global conflicts and environmental issues. The research highlighted the necessity of incorporating innovative technology and alternative energy sources to guarantee the sustainability of energy supply, particularly in light of contemporary geopolitical issues.

A. Polukhin *et al.* (2023) examined the ramifications of the war on Ukraine's energy security, encompassing a reduction in production, increased energy prices, and infrastructure loss. The authors underscored the necessity of implementing measures for effective state support to maintain the stability of the energy sector during crises. A. Mazaraki & T. Melnyk (2024) delineated the present condition of Ukraine's energy system during military assault, highlighting the necessity of achieving energy independence and integration with the EU energy market. The study analyses the repercussions of the devastation of the energy infrastructure, encompassing the depletion of a substantial portion of renewable energy sources, as well as nuclear and thermal generating. Special emphasis is placed on the effective synchronisation of the Ukrainian power system with ENTSO-E and the initiation of electricity exports to European nations.

Researchers O. Malinovska & M. Vysochanska (2023) established the notion of energy security in Ukraine as a critical element for the effective operation of the national economy. The authors underscored the necessity of implementing competitive strategies in the electrical market, including contractual agreements, day-ahead market operations, and the utilisation of balancing devices to maintain the stability of the power system. V. Goryn (2024) underscored the necessity of advancing distributed generation, necessitating the elimination of legislative and organisational impediments, alongside the establishment of

financial incentives for investment in renewable energy sources. The author underscores the necessity of implementing energy efficiency programs via concessional lending and Energy Service Company funding, which will enhance the sustainability of the national energy system.

V. Vovk & A. Krasnoselska (2023) examined the environmental and economic dimensions of transformations in Ukraine's energy sector amid the war and subsequent recovery efforts. The authors analyse the trends toward the more vigorous use of renewable energy sources in Ukraine and the EU, highlighting the potential of biogas as a replacement for natural gas. The authors underscore the necessity of optimizing regulatory elements of biomethane characteristics for their incorporation into gas distribution and transmission networks, thereby facilitating domestic consumption, exports, and contributing to the nation's economic development. E. Lapenko (2023) examined critical facets of Ukrainian energy security, encompassing the influence of military activities on gas consumption and the national commitments under the Association Agreement with the EU to establish strategic reserves of oil and petroleum products. The author emphasized the particulars of establishing such reserves, including the criteria for their composition, storage, and the potential for their relocation overseas. The author analysed the fluctuations of fuel costs during the conflict, which were contingent upon inexpensive supply of Russian origin and reduced excise duties. The report emphasized the dangers presented by Russian activities at nuclear power plants and their effects on the energy stability of Ukraine and Europe.

Notwithstanding extensive research, unanswered concerns persist concerning the evaluation of the energy system's capacity to address wartime challenges and the energy crisis's effect on the nation's economic stability. Contemporary study necessitates a comprehensive examination of the correlation between energy security and economic resilience during conflict, with the exploration of creative strategies to enhance the robustness of the energy system.

The research aimed to examine the condition of Ukraine's energy system amid the war, identify principal issues and strategies for resolution, and evaluate the influence of energy security on national economic stability. The study objectives encompassed identifying primary issues in the energy system's operation resulting from military activities; evaluating the efficacy of diverse crisis response strategies; analysing the economic repercussions of energy instability; and formulating recommendations for innovative approaches to enhance the energy system's reliability.

Materials and Methods

In the period of 2022-2024 years, a study was conducted to assess the consequences of the armed conflict. The main data sources used were official documents prepared by national and international institutions, such as the Organisation for Economic Co-operation and Development (2023a; 2023b), United Nations Development Programme (2023), and analytical materials of ENTSO-E (2024). These sources provided important data on the state of the infrastructure, the extent of damage, and the scale of economic losses.

The study analysed data regarding the status and capacities of the energy system's generation facilities, heating networks, gas transmission infrastructure, and renewable energy sources. Information on damage to energy infrastructure facilities was obtained from reports and satellite images processed in Quantum geographic information system software.

The study analysed international experience in stabilising energy systems in crisis conditions. The reports of the International Energy Agency (2024) and ENTSO-E (2024) provided information on best practices for implementing decentralised generation systems, integrating alternative energy sources, and creating conditions for the long-term sustainability of energy systems. This information formed the basis for the development of scenarios for the restoration of the Ukrainian energy system. The indications of financial losses and rehabilitation requirements for the Ukrainian energy sector from 2022 to 2024 were studied. The primary focus was on examining the repercussions of the loss of critical infrastructure, including the Zaporizhzhia Nuclear Power Plant and thermal generation facilities. The primary elements of securing funding for the rehabilitation of Ukraine's energy infrastructure through diverse procedures that mitigate the particular risks linked to investment in the nation amid military aggression are defined.

The analysis confirmed the distinct characteristics of several regulatory and legal reforms designed to stabilise and expand Ukraine's energy industry throughout the wartime conflict. In particular, the authors provided a detailed description of the Law of Ukraine No. 3220-IX "On Amendments to Certain Laws of Ukraine on the Restoration and "Green" Transformation of the Energy System of Ukraine" (2023), the Resolution of the Cabinet of Ministers of Ukraine No. 227 "On the Introduction of Guarantees of Origin of Electricity Generated from Renewable Energy Sources" (2024a), and the National Renewable Energy Action Plan for the period up to 2030 (Resolution of the…, 2024b). The study analysed and processed data on sources of international financial support in 2023-2024 from the European Investment Bank, the World Bank, the European Bank for Reconstruction and Development, the EU and the United States.

The examination of an extensive model of energy system development, encompassing the interplay of financing, technology, legislative regulation, and international alliances, constituted a crucial component of the study. A specialised model was utilised to evaluate the impact of incorporating renewable energy sources on the stability of the energy system, emphasising responses to external challenges and energy efficiency. The model also incorporated regional peculiarities and specific risks for different sectors of the energy infrastructure, which was used to create adaptive recovery scenarios. The work with the documents included a review of reports from international do-

nors, such as the European Bank for Reconstruction and Development, which provided financial support for the restoration of critical energy facilities. The data was subjected to a thorough analysis, which determined the impact of innovative technologies on restoring the stability of the power system.

Results

The Ukrainian energy system is critically compromised due to extensive destruction from ongoing missile assaults and the takeover of regions housing essential energy infrastructure. Since the commencement of the large-scale invasion in 2022, over fifty percent of the nation's generating capacity has been impaired, obliterated, or appropriated, substantially constraining the country's energy supply alternatives. The loss of the Zaporizhzhia Nuclear Power Plant (6 GW) and the intense attacks of 2024, which additionally deprived Ukraine of 9 GW of capacity, created the conditions for a serious energy crisis (International Energy Agency, 2024). The situation is further complicated by the destruction of heating facilities, gas infrastructure and other key components of the energy system (Table 1).

Table 1. Analysis of key data on the state of Ukrainian heating networks (2022-2024)

Metric	Data
Number of households connected to district heating	More than a third
Share of heat generated by gas	70%
Share of combined heat and power production	30%
Destroyed or damaged facilities:	
Combined heat and power plants	18 units
Boiler houses	815 units
Central heating stations	152 units
Heating networks	354 km
Direct losses	USD 2.4 billion
Debts of heating companies to Naftogaz	UAH 95 billion (USD 2.6 billion)

Source: compiled by the authors based on International Energy Agency (2024)

An analysis of Table 1 demonstrates that Ukrainian district heating infrastructure, which supplies more than a third of households, has suffered significant damage. The critical dependence of heat supply on natural gas (70%) and combined heat and power plants (30%) significantly increases the system's vulnerability to external attacks and supply disruptions. The substantial subsidisation of heat tariffs has resulted in the buildup of loans within the sector, complicating its recovery. The Public Service Obligation mechanism introduced in 2022, which provides for the supply of gas at a reduced price compared to the market price, helped stabilise heat supply but also increased the financial burden on Naftogaz. As of October 2023, the debt of heating companies reached USD 2.6 billion, which required debt restructuring and the search for additional financial sources (World Bank, 2023). The electricity shortage was particularly acute in 2024 when generating capacity was unable to cover the peak demand of 12 GW, even with electricity imports from neighbouring countries. The most affected regions were forced to limit electricity supply to a few hours a day, which negatively affected economic activity and the basic needs of the population. During this period, international partners provided critical equipment to stabilise the power system.

Energy security is a key factor in Ukrainian economic resilience in times of war, as the destruction of critical infrastructure caused large-scale financial losses and significant challenges for the economy. The electricity sector suffered the greatest losses, with restoration needs estimated at USD 33.8 billion. This is estimated at USD 33.8 billion due to the destruction of electricity generation and distribution facilities. The oil and gas sector incurred substantial losses, requiring about USD 14.8 billion for restoration. The oil and gas industry, as well as the coal industry and the heating system, have also suffered significant losses. Funding for the reconstruction measures involves attracting international assistance from the EU, the World Bank, the International Monetary Fund and other donors, as well as reparations from Russia, which requires the development of appropriate legal mechanisms (Table 2).

Table 2. Financial losses and restoration needs in the energy sector of Ukraine (2022-2024)

Sector	Direct losses (million USD)	Indirect losses (million USD)	Recovery needs (million USD)	Possible sources of funding
Electricity sector	11,425	18,607	33,839	EU, World Bank, European Bank for Reconstruction and Development, state budget, private investors
Electricity generation	8,520	12,582	14,065	International Monetary Fund, Green Climate Fund, private investors
Oil and gas sector	3,331	1,387	14,812	World Bank, International Monetary Fund, European Bank for Reconstruction and Development, reparations from Russia

Table 2, Continued

Sector	Direct losses (million USD)	Indirect losses (million USD)	Recovery needs (million USD)	Possible sources of funding
Coal industry	840	676	521	European Bank for Reconstruction and Development, reparations from Russia, state budget
Heat supply	972	872	1,350	State subventions

Source: compiled by the authors based on Kyiv School of Economics (2024)

The Ukrainian gas supply system has sustained considerable damage due to fighting and assaults on essential infrastructure. In particular, the above-ground gas storage facilities were heavily damaged, while the underground ones remained largely intact, providing reserve capacity to meet domestic demand. However, the situation is exacerbated by a growing gas shortage due to the seasonal increase in demand in winter and the possible termination of Russian gas transit from January 2025. These developments pose significant risks to ensuring stable gas supplies, both for domestic consumption and for energy imports from the EU.

The winter period of 2024-2025 poses new challenges for the Ukrainian energy system, as the expected increase in energy demand and the high probability of new attacks on infrastructure could lead to a deepening of the crisis. In such circumstances, stabilising the energy system requires a comprehensive approach, including modernising grids and introducing decentralised generation technologies. Special emphasis must be placed on the implementation of alternative energy sources and the optimisation of energy consumption to diminish reliance on conventional energy supplies (International Energy Agency, 2024).

The Ukrainian energy system may develop under several scenarios in the period of 2025-2026 years, depending on the success of reforms, the foreign policy situation and the level of international support. A primary alternative entails the active integration of Ukraine into European energy markets, necessitating the modernisation of energy infrastructure, the adoption of European standards, and an augmentation of the proportion of renewable energy sources. According to the National Bank of Ukraine, the national electricity deficit is expected to decrease from 4% in 2025 to 2% in 2026, indicating a gradual improvement in the energy situation as reforms are implemented (Petrovsky, n.d.). The government intends to elevate the proportion of renewables in the energy mix to 27% by 2030, thereby diminishing reliance on conventional energy sources and enhancing the resilience of the energy system. A crucial measure is the complete integration of Ukraine's power and gas markets with the EU by 2025, which will enhance energy import prospects during crises and draw European investment (Order of the…, 2023).

Despite the significant pressure on the Ukrainian energy system, strategic planning and international support helped ensure the basic stability of energy supplies. At the initial stage, the Group managed to arrange electricity imports from the EU, which reached 1.7 GW to cover its needs. These actions were key in meeting the needs of the regions that suffered the most damage, where domestic generating capacities were partially or completely out of action. The stability of the energy system largely depends on the three operating nuclear power plants of Rivne, Khmelnytsky and South Ukrainian Nuclear Power Plants (Fig. 1).

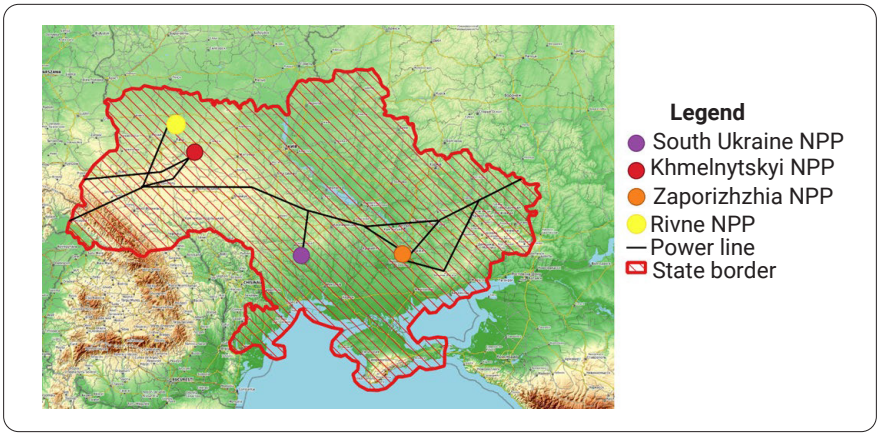

Figure 1. Map of locations of operating nuclear power plants in Ukraine

Source: compiled by the authors using Quantum geographic information system software tools based on the Quick Map Service and Open Topo Map software modules

Rivne Nuclear Power Plant, located in the northwestern part of the country, is one of the key sources of energy supply for the western regions. Its operation remains relatively stable due to its distance from active combat zones,

but the risks of attacks on transmission networks remain. Khmelnytskyi Nuclear Power Plant, located near the western border, is important not only for supplying energy to the central and western regions but also for establishing energy cooperation with the EU. The South Ukrainian Nuclear Power Plant supplies electricity to the southern and central regions, but its proximity to the war zone poses significant risks to stable operation. At the same time, the Zaporizhzhya Nuclear Power Plant, which provided about 25% of the national electricity before the war, remains under occupation by Russian troops, which significantly limits the possibilities of energy supply (Organisation for Economic Co-operation and Development, 2023a).

In the heating industry, there is an urgent necessity to formulate contingency plans for heat supply, particularly in major cities like Kyiv and in areas that have experienced substantial infrastructure damage. This includes the installation of supplementary mobile boiler houses, the implementation of decentralized heating systems, and the utilisation of cogeneration units. These efforts will somewhat offset the losses incurred from the demolition of central heating facilities and address the essential demands of the populace amid the energy crisis.

International assistance remains an important factor in stabilising the Ukrainian energy system. Integration into the European energy market through ENTSO-E (2024) is a significant achievement that provides Ukraine with access to alternative sources of electricity. However, further investments in infrastructure modernisation, energy efficiency and decentralisation of energy supply are needed to ensure long-term sustainability.

In light of the substantial risks associated with investing in the energy sector, the Ukrainian government is proactively enacting measures to decentralise generating. The emphasis is on the utilisation of tiny modular gas turbines with capacities ranging from 5 to 40 MW, rather than conventional huge power units, which are vulnerable targets. The emphasis is placed on the advancement of decentralized generation via the installation of rooftop solar panels equipped with energy storage systems in administrative buildings, hospitals, schools, residences, and enterprises. By early 2024, the total capacity of this generation approached 1.5 GW, and this number is steadily increasing thanks to the government's consistent support (Organisation for Economic Co-operation and Development, 2023a).

An evaluation of the damage to the energy infrastructure is crucial for assessing Ukrainian energy security, which is essential for economic sustainability. The persistent armed war, coupled with systematic assaults on energy infrastructure, severely restricts the state's capacity to fulfil the requirements of the populace, industry, and social sector. This analysis not only determined the extent of the destruction but also demonstrated which elements of the energy system need to be restored as a matter of priority. At the same time, an important challenge for the energy sector is the outflow of skilled personnel, which complicates the recovery process and requires the development of effective mechanisms for their retention, retraining and training. In addition, systematic data on damage serves as a basis for developing recovery strategies, attracting international financial support, and further modernising infrastructure (Fig. 2).

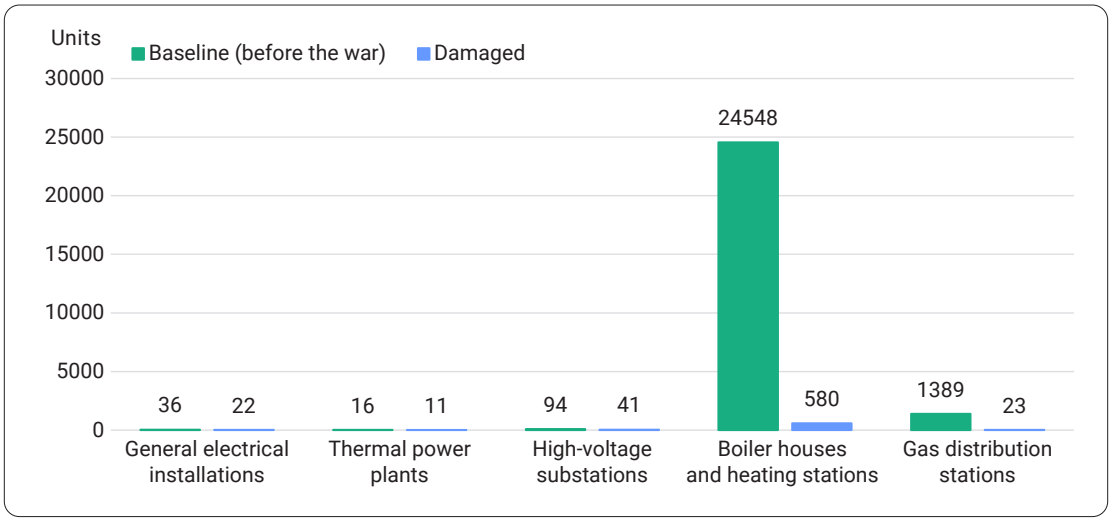

Figure 2. Assessment of damage to key energy assets in Ukraine

Source: compiled by the authors based on Organisation for Economic Co-operation and Development (2023a), International Energy Agency (2024)

The analysis of the data in Figure 2 shows significant losses in all sectors of energy infrastructure, which makes it difficult to ensure a stable energy supply in the context of the ongoing conflict. In the power generation sector, losses amount to 61.4% of the baseline. Out of a total installed capacity of 36 GW, only 14 GW remain available for use. Much of the capacity is located in the temporarily occupied territories, including the Zaporizhzhia nuclear

power plant (6 GW), depriving the country of a critical resource. The destruction of high-voltage grids further complicates the transmission of electricity between regions, which destabilises the power system. In the thermal power and combined heat and power plants sector, losses reached 71.5%. Only a third of the 16 GW of capacity is available (International Energy Agency, 2024). This poses significant risks to the district heating system, which meets the needs of large cities such as Kyiv, Kharkiv and other urbanised regions. These losses directly affect the national ability to provide heat in the winter.

The high-voltage infrastructure also suffered significant damage. Out of 94 critical high-voltage substations, 41 were damaged, or 43.6% of the baseline. Most of them have suffered repeated strikes, significantly reducing their reliability. The destruction of this infrastructure makes it impossible to effectively redistribute electricity in the grid and leads to energy shortages in some regions. Damage to heating networks and boiler houses is relatively less severe, but the impact on social stability is significant. Out of more than 24,500 units, 580 were damaged, or 2.4%. The bulk of the losses occurred in the regions of active hostilities, where district heating became unavailable to thousands of households (Trading Economics, 2024). The gas infrastructure suffered less damage compared to other sectors. Out of a total of 1,389 gas distribution stations, 23 were damaged, or 1.7% of the baseline. However, even these relatively minor losses significantly affected the gas supply to regions that depend on stable energy supplies.

The scale of the destruction in all sectors significantly increases the threat of an energy crisis, especially during the winter season and high energy consumption. The loss of 61.4% of generating capacities and 71.5% of thermal power plants and combined heat and power plants indicates a significant reduction in the ability of the energy supply system to meet the basic needs of the population and industry. This is especially critical for heating in urban agglomerations such as Kyiv and Kharkiv, where the district heating system is the main source of heat (United Nations Development Programme, 2023).

The destruction of 43.6% of high-voltage substations highlights the vulnerability of the electricity transmission system, which has caused a serious imbalance due to damage to key nodes. The inability to ensure efficient redistribution of energy between regions is leading to local energy shortages, especially in the eastern and southern regions, where the infrastructure has suffered the most damage. At the same time, even minor damage to the gas infrastructure (1.7%) significantly affected the stability of gas supplies in the affected regions. The hostilities make it difficult to quickly repair the damaged facilities, which increases the risk of prolonged disruptions in energy supplies.

The stability of the district heating system remains under threat due to significant losses in the combined heat and power plants and boiler house sector, which is critical for regions with severe winter conditions. Winter conditions in 2024 exacerbate these risks, given the projected increase in energy demand and the risk of repeated attacks on infrastructure. An analysis of the economic damage caused to the energy infrastructure as a result of hostilities highlights the urgent need to develop and implement solutions aimed not only at restoring but also at increasing the resilience of key energy facilities. Energy security is crucial in ensuring the economic stability of the state, as it directly affects the social sphere, industry and the ability of the economy to operate in crises (Order of the…, 2023).

Ukraine is actively implementing comprehensive measures to modernise its energy system, given the difficulties caused by the armed conflict. In 2024, the Energy Strategy of Ukraine until 2050 was approved, which envisages integration with the EU energy system, development of renewable energy sources, renovation of heating networks and buildings, and encouragement of private sector investment (Table 3).

Table 3. Key areas for modernising the Ukrainian energy system

Direction	Description	Expected effect
Strategic planning	Implementation of the plans of the Energy Strategy of Ukraine until 2050 and integration with the EU energy system	Ensuring long-term energy security
EU integration	New interconnectors with Romania and Slovakia by 2026	Increased exports and security of supply
Energy efficiency	Modernisation of buildings and heating networks through financial mechanisms	Reduced energy consumption by up to 50%
CEP development	Launch of biomethane plants and development of solar and wind power plants	Increase the share of renewable energy sources and reduce gas dependence
Tariff reform	Introduce differentiated tariffs to protect vulnerable consumers	Stimulating investment and optimising costs
“Smart” technologies	Implementation of smart meters and demand side management	Optimisation of energy consumption and reducing peak loads
Support for the private sector	Transparent rules and mechanisms for investment insurance	Raising capital to modernise the system
Integration of gas storage facilities	Provision of 10 billion cubic metres to European partners for gas storage	Additional revenues and enhanced security for Europe
Citizen engagement	Energy saving campaigns and public education	Increase efficiency and reduce costs

Source: compiled by the authors based on Organisation for Economic Co-operation and Development (2023a), United Nations Development Programme (2023), International Energy Agency (2024)

Considering the main directions of modernisation of the Ukrainian energy system, it should be emphasised that the creation of new energy connections is an important project within the framework of integration with the EU. In particular, it is planned to launch new 400 kV power lines between Ukraine and Romania by 2026, estimated at 300 million EUR, partially financed by the European Bank for Reconstruction and Development. The Hungarian route provided supplies of up to 9 million cubic metres of gas per day, but the agreement was only valid until January 2025, and its extension is critical (World Bank, 2023). Funding was made possible through initiatives such as the G7+ Energy Coordination Group, which provided 1.4 billion dollars in 2023 to restore critical infrastructure (European Commission, 2024). In addition, Ukraine used the AggregateEU platform to purchase an additional 0.6 billion cubic metres of gas from the EU in September-October 2024, with a total value of 250 million EUR.

Funding for the restoration of Ukrainian energy infrastructure is raised through various mechanisms that consider the specific risks associated with investing in a country under military aggression. One of the key sources of financing is international financial institutions, such as the European Bank for Reconstruction and Development and the International Finance Corporation. These institutions provide long-term loans and investments aimed at supporting Ukrainian enterprises, in the energy sector, agribusiness and infrastructure. In addition, export credit agencies, such as the U.S. Corporation for International Development and the UK Export Finance, are important. These institutions offer insurance and reinsurance of investments against political and military risks, which helps to attract private capital (Ministry of Economy of Ukraine, n.d.).

An additional mechanism of financial support is provided by the Multilateral Investment Guarantee Agency, a member of the World Bank Group that specialises in political risk insurance for foreign investors investing in the Ukrainian economy. In addition, some governments have created special investment funds to support projects in Ukraine. For instance, the Danish Government Investment Fund finances economically viable projects that promote a green transition and energy infrastructure development (Insurance of investments…, 2024).

However, investing in the energy sector of Ukraine is accompanied by significant risks. The most significant of these are military risks, as the ongoing aggression significantly increases the probability of damage or destruction of critical infrastructure, which could cause a loss of investment. Political risks also remain a serious factor, as the unstable situation in the country creates the possibility of changes in legislation that could affect investors' rights. In addition, there are economic risks associated with the volatility of macroeconomic indicators, which may affect the government's ability to meet its financial obligations to creditors. Operational risks, such as the destruction of infrastructure, logistical problems, and a shortage of qualified personnel, can complicate the implementation of investment projects. Several key mechanisms are used to minimise these risks. First, international financial institutions provide guarantees and insurance, which reduce the risks for private investors. Second, state guarantees and government participation in financing infrastructure projects increase confidence in investing in Ukraine.

The advancement of renewable energy sources is a specific emphasis. In 2024, Ukraine inaugurated 10 biomethane facilities with a combined capacity of 1.5 million cubic meters annually. This diminishes reliance on natural gas and aids in the attainment of sustainable development objectives. In the Mykolaiv region, a 200 MW wind farm was completed with a budget of 450 million USD, 70% of which was financed by the European Investment Bank. Tariff reform is also central to the development of the region. In 2024, differentiated electricity tariffs were introduced: basic household consumption is subsidised, while consumption above the standard is paid at market prices. This helps to stimulate energy saving and attract private investment (World Bank, 2023).

During the period of military operations, Ukraine implemented several regulatory reforms aimed at stabilising and developing the energy sector. One of the key changes was the implementation of European standards in the energy sector. The Law of Ukraine No. 3220-IX "On Amendments to Certain Laws of Ukraine on the Restoration and "Green" Transformation of the Energy System of Ukraine" (2023) introduced the concept of an "active consumer", which allowed citizens and businesses to install private generating units to produce electricity on their own and sell its surplus to the grid. In January 2024, the relevant amendments to the Distribution Systems Code enshrined the legal mechanisms for implementing this process (Resolution of the…, 2018).

The government has initiated a corporatisation process to enhance the transparency of state-owned energy company management. In February 2024, a resolution was enacted to convert the State Enterprise Guaranteed Buyer into a joint-stock corporation, retaining 100% of its shares under state ownership. This was intended to bolster confidence among foreign partners and investors (Petrov & Andarak, n.d.). The ratification of Cabinet of Ministers of Ukraine Resolution No. 227, titled "On the Introduction of Guarantees of Origin of Electricity Generated from Renewable Energy Sources," marked a pivotal advancement in renewable energy development (2024a). The program sought to entice international investment in the renewable energy sector, as assurances of origin offer the potential for enhanced tax incentives and advantageous financing conditions.

In August 2024, the government ratified the National Renewable Energy Action Plan for the period leading to 2030, which anticipates an augmentation of the renewable sources' participation in the energy consumption framework to 27% (Resolution of the…, 2024b). The proposed actions entail conducting auctions for the establishment of new renewable energy installations, thereby fostering advantageous conditions for industry advancement. A crucial

aspect was to promote the advancement of distributed generating. In response to the risks of physical destruction of centralized infrastructure, the government has formulated a strategy for the advancement of small-scale generation from renewable energy sources. This streamlines the processes for integrating such plants into the grid and offers them enhanced financial and regulatory incentives. This method facilitates the decentralisation of electricity generation and strengthens the resilience of the power system. Notably, a significant measure in enhancing state control over energy assets was the transfer of 27 gas distribution companies to state oversight in 2023. This method seeks to guarantee a continuous gas supply and mitigate the impact of oligarchic entities on the gas market (Scientific concept of…, 2024).

The implemented regulatory modifications enhanced the electricity system's resilience and its capacity to respond to wartime conditions. The incorporation of European standards guarantees market transparency and establishes the prerequisites for attracting investment. The advancement of renewable energy and distributed generation facilitates the decentralisation of electricity supply, hence mitigating the hazards linked to physical assaults on energy infrastructure. Strengthening state control over gas networks and implementing measures to develop nuclear power form the basis for ensuring long-term energy security.

To improve the efficiency of energy consumption in buildings, in 2023 the Energy Efficiency Fund of Ukraine provided grants totalling UAH 600 million, which covered the insulation of more than 500 apartment buildings. In 2024, this figure will be increased to UAH 1 billion, which will allow for the modernisation of about 1,200 more facilities (International Energy Agency, 2024). In addition, modernisation includes the active introduction of smart technologies. As of the end of 2024, more than 1.5 million smart electricity meters had been installed, funded by a USD 200 million loan from the World Bank (2023). Strategic measures focused on integration with the EU, tariff reform, and infrastructure development allow Ukraine to ensure not only energy security but also lay the foundation for economic sustainability.

Strategic planning to enhance Ukrainian energy security include many initiatives focused on modernizing infrastructure, diversifying energy sources, enhancing energy efficiency, and connecting with European energy networks. The execution of these efforts will guarantee the stability of the energy system and enhance the nation's economic resilience against military threats. The modernisation of Ukrainian energy infrastructure emphasizes sustainable outcomes. The utilisation of renewable energy sources, along with the incorporation of smart grids and energy storage systems, is essential for diminishing reliance on conventional energy resources and enhancing energy efficiency. Furthermore, these technologies generate new prospects for Ukrainian integration into the European energy sector, thereby enhancing energy independence and economic stability.

Implementing creative solutions can markedly diminish the dangers linked to external threats. These methodologies facilitate the establishment of local energy systems capable of guaranteeing a reliable energy supply for essential facilities, including medical institutions and industrial businesses. Special emphasis must be placed on the cybersecurity of energy systems, as contemporary digital threats considerably impact the security of energy infrastructure (Fig. 3).

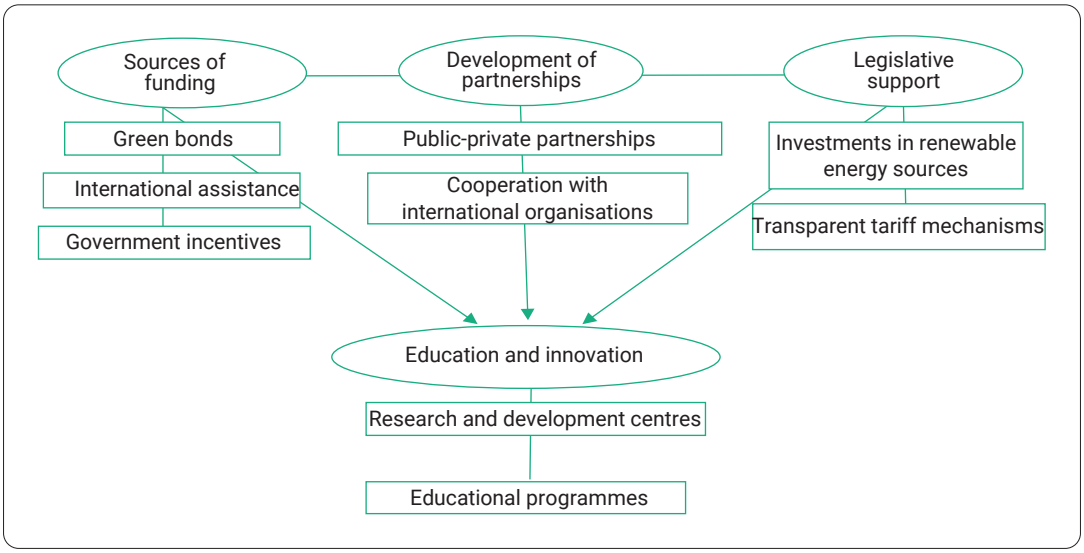

Figure 3. Model of integrated development of energy security in the country as a key to economic sustainability
Source: compiled by the authors

The model presented in Figure 3 is key to assessing Ukrainian energy infrastructure, focusing on the relationships between funding sources, partnerships, legislative support and innovation. It aims to identify vulnerabilities in the energy system and develop effective strategies to enhance energy security and economic resilience. Financing

sources such as green bonds, international aid, and government incentives form the basis for implementing renewable energy projects and infrastructure upgrades. For instance, the use of green bonds allows attracting investment in solar and wind energy projects, which reduces the country's carbon footprint. In 2023, such bonds provided more than EUR 500 million to finance energy initiatives (Organisation for Economic Co-operation and Development, 2023b). International support, in particular funding from the European Bank for Reconstruction and Development, has enabled Ukraine to implement urgent infrastructure rehabilitation projects. The development of cooperation through public-private partnerships and integration with international organisations, such as the Energy Community (2024), helps to attract investment and introduce innovative technologies. For instance, private investors, together with the state, are financing the construction of new wind farms with a capacity of 200 MW, which will ensure energy independence for certain regions. Cooperation with international organisations also allows Ukraine to adapt its legislation to European standards, creating preconditions for further integration into the EU energy market.

External financial assistance during the 2023-2024 period has been vital for Ukraine's energy sector, bolstering its resilience against the winter months and the impacts of the conflict. Financial assistance from the European Investment Bank, the World Bank, the European Bank for Reconstruction and Development, the European Union, and the United States facilitated the rapid restoration of damaged infrastructure, averted energy crises, and bolstered the transition to a more stable and autonomous energy system. Without this assistance, Ukraine would have faced large-scale power outages and critical disruptions in vital services (Table 4).

Table 4. Main sources of financing for the energy sector of Ukraine in 2023-2024

Sources of funding	Amount of funding	Usage	Period
World Bank	200 million USD	Repair of Ukrainian energy infrastructure, with the possibility of additional financing of up to 300 million USD	During March 2023
European Bank for Reconstruction and Development	300 million EUR	Repair of energy infrastructure before the winter season	August 2024
European Investment Bank	600 million EUR	Providing for the urgent heating and electricity needs of Ukraine during the war, as well as supporting green energy initiatives, including energy efficiency and renewable energy development	October 2024
European Commission and the US government	106.6 million EUR	Restoration of energy facilities damaged by Russian attacks	November 2024

Source: compiled by the authors based on Energy rescue plan approved to finance EU-backed emergency heating and power projects for Ukraine ahead of winter season (2024), BDO (2024), K. Strohecker & O. Harmash (2024), Ukraine's DTEK to receive 107 mln euros from EU, US to rebuild power facilities (2024)

Legislative support in Ukraine enhances transparency and creates conducive conditions for renewable energy investments, with initiatives such as the feed-in tariff and streamlined import procedures resulting in a 25% rise in investments. Education and innovation are emphasized via research institutions and specialized training, concentrating on technologies such as Smart Grids and energy storage systems. In 2024, three new research facilities were inaugurated, and instructional programs on cyber protection for the energy sector were instituted. This holistic strategy, encompassing financing, public-private collaboration, legal assistance, and innovation, fortifies energy system sustainability, diminishes import reliance, curtails CO2 emissions, and bolsters economic stability, establishing a foundation for sustainable development, particularly in response to external threats.

Discussion

The findings of this study are essential for developing strategies to rehabilitate and modernise the Ukrainian energy sector. The evaluation of the destruction underscored essential areas for intervention, with systemic reorganisation being of utmost importance. The recovery must prioritise decentralisation, including the promotion of distributed generation, the establishment of local energy sources, and the improvement of regional autonomy. This method will reduce the vulnerability of power networks to attacks and lessen dependence on large, centralised power plants, which are increasingly favoured targets for adversaries. To ensure energy security, it is imperative to diversify energy sources by increasing the share of renewables, establishing additional wind and solar power installations, and enhancing biomethane production facilities. This method will reduce dependence on fossil fuels and improve the energy system's adaptability and robustness against external threats. (Sirko *et al.*, 2023).

To avert such losses, it is essential to establish robust measures for safeguarding critical infrastructure. This encompasses the physical safeguarding of energy infrastructure, cybersecurity measures, and the advancement of smart grids that provide prompt threat response and load redistribution during energy shortages. A crucial element is the upgrading of power transmission networks and high-voltage infrastructure, which will reduce losses

during electricity transmission and guarantee the stability of energy supply to the regions most impacted by devastation (Hrytsiuk *et al.,* 2024).

The results align with the findings of J.D. Colgan *et al.* (2023), highlighting the necessity to modify energy systems for crisis conditions through the diversification of energy sources and enhancement of their resilience. The authors emphasise that countries which rapidly adopt renewable technology and establish distributed energy networks are more resilient to external threats. The conclusions are thoroughly substantiated by the findings of the current study, which indicate that the restoration of Ukraine's energy system should prioritise decentralisation, the advancement of renewable energy sources, and the enhancement of infrastructure resilience.

This study also corroborated D. Borozan's (2024) views regarding the necessity of technological modernisation to provide energy security. The research demonstrated that the implementation of intelligent technologies, including automated energy flow management, energy storage system development, and digital network monitoring, is essential for enhancing system resilience and optimising its performance.

Further development of the energy sector requires significant investment, which is consistent with the findings of G. Ofosu-Peasah *et al.* (2024), who emphasised the importance of investing in the modernisation of energy infrastructure to prevent future crises. In the Ukrainian context, this is especially relevant for the restoration of the destroyed heating system, which puts significant pressure on the government and international partners. To effectively address this problem, a well-coordinated approach to international assistance, government programmes, and private capital is needed. In addition, the study by H.H. Nguyen *et al.* (2024) proved that global geopolitical crises can boost the transition to renewable energy sources. For Ukraine, this conclusion is of strategic importance, as the energy crisis caused by the war accelerates the need to create local heating networks with high energy efficiency. The introduction of such systems will reduce the load on centralised heating networks, increase regional autonomy and create a more reliable energy supply system in an unstable environment.

In addition to restoring the destroyed infrastructure, an important strategic direction is the international integration of the Ukrainian energy system (Ostudimov & Kaminska, 2023). The concept of energy sovereignty, presented by M.C. LaBelle (2024), is key to defining the significance of Ukrainian accession to ENTSO-E. International cooperation, which enables the interconnection of energy systems, is an important step towards strengthening resilience. At the same time, Ukraine faces challenges in balancing its energy sovereignty and dependence on external partners. Implementing such a model of cooperation will allow Ukraine not only to strengthen its energy potential but also to gain access to stable reserve capacities, which is critical in the context of future crises.

The financial support provided by international partners, including a USD 1.4 billion loan from the G7+ Energy Coordination Group, is crucial to stabilising the situation. However, to ensure the effective use of these resources, Ukraine must ensure transparency and targeted use of financial assistanc (Berdar *et al*., 2024). This aspect becomes even more relevant given the development of the green bond market, which has already been successfully used by Ukraine. E. Akusta (2024) highlighted the potential of such instruments to finance sustainable energy development in crisis conditions. In addition, the introduction of financial aid monitoring systems can be a crucial factor in ensuring its effectiveness.

Ukraine is demonstrating an accelerated introduction of renewable energy sources, such as the construction of 10 biomethane plants and the installation of 200 MW of wind power in 2024 (Shahini *et al*., 2024). This reflects the trend described by B. Wang *et al.* (2024), emphasising the importance of renewables for ensuring both energy security and environmental sustainability. The financial challenges associated with infrastructure rehabilitation, such as debt in the district heating sector, indicate the need to use innovative financial instruments (Skochko *et al*., 2024).

In contrast to the more stable situation in the UK, where, according to M. Mersch *et al.* (2024), energy security can be combined with the transition to carbon neutrality, in Ukraine, long-term strategic planning often gives way to the need for immediate stabilisation measures. The destruction of Ukrainian energy infrastructure also confirms the need for decentralisation of energy systems, as discussed by J. Du *et al.* (2024). The authors emphasised that centralised energy systems are much less adaptive to crises, while decentralised energy supply models can respond more quickly to changes and function even in cases of destruction of part of the infrastructure. The current study confirms this conclusion, as the analysis of losses showed that centralised heating networks and large power plants were the most affected, while local generation facilities showed higher resilience.

The influence of natural resources on energy security stability, as observed by F. Ullah *et al.* (2024), highlighted the disparity between Ukraine and resource-abundant nations like the BRICS. Ukraine, constrained by its limited resources, heavily relies on international assistance to maintain the viability of its energy infrastructure. J. Kim *et al.* (2022) confirm the significance of global collaboration in enhancing energy security. The authors of the current study observed that nations with restricted access to indigenous energy resources require extensive international investment, technical support, and policy alignment to attain energy stability. In the Ukrainian context, limited resources include not only domestic energy capacities destroyed as a result of military operations but also insufficient financial capacities to restore energy infrastructure independently (Krawczyńska *et al*., 2024). The substantial financing of the sector's reconstruction by the EU, the World Bank, the foreign Monetary Fund, and other foreign partners confirms this assertion.

The Ukrainian experience also confirms the importance of a comprehensive risk assessment. At the same time, the predictive models developed by M. Tao *et al.* (2024) can predict and minimise the impact of future crises. The contribution of L. Tichý & Z. Dubský (2024), who emphasise the need to improve the mechanisms of international cooperation to prevent energy crises, is also substantial. Furthermore, the Ukrainian Energy Strategy until 2050 envisages large-scale integration with European energy markets, which is key to system stability. This plan, supported by international collaborations, aligns with global trends that underscore the significance of advancing renewable energy and innovative technologies for attaining energy sustainability, as articulated by M.F. Bashir *et al.* (2024). This underscores the necessity for tailored solutions to particular area concerns. The effective execution of this approach will substantially influence the economy by attracting investment, generating new employment opportunities, and enhancing energy independence. An auspicious domain for additional investigation is the examination of the effects of decentralised energy systems during crises. Y. Fan *et al.* (2024) assert that the diversification of energy sources is crucial for mitigating the risks linked to supply disruptions. In Ukraine, this can be implemented through the development of local networks and the introduction of microgrids.

The study emphasises the substantial destruction inflicted on Ukraine's energy infrastructure by the conflict, exacerbating financial burdens and social hazards owing to interruptions in heating and electricity provision, while highlighting the necessity for adaptive system management. Reconstruction initiatives necessitate a holistic strategy encompassing investments in physical security, digital transformation, tariff policy reform, and enhanced collaboration with foreign partners. This corresponds with the conclusions of A. Gatto & C. Drago (2020) regarding the multifaceted character of energy sustainability, encompassing economic, social, environmental, and governance dimensions. The research underscores the significance of decentralised generation in bolstering resilience against external threats, along with J. Jasiūnas *et al.* (2021) examination of the susceptibility of energy networks to extreme weather and cyber threats. The results necessitate a comprehensive strategy for Ukraine's energy security, tackling both technological and socio-economic issues.

The current study highlights the necessity of developing autonomous solutions to address the population's needs, including local heating systems, heat pumps, and cogeneration units. These results have certain parallels with the research by Y. Zou *et al.* (2023), who analysed the energy sustainability of the residential sector in China in the context of climate change. The authors argue that an increase in demand for energy for cooling is inevitable and puts an additional burden on the power system. In the case of Ukraine, a similar situation may occur due to the increased load on heating systems in winter, which once again proves the need to diversify energy consumption and develop autonomous solutions.

The energy crisis in Ukraine demonstrates the complex interplay between geopolitical risks, infrastructure vulnerabilities and the prospects for a transition to renewable energy sources. Incorporating the findings with international research facilitates the identification of appropriate strategies and policies to guarantee the long-term sustainability of Ukraine's energy system. At the same time, further research should address the adaptation of international experience to Ukraine's conditions, with a focus on decentralisation, renewable energy development and investment attraction. Successful implementation of such initiatives can significantly enhance economic stability, reduce dependence on energy imports, and increase the competitiveness of the national economy in the long run.

Conclusions

The research indicated that Ukrainian energy infrastructure is in a precarious state due to extensive damage inflicted by fighting and recurrent missile strikes. Since the comprehensive invasion in 2022, almost 61.4% of energy-generating facilities, encompassing 71.5% of thermal power plants and combined heat and power plants, have sustained damage or lost control. Such losses severely impede the delivery of essential services to the populace and the consistent functioning of industry, particularly during the winter months.

A critical analysis of the state of the heating networks revealed a dependence on the district heating system, which supplies more than a third of households. The main challenges are the high dependence on natural gas (70%) and the debt burden of district heating companies, which has reached USD 2.6 billion. The study also stated that the restoration of the system is complicated by the destruction of key facilities, such as boiler houses (815 units) and heating networks (354 km).

The total financial losses of the energy sector because of the destruction in 2022-2024 were estimated at USD 33.8 billion. The electricity sector suffered the largest losses (USD 11.4 billion in direct losses) and the oil and gas industry (USD 3.3 billion). The restoration of essential infrastructure necessitates substantial investments, particularly in renewable energy and the upgrading of heat supply systems.

The study period from 2022 to 2024 determined that financing was provided by international institutions, including the World Bank (USD 200 million), the European Bank for Reconstruction and Development (300 million EUR), the European Investment Bank (EUR 600 million), as well as assistance from the European Commission and the US government (EUR 106.6 million). In addition, private capital attraction is stimulated by the reform of the electricity market and the introduction of insurance mechanisms to reduce investment risks. Accordingly, in 2024, differentiated tariffs were introduced, which contributed to a 25% increase in renewable energy investments. Additional measures, such as integration with ENTSO-E, construction of new interconnectors and modernisation of high-voltage

infrastructure, will help reduce energy dependence and stability of Ukraine's power system.

Promising directions for future research encompass the examination of the effects of decentralised energy technologies on overall energy security, the development of models for climate change adaptation, and the enhancement of power grid resilience against cyber threats. The complete implementation of these solutions would enhance the stability and reliability of the energy system amidst present problems.

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None.

Conflict of Interest

None.

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Анотація. Метою дослідження було оцінити стан енергетичної системи України в умовах війни, визначити масштаби пошкодження інфраструктури та проаналізувати можливості відновлення і забезпечення стабільного енергопостачання. Дослідження протягом 2022-2024 років базувалося на аналізі офіційних звітів, супутникових знімків та аналітичних матеріалів щодо пошкоджень та відновлення енергетичної інфраструктури України. Особливу увагу було приділено фінансуванню відновлювальних робіт та регуляторним реформам в енергетичному секторі. Дослідження встановило, що загальні фінансові втрати енергетичного сектору становлять понад 33,8 млрд доларів США. З них 11,4 млрд доларів США – це прямі втрати в електроенергетиці. Аналіз показав значне боргове навантаження на підприємства теплокомуненерго (2,6 млрд. дол. США) та необхідність реструктуризації боргів. У дослідженні охарактеризовано показники рівня пошкодження енергетичної інфраструктури, що є важливим етапом аналізу енергетичної безпеки України як фундаментального фактору національної економічної стабільності. Наголошено на оцінці можливих джерел фінансування відновлення галузі, включаючи міжнародну допомогу, грантові програми та інвестиції приватного сектору. Розглянуо роль міжнародних фінансових інституцій, таких як Європейський банк реконструкції та розвитку, Світовий банк та Європейський інвестиційний банк, які вже виділили понад 1,1 мільярда доларів США на надзвичайні заходи з відновлення енергетичної інфраструктури України. З огляду на фінансові виклики, були розроблені рекомендації щодо залучення додаткових ресурсів через механізми страхування інвестицій, «зелені» облігації та державно-приватне партнерство. У дослідженні також розглянуто питання адаптації тарифної політики та запровадження диференційованих тарифів для покриття витрат на відновлення інфраструктури та стимулювання енергозбереження. Ця модель інтегрує технічні, фінансові та управлінські рішення для забезпечення економічної стабільності та залучення капіталу, необхідного для модернізації енергетичного сектору України

Ключові слова: інфраструктурні виклики; децентралізована генерація; відновлювані джерела енергії; мережева інтеграція; інноваційний розвиток

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Impact of martial law on public investment in innovation

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Abstract. The study aimed to examine the degree of influence of martial law on investment activity in innovative project development. The methodological approach was based on analysis, synthesis and generalisation. The study determined a significant negative impact of the introduction of martial law in Ukraine on the processes of attracting investment from the state in various innovative areas. The study determined that the most promising areas of investment during the introduction of martial law in the country are the agricultural sector and construction. The least promising areas of activity for potential investors are the information technology industry, as well as heat and power supply. In addition, government bonds are one of the most common areas of investment funds. Domestic government bonds in wartime should be addressed quite reliably because their profitability is guaranteed directly by the state. After the introduction of martial law in Ukraine, military bonds became widely popular. The study determined that the yield on such securities can reach 18.5% per annum. The study noted a substantial increase in state budget expenditures (from UAH 1,490,258.9 million in 2021 to UAH 4,486,682.7 million in 2024) with an increase in defence spending (from 8.6% in 2021 to 66.1% in 2025). All of this is occurring in the context of a growing state budget deficit during the martial law period. At the same time, a sharp decline in investment in innovation was noted in Ukraine due to a significant increase in the risk of loss of funds from potential investors as a result of the impossibility of implementing investment projects during the hostilities and the suspension or complete shutdown of business structures that were able to fully implement these projects before the war. The factors that influenced the possibility of attracting public investment in the field of innovation by the state during the war were identified to find ways to effectively implement innovative development measures after the end of hostilities

Keywords: development prospects; financial borrowings; effective solutions; external aggression; economic instability; innovations

Introduction

In the context of martial law, the state faces a need to create effective mechanisms to support economic development, particularly in areas focused on the creation of new technologies, products and solutions. In a situation of political instability, increased risks and significant redistribution of budgetary resources, investment attractiveness is significantly reduced, which negatively affects the dynamics of scientific and technological progress. At the same time, the development of innovative solutions and the introduction of modern technologies are the key factors in ensuring the competitiveness of enterprises, strengthening their adaptability to crisis challenges and creating sustainable models of operation. Attracting capital to develop and implement new solutions is a prerequisite not only for maintaining market positions but also for expanding the country's economic potential.

S.O. Perminova *et al.* (2024) studied the issues of innovation activity in Ukraine during the external armed aggression. According to the authors, the current period of Ukraine's history is characterised by substantial challenges in various spheres of life and requires a rapid response and ensuring the national defence capability, as well as security in the production, information and economic spheres. At the same time, V.V. Bilyk (2022), in an analysis of the state regulation of investment activity, noted that the possibility of such regulation is of great importance at the current stage of economic development and in the context of Ukraine's European integration vector. Further progress of the country is impossible without scientific and technological progress in industry and the modernisation of its management system. However, during the armed conflict, attracting public investment in innovation becomes largely impossible or even more difficult, as there is a real threat of losing the invested funds without any prospect of their further return.

At the same time, A. Kostruba (2024), who explored various aspects of managing investment activities in Ukraine during the war, pointed out that following Russia's armed invasion of Ukraine in February 2022, nearly all innovative and business operations aimed at attracting investment were halted. By 2025, businesses across all sectors are undergoing recovery from numerous difficulties, including a volatile security environment, damaged infrastructure, supply chain disruptions, and a highly unpredictable business climate. T.O. Gutsan & O.M. Melnikova (2024) analysed the main trends affecting Ukraine's investment appeal under martial law. The authors emphasise that assessing a company's level of investment attractiveness is a crucial factor for potential investors when making decisions about investing in its development. In a highly competitive global investment market, the introduction of martial law in the country negatively affects the investment attractiveness of individual enterprises and entire industries, largely levelling the investment attractiveness of enterprises and minimising the prospects for innovation in various fields (Lyndyuk *et al.*, 2023).

O.P. Podtserkovny & D.V. Zyatina (2023) addressed a wide range of issues of stimulating investment in the development of innovations in wartime. The study noted that under martial law, society faces the issues of supporting and stimulating innovation and investment activities in various fields. These conditions force Ukrainian businesses to operate, constantly looking for opportunities to attract investment, while these opportunities are decreasing, as the number of investors willing to risk financial resources in a situation of increased risk of losing investments is significantly narrowing.

In turn, a research group consisting of O.M. Mykhailyk & Y.V. Birak (2023) in an analysis of problematic issues

of building investment and innovation activities of enterprises under martial law highlighted that since the proclamation of martial law, significant changes have occurred in the sphere. The awareness and responsibility of business entities in the use of funds for the development of domestic enterprises has significantly increased. This was determined by the active educational activities of the state and professionals in this area. Based on in-house experience, various enterprises gradually introduced various areas of development and invested in the development of innovative solutions and technologies. The imposition of martial law reduced investment and business activity, pushing some enterprises to the brink of closure and forcing others to cease operations in a situation where they could not attract investment in development (Gavrysh *et al.*, 2024).

M. Nehrey & R. Finger (2024) examined the issues of assessing the impact of the Russian invasion on Ukrainian agriculture in the context of the problems of further attracting investments in the activities of enterprises in this sector of the country's economy. According to the authors, at the beginning of the armed conflict, Ukrainians were forced to deal with significant food shortages and limited access to medicines and other essential products. The deterioration of the situation in the national economy reduced investment activity, which suspended innovative projects and the cancellation of public investment in many areas of activity. G. Allard *et al.* (2022) analysed a wide range of issues related to the impact of political instability on national systems that shape technological development, in particular under martial law. The authors highlighted that such systems have a much greater potential in politically stable countries, while in unstable ones – the probability of their effective functioning is significantly reduced. Therefore, according to the authors, the introduction of martial law significantly limits the possibility of attracting public investment in the relevant areas, as there are no appropriate conditions for the active implementation of projects in this area.

Despite considerable research on the general assessment of the impact of martial law on the investment climate, the issue of attracting public capital to innovative projects in crisis conditions is still understudied. In particular, there is a lack of studies analysing the structure of public investment, the priority areas of its allocation, and the assessment of the effectiveness of such financing during the war.

The study aimed to highlight the prospects for obtaining investment from the state in the context of martial law in the country. The objectives of the study were to compare the investment opportunities of the state before the introduction of martial law and during its operation, as well as to identify the optimal investment areas after the end of hostilities.

Materials and Methods

The materials of this study are legal and regulatory acts governing the investment policy of Ukraine in the field of innovation projects. In addition, to analyse the foreign experience of the impact of martial law on attracting investment in the field of innovation, the materials of the scientific study by A. Saran & K.S. Yildirimer (2023), which covers the relevant experience of South Korea, as well as the data of the statistical report dedicated to a similar situation in Israel, were analysed (Bakushinskaya, 2024).

The general provisions of the Law of Ukraine No. 40-IV "On Innovative Activity" (2002), the Resolution of the Cabinet of Ministers of Ukraine No. 1351-r "On Approval of the Strategy for the Development of Innovative Activity of Ukraine for the Period until 2030" (2024), as well as the general provisions of the State Programmes to Support Innovation Activities were analysed (Ministry of Economy of Ukraine, 2023). In addition, an analysis of the State Budget Reports of Ukraine (n.d.) for 2021-2024 was conducted, which was used to compare changes in the balance of revenues and expenditures of the state budget of Ukraine before and during the introduction of martial law. This analysis identified the most promising areas of investment in Ukraine during the martial law period (2022-2024), as well as the key areas of public investment in the development of innovative projects in the country. The analysis method in the theoretical study identified the key prerequisites for public funding of investment projects in the field of innovation during the war, as well as the factors affecting the probability of implementation of such projects.

In addition, the study conducted a comparative analysis of the losses of the region's largest enterprises in terms of assets, including public joint stock company Ukrainian Power Machines, Philip Morris Ukraine, and state enterprise Malyshev Factory. This analysis estimated the scale of economic losses in an industrially important region of Ukraine, which is critical for justifying the priority of investment support from the state. To process this data, a method of comparative analysis of the volume of losses was used, which identified priority areas of funding in the post-war recovery process, considering the regional characteristics of the Kharkiv region.

The synthesis method was used to identify the key factors that complicate the full implementation of innovation projects in the field of innovation development directly during the introduction of martial law in the country. At the same time, this method identified the main factors that made it impossible to implement innovative projects in Ukraine during the introduction of martial law, as well as the risks closely related to this. This determined the prospects for the implementation of innovative projects related to the need to obtain investment funds from the state in the post-war period, when there will be a need to rebuild the national infrastructure, which, in turn, requires the involvement of effective innovative solutions.

The generalisation method was used to outline a wide range of issues related to the possibility of attracting investment funds from the state in the development of innovative projects in various sectors of the economy. The key factors that most significantly affect the prospects of attracting innovations from the state for the creation and implementation of innovations in any sphere are identified. In addition, the prospects for the implementation of

innovations in various economic spheres after the end of hostilities and the lifting of martial law, after all the necessary measures aimed at the post-war recovery of the country have been taken, are identified. The key advantages of attracting investment funds from the state for the development and implementation of investments in innovative areas, as well as the implementation of investment projects aimed at the country's infrastructure after the lifting of martial law, were identified.

The combination of the identified research methods established the sequence of processing of public investment funds allocated for the development of innovations and to assess the prospects for implementing such a scheme directly during martial law. This identified the key circumstances that make it impossible to implement innovative projects in various fields within the specified period, while at the same time determining the probability of full implementation of these initiatives after the end of the war.

Results

The state's policy on the development of innovations in various areas is based on the previous experience of implementing similar projects and its effective implementation in the current environment. The current problems that are to be solved through the introduction of innovations and the potential of the innovations being developed and implemented in the future are also substantial (Schot & Steinmueller, 2018). Receiving the necessary amount of investment funds from the state for the development and implementation of investments significantly contributes to the rapid economic development of the country, acting as a catalyst for important economic changes in various areas.

According to the official data of the State Budget Reports of Ukraine (n.d.) for the period 2022-2024, an annual allocation of UAH 2,717.275 million is planned for the development and implementation of state projects in the field of innovation. They will be allocated following the procedure established by the Interagency Commission for State Investment Projects. The greatest attention is paid to the priority areas defined in the Procedure for Selecting State Investment Projects. These areas of investment are social and cultural; healthcare; environmental protection; transport; fuel and energy; functioning of public authorities and provision of relevant services.

Based on the Law of Ukraine No. 40-IV "On Innovative Activity" (2002), innovative products are the results of research and (or) development that are competitive and meet the requirements of the said Law. At the same time, according to the Resolution of the Cabinet of Ministers of Ukraine No. 1351-r "On approval of the Strategy for the Development of Innovative Activity of Ukraine for the Period until 2030" (2024), the national financial support for the development of innovative products is provided to cover the following costs: salaries of employees and specialists in certain industries; payment for advisory services; costs of purchasing and maintenance of the necessary equipment; general promotion costs.

The regulatory framework of Ukraine, which defines the key aspects of attracting public investment in innovation, was developed based on the standards of the European Bank for Reconstruction and Development (World Bank, 2022). Accordingly, the selection of investment projects for investment in Ukraine is also based on the scheme developed by the European Bank for Reconstruction and Development. Figure 1 shows a diagram of the practice of preparing and selecting innovative projects to attract public investment for their development according to the European Bank for Reconstruction and Development.

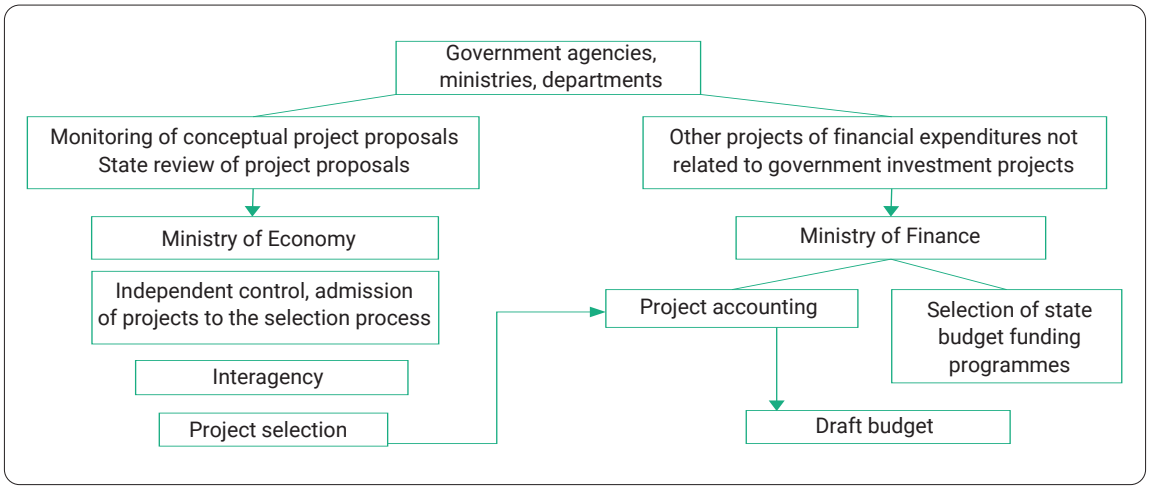

Figure 1. Practice of preparation and selection of innovative projects for attracting public investment for their development

Source: World Bank (2022)

According to the data presented in Figure 1, there is an established procedure for the preparation and selection of innovation projects in Ukraine, as well as a reserve path. The reserve path is also fully legal when state budget funds are

used. In any case, the selection of projects is the responsibility of an interagency commission, which determines the feasibility of attracting public funds for their development. It is this commission that also determines the sequence of financing innovations from the state budget. Funding is allocated following the planned state budget expenditures for each current year. This practice is recommended by the European Bank for Reconstruction and Development for all European countries and is successfully applied in Ukraine. As noted above, public innovation in any area is financed from the budget. Table 1 shows the data on state budget revenues and expenditures in Ukraine from 2021 to 2025.

Table 1. Income and expenditures of the state budget of Ukraine for the period 2021-2025 (for 2025, the figures are predicted by the authors)

Year	Total revenues (million UAH)	Total expenses (million UAH)	Share of defence spending (%)
2021	1,296,852.9	1,490,258.9	8.6
2022	1,787,395.6	2,705,423.3	42.2
2023	2,671,998	4,014,418.1	52.3
2024	3,122,713.4	4,486,682.7	51.5
2025	283,224.9	353,779.1	66.1

Source: State Budget Reports of Ukraine (n.d.)

The values presented in Table 1 indicate a gradual increase in the total expenditures of the state budget of Ukraine during 2021-2024 (from UAH 1,490,258.9 million in 2021 to UAH 448,668,7 million in 2024). The study also revealed a significant increase in the percentage of annual public spending on defence (from 8.6% in 2021 to 66.1% in 2025). These indicators indicate a significant increase in public defence spending during the introduction of martial law in the country, which significantly limits the ability to invest in other areas of the state budget, including the financing of innovative projects. Moreover, during the studied period, the state budget deficit of Ukraine has been steadily growing, from UAH 186,908.3 million (3.42% of gross domestic product in the last pre-war year 2021 to -1,350,614.1 (24.71% of gross domestic product) in 2024 (State Budget Reports of Ukraine, n.d.).

In 2021, the EU launched the Horizon Europe initiative to support the EU's research and development initiatives. This initiative provides funding for research and development in the field of innovation, as well as the implementation of innovative projects in various industries. An annual investment of EUR 100 billion from the EU budget is planned for the period 2021-2027. Of this amount, EUR 2.4 billion was allocated to Euratom's nuclear research programme, and 3.6 billion EUR was reserved for an umbrella investment fund called InvestEU. After accounting for 2% annual inflation in 2018, HorizonEurope's funding was EUR 86.6 billion (Kelly, 2018).

To conduct a comparative quantitative analysis, Table 2 presents statistics on the state budget expenditures for economic activities in Ukraine from 2021 to 2025 (before the introduction of martial law, and during its duration). Notably, the share of funding for innovative projects does not exceed 10-15% (Budget Declaration for…, 2022).

Table 2. State budget expenditures of Ukraine for economic activities (including investments in innovations) for the period 2021-2025

Years	Expenditure on economic activity (billion euros)	Expenditure on innovation (billion euros)	Share of innovations in total expenditures on economic activity (%)	Number of financed projects	Primary areas of support
2021	6.4537022	0.96	15	7234	IT, artificial intellect, construction, agricultural sector
2022	3.4415546	0.36	10.5	3456	Construction, agricultural sector, military bonds
2023	5.4404086	0.59	11	5184	Construction, agricultural sector, military bonds
2024	5.7169068	0.58	10.3	5243	Construction, agricultural sector
2025	0.2914406	0.0297	10.2	268	Construction, agricultural sector

Note: for 2025, the figures are predicted by the authors
Source: State Budget Reports of Ukraine (n.d.)

According to Table 2, a substantial decline in state budget expenditures occurred after the introduction of martial law in the country. The total amount of expenditures on economic activity in Ukraine, including innovations, from 2021 to 2025 does not exceed EUR 22 billion, which is not comparable to the amount of funding for innovations in the EU under the Horizon Europe initiative (EUR 100 billion). At the same time, the share of investment in innovation in Ukraine does not exceed EUR 2.4 billion. In addition, the share of innovation in total economic expenditures before the introduction of martial law decreased significantly, from 15% in 2021 to 10.2% in 2025. In addition, the total volume of funded investment projects decreased from 7,234 in 2021 to 5,243 in 2024 and 268 in 2025, with only construction and the agricultural sector remaining among the promising investment areas by 2025. It is the introduction of martial law in the country that has become the main factor preventing the state from providing stable funding for innovation development.

The experience of South Korea in stimulating innovation activity during the 1950-1953 war demonstrated that with the invasion, the volume of agricultural production, which at that time was the basis of the national economy, significantly decreased. After the end of hostilities and the introduction of the "land reform" in 1956, the country gradually managed to move to an industrial society with the partial elimination of large landowners and the redistribution of capital. In the long run, this helped to attract public investment in industrial development, which eventually contributed to the country's high level of economic development (Saran & Yildirimer, 2023).

Similar trends were observed in the Israeli economy since the outbreak of hostilities in the country. According to a report prepared by RISE Israel, a research and policy institute, in cooperation with the Israeli Association of Advanced Industries, in 2024, there was a 6% decrease in public investment in start-ups compared to 2023. In addition, the 10 largest investments made in the first nine months of 2024 accounted for 47% of total capital invested in various sectors of the economy, compared to about a quarter of the capital in 2023. Less than 50% of public investment in 2022 was repeated (Bakushinskaya, 2024). According to analysts, the situation will only improve after the end of hostilities, when the risk of losing invested funds is eliminated (Hryhorian, 2024).

Any war causes significant destruction, which prevents the full development of the national economy for a certain period. The imposition of martial law in a country caused by the outbreak of war inevitably causes significant changes in the way of social life and the usual course of economic processes. Investment in construction was very profitable before the war, but after the introduction of martial law in Ukraine, the demand for real estate has significantly decreased. This is due to the possibility of losing real estate as a result of hostilities and the inability to predict the approximate timing of the end of hostilities. However, after the end of hostilities and the lifting of martial law, demand for real estate will recover as the risk of loss decreases and the country's infrastructure begins to be rebuilt on a large scale.

Significant prospects for investment in the agricultural sector are due to the impossibility of destroying land as such as a result of hostilities. The development of investment in the agricultural sector occurs mainly in those areas where there have been no active hostilities and no large-scale damage to residential and non-residential real estate.

At the same time, according to the programmes to support innovation activities adopted in Ukraine as of the beginning of 2025, the following areas of investment in support of innovation are relevant: the state support programme "Affordable loans 5-7-9%"; the programme "Ukraine: Sustainable Innovations in the Bioenergy Value Chain"; and the pilot project to provide financial support to start-ups in Ukraine, including in the field of information technology, on a competitive basis. In turn, the implementation of the "affordable loans 5-7-9%" programme aims to: develop entrepreneurship by increasing the production of innovative products, as well as introducing innovations to create new jobs at existing enterprises; implement measures to localise epidemics and prevent their spread (in particular, COVID-19 caused by the SARS-CoV-2 coronavirus); refinance debts in Ukrainian banking structures on loans to business entities. The state support programme "Ukraine: Sustainable Bioenergy Value Chain Innovations" is funded by the European Bank for Reconstruction and Development and the Global Environment Facility. The project aims to attract investments in the development of innovative bioenergy technologies, as well as innovative projects aimed at using agricultural residues to create bioenergy value chains.

A pilot project to provide financial support to start-ups in Ukraine, including those in the information technology sector, on a competitive basis, involves holding competitions for start-ups at the initial stages of obtaining financial support, with further monitoring of the effectiveness of the investment funds provided (Ministry of Economy of Ukraine, 2023). During the introduction of martial law in the country, investment activities aimed at developing innovative products and technologies in various spheres of economic life are associated with significant risks and are significantly complicated. However, even in such conditions, attracting investment from the state in the development of innovative products and technologies is extremely important in terms of stimulating the activities of manufacturing enterprises and creating a healthy competitive environment (Mykhailyk & Birak, 2023). Figure 2 shows a flowchart that reflects the relationship between the key areas of public investment in innovation during the introduction of martial law in Ukraine. This flowchart shows the main trends in the mutual influence and interconnection of these investment areas, which was used to assess the prospects of innovation markets in Ukraine in various fields.

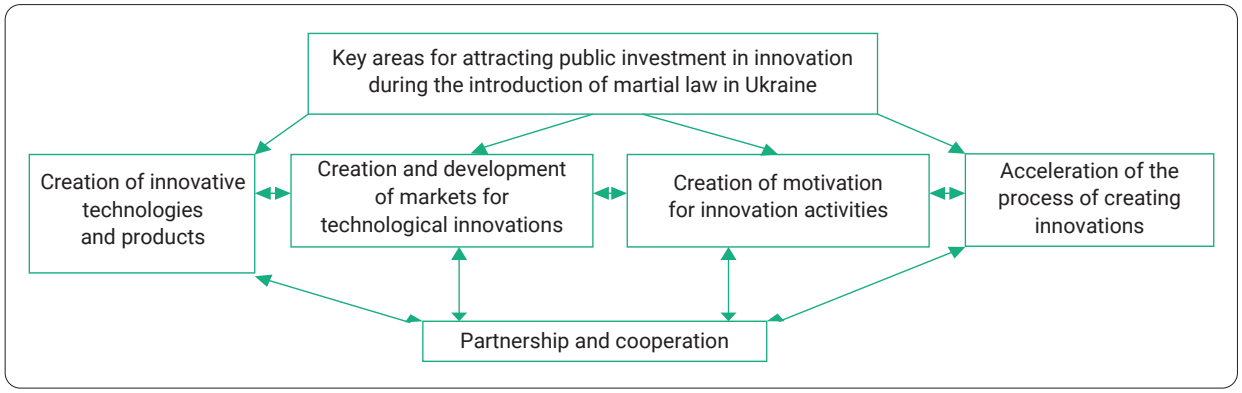

Figure 2. Key areas of public investment in innovation during the introduction of martial law in Ukraine
Source: O.M. Mykhailyk & Y.V. Birak (2023)

The interconnection between the key areas of investment by the state in the development of innovations is determined by the following factors. The creation of new technologies and products implies the need for innovative means of production, services or technological solutions that can be used during the war or sold profitably after its end. For instance, this could be the production of food products, innovative medical equipment, or innovative developments in the field of military protection.

The creation of markets for technological innovations and their further development is driven by a sharp decline in demand for the main products of manufacturing companies, due to political and economic instability in the country, as well as the resulting lack of funds to purchase goods from potential consumers. These factors are prompting companies to actively seek opportunities to export products to other markets or adjust current orders to compensate for the fall in demand for their products.

The imposition of martial law in the country as a result of Russian aggression has caused a significant reduction in the volume of investments in the development of enterprises located in the combat zone, or even the termination of the existence of these enterprises. This is determined by the uncertainty of the fate of these enterprises, as well as the inability to predict the development of events and the state of the markets for their products in the medium and long term. In addition, during the martial law period, the costs of ensuring the security of their property and individual employees increase significantly. This may be reflected in investments in the development of security systems, as well as the purchase of security equipment and the creation of security units.

The introduction of martial law significantly reduces the amount of public funds that can be allocated for the development of innovative projects in any area. The possibilities of obtaining investment funds by other means, including through lending or other financial sources are also significantly deteriorating. Financial institutions are aware of the high risk of such transactions, and therefore mostly refuse to provide investment funds to enterprises.

The imposition of martial law also caused a drop-in investment activity of many companies due to a significant increase in business risks caused by the hostilities, as well as resource constraints and lack of motivation to develop in the current situation. Since the start of the full-scale invasion of Ukraine, a significant number of investment projects in various industries have been closed or frozen. This applies even to the information technology sector, which was highly developed in the country in the pre-war period (Khoma & Vorobiy, 2023).

This is especially relevant for start-ups, as most innovative projects were launched or planned before the war. In Ukraine, the main obstacle to their development was the almost complete absence of customers who formed the demand for the final product, so the creation of startups in Ukraine is aimed at finding customers from foreign markets (United States, Europe, Asia, etc.), which greatly simplifies the process of obtaining investment funds and bringing certain tasks and programmes to mass production (Kroitor, 2023). To address this situation, in 2018, Ukraine created the Ukrainian Startup Fund (2022), which aimed to attract investor funds and then invest them in innovative projects. After the introduction of martial law, a significant number of start-ups, as well as their founders, went to defend the country as part of the military forces, territorial defence units and the information technology army of Ukraine, so the Fund is unable to provide the full, necessary funding for the development of innovations.

The outbreak of hostilities in Ukraine has caused significant damage to many of the country's infrastructure facilities. According to information received from the Ministry of Environmental Protection and Natural Resources, there have been large-scale attacks on critical infrastructure in the country since the introduction of martial law. A solar power plant was destroyed in Merefa, Kharkiv region, and one of Europe's largest salt deposits in Soledar, Donetsk region, was almost destroyed by a massive missile strike. In 2022 alone, more than 100 medium and large enterprises were destroyed in six regions of Ukraine: Kyiv (17% of infrastructure damage), Donetsk (17%), Zaporizhzhia (14%), Kharkiv (13%), Luhansk (10%), and Mykolaiv (8%) (Hryhorian, 2023). By the end of 2022, the total amount of

damage from these losses is estimated at around USD 140 billion. The consequences of environmental pollution after this destruction will be evident for years. Figure 3 shows a comparative analysis of the damage to the largest enterprises in the Kharkiv region in terms of assets in 2022 as a result of hostilities in the region.

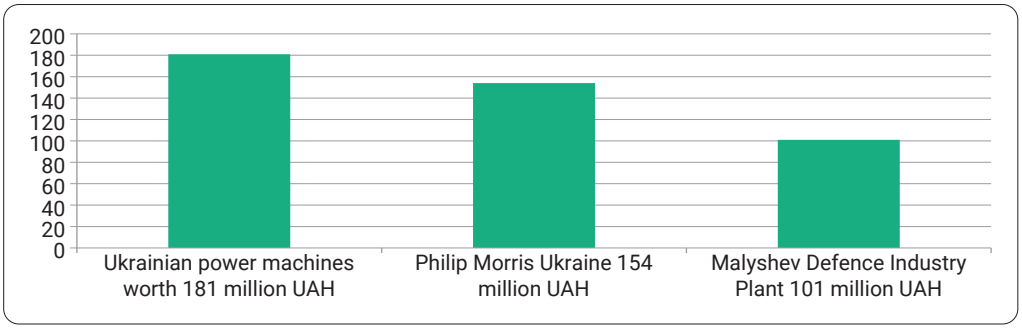

Figure 3. Damage to the largest enterprises in the Kharkiv region in terms of assets in 2022 as a result of hostilities in the region

Source: O. Hryhorian (2023)

According to the data presented in Figure 3, in 2022, losses due to hostilities among the largest enterprises in the Kharkiv region in terms of assets were as follows: Ukrainian Power Machines – UAH 181 million, Philip Morris Ukraine – UAH 154 million, Malyshev Defence Industry Plant – UAH 101 million. In the current situation in this region, public investment funds are directed primarily at restoring the losses incurred by enterprises during the hostilities and the introduction of martial law in the country, rather than at developing innovative projects in various fields. Public investment in innovation can only be directed after the infrastructure of enterprises has been restored, and wether it is possible to implement investment projects of this kind. Following the Decree of the President of Ukraine dated 21 April 2022 No. 266/2022, the National Council for Post-War Reconstruction of Ukraine developed a series of measures within 24 working groups to restore and develop Ukraine after the end of hostilities and the lifting of martial law in the country. In the context of the implementation of this initiative, a list of proposals for priority reforms and strategic measures, and draft legislative acts was created, the adoption and further, systematic implementation of which is necessary to improve the effectiveness of work on the restoration of Ukraine during the war period, as well as after the end of active hostilities and the lifting of martial law (Hryhorian, 2023).

The commercial structures that comprise the various potential investors almost always lack the financial capacity and regulatory framework for collecting and processing information that is typical for public institutions (Kraus *et al.*, 2023). Therefore, regional investment market players have significantly fewer sources of information: official web portals and Internet resources directly owned by state and regional government agencies; scientific publications; information from trade or any other commercial publications; reference materials; media advertising; information obtained from firms and business circles that perform market research and sell the information obtained; presentation events: exhibitions, open days; credit or investment ratings of individual regions; private meetings, as well as networking and communication between employees of enterprises. The underlines the higher efficiency and expediency of attracting public investment in the development of innovative areas compared to investments received from other investors.

Attracting public investment funds to develop innovations always involves several stages. Firstly, preliminary monitoring of potential projects that could be relevant in terms of their development is conducted to further implementation of investment solutions. Secondly, those projects are selected for which certain tax benefits can be determined in the future during their further implementation (Davies, 2005). Such a scheme of interaction between the state, which allocates funds for the implementation of innovations, and the final executors excludes possible mistakes in the use of investment funds and make the process of innovation implementation as safe as possible. However, during martial law, the situation changes dramatically, as it becomes completely impossible to guarantee certain tax vigilance from the state during the implementation of innovative projects. Moreover, the source of funding may be extremely limited due to the combination of factors identified above.

Since the outbreak of hostilities in Ukraine, the volume of investment funds has significantly decreased, even between countries of geopolitically distant blocs, which indicates difficulties with the implementation of any economic projects during the war and the declaration of martial law. In the current situation, the implementation of innovations is impossible, as the persistence of geopolitical tensions and the tightening of trade restrictions during the war prevent the quality implementation of investment projects. At the same time, amid the many challenges posed by Russia's ongoing full-scale invasion, there are still opportunities to attract investment in many areas of the national economic and

social life. Ukraine has a large consumer market, a highly educated and competitive labour force, and even rich natural resources (Ivanov *et al*., 2020). The Ukrainian government continues to create appropriate legislation and regulations to capitalise on this potential through numerous completed or ongoing governance and economic reforms designed to bring Ukraine into line with current European Community standards and improve the business climate (U.S. Department of State, 2024). During the martial law period (2022-2025), there is every reason to expect that hundreds of billions of dollars of investment funds from governments, international financial institutions and the private sector will be attracted during Ukraine's post-war recovery, creating a wealth of investment opportunities.

For example, this concerns the attraction of public investment in the creation and advancement of innovations within the energy sector. Since mid-2021, global energy prices have been consistently rising, as the post-pandemic recovery has led to heightened tensions in the energy market. These trends were especially evident in Europe, where Russia's invasion of Ukraine exerted extraordinary pressure on the region's energy market: between 23 February 2022, the day before the invasion, and 31 July of the same year, European wholesale prices for gas and electricity surged by 115% and 237%, respectively (Ferriani & Gazzani, 2023). Therefore, potential investments in the development of alternative energy sources are of great promise, as they create the prospect of obtaining the necessary amount of cheap energy in a situation where there is a steady upward trend in the price of electricity produced by conventional means.

At the same time, global practice demonstrated that with the outbreak of war in Ukraine on 24 February 2024, uncertainty and turmoil in world markets were observed (Patel *et al*., 2023). As a result, there has been a significant reduction in potential investment opportunities in various areas, both for private investors and for the prospects of attracting public investment in the development of various sectors. This applies to investments in the development of environmental innovations and green technologies, such as solar energy, the use of alternative sources of electricity, environmentally friendly methods of waste disposal, etc. In addition, the situation is complicated by significant uncertainty in global financial markets, as well as growing concerns about its potential consequences for the global economy and financial systems (Zeinedini *et al*., 2024). The ongoing war has brought about not only immediate economic repercussions for Ukraine, including the imposition of martial law and various adverse effects of the conflict. Overall, the situation has led to a sharp rise in the volatility of energy and agricultural commodity prices, as well as instability in global financial markets. The crisis has highlighted the fragility of international supply chains, especially in the energy and food industries, resulting in inflationary pressures and growing economic uncertainty across numerous regions.

The war in Ukraine has greatly intensified economic risks throughout Europe. Among the numerous consequences of this development was the collapse of Silicon Valley Bank in March 2023 – the second largest bank failure in U.S. history – followed by the downfall of Silvergate and Signature Banks, mounting credit risks, and the bankruptcy of Credit Suisse. This chain of events has fuelled rising commodity prices and heightened uncertainty in global economic markets. Furthermore, the conflict altered the relationship between idiosyncratic volatility and market portfolio volatility even prior to the outbreak of hostilities (Saliman & Le Squot, 2024). The war's impact on the global economy, including the EU, has been substantial. Before the onset of hostilities and the imposition of martial law, Ukraine was the EU's third-largest supplier of agricultural and food products, while Russia accounted for nearly 45% of the gas market by the end of 2021 (Semenenko *et al*., 2021). Geopolitical instability triggered declines in stock markets, a trend that persisted across all major global financial centres until September 2022. At the same time, the conflict poses a threat to global food security due to reduced export capacity from Ukraine, labour shortages, and limited access to fertilisers (Wang *et al*., 2023). The situation can only improve significantly after the end of hostilities and the lifting of martial law when the economy in Ukraine and the EU stabilises and there are opportunities to attract public investment in the development of innovative projects.

To attract public investment in the development of innovative projects, it is necessary to establish a special stabilisation fund in Ukraine after the war to stimulate investment in the development of innovative projects and investment support for start-ups. This will stabilise the state investment policy in the field of innovation support and systemise the distribution of investment funds for their efficient use.

Discussion

The research demonstrated that the introduction of martial law substantially decreased the prospects for attracting public investment in the development of innovation. T.P. Wisniewski & S.K. Pathan (2024) analysed the impact of changes in the external political environment, which leads to the introduction of martial law in a country, on the ability to attract investment in the development of innovations. According to the researchers, it is impossible to attract long-term investment in the country's economy after the declaration of martial law, as there are no guarantees of return on investors' funds. In addition, it is impossible to attract public investment in the field of innovation, as there are no prerequisites for the implementation of innovative projects in such conditions. The opinion of the researchers fully correlates with the results of the current study, as during the introduction of martial law due to hostilities, the risks of loss of funds by potential investors increase, and the possibility of receiving investment funds from the state decreases while the state budget expenditures on defence of the country increase.

A. Nowinska & T.R. Olesen (2024) concluded from the Russian Ukrainian war in the context of the dynamics of

interstate military confrontation and its impact on attracting investment in economic development. According to the researchers, wars between individual states should be regarded as much more dynamic and destructive to institutional conditions compared to all types of conflicts directly related to the use of violence. The introduction of martial law in a country as a result of the war significantly limits the ability of the state to attract investment in any economic sphere, and for a certain period makes it impossible to fully develop the country's economy (Meleshchenko, 2024). The conclusions of the authors coincide with the results of the presented scientific research, since during the introduction of martial law in a country, full economic development is impossible for a certain period since the volume of public expenditures by expenditure items undergoes significant changes during the introduction of martial law.

A similar topic was addressed by T.T. Luu & D.P. Pham (2024) in a study of the impact of American military aggression on the decline in investment activity in the Vietnamese economy in 1960-1975. According to the researchers, this war significantly changed the economic landscape of Vietnam, as large-scale bombing caused huge damage to the country's infrastructure, transport, and industry, making it impossible for the national economy to develop for a long time by attracting foreign and public investment. This does not coincide with the results of the current study, as the restoration of Vietnam's infrastructure after the war was achieved precisely by attracting foreign investment aimed at ensuring the country's further economic development, although during the fighting and the introduction of martial law in the country, all this was completely impossible. In addition, in Ukraine, during the introduction of martial law, there has been a steady decline in public investment in innovation, which makes it impossible to develop innovation until the end of hostilities.

X. Cai *et al*. (2024) addressed the probability of geopolitical risks affecting the probability of martial law in a particular country and the associated drop-in investment activity at the state level. The researchers noted that geopolitical risk has a significant economic impact on government and corporate actions, contributing to a sharp drop-in investment activity in many economic sectors. In addition, the escalation of such risks mostly has a negative impact on the country's overall investment potential in the long run. The conclusions of the scientists fully coincide with the results obtained in the presented study, because the potential of any country in terms of attracting public investment in development directly depends on the presence and level of geopolitical risks associated with the possibility of escalation of the war and the introduction of martial law in the country, which affects the ability to raise funds from the state budget for the development of innovative projects. C.V. Nguyen *et al*. (2024), in their research on the long-term impacts of war on foreign direct investment and economic growth, emphasised that the outcomes of war are devastating – including the destruction of physical infrastructure, environmental harm, the erosion of economic and political institutions, and loss of human life. According to the authors, the forced introduction of martial law in the country as a result of the outbreak of war can be explained by the presence of significant dangers to activities in various spheres of society and the economy, including. This greatly complicates the implementation of state investments in economic development and innovation. The study results could be expanded based on the findings of the current study, as military bonds backed by developments in the field of military innovation can still be profitable for some time after the introduction of martial law in the country and the impossibility of receiving investment funds from the state.

Researchers M. Ahad *et al*. (2024) examined various aspects concerning the establishment of a secure economic environment between European environmental, social, and governance initiatives and the energy sector amid the Russian-Ukrainian war. Their study pointed out that with the imposition of martial law in Ukraine due to Russian aggression, the supply of Russian gas across the country declined significantly, eventually coming to a complete halt. As a result, the possibility of implementing innovative projects in the economy was practically minimised by the introduction of state investments, which, according to the researchers, is a prominent example of the negative impact of martial law on the development of investment processes. The conclusions correlate with the current study in the context of assessing the impact of martial law on the prospects for investment development in Ukraine, but they could be expanded, as the termination of gas supplies through the territory of Ukraine also negatively affected the prospects for innovative development of the economies of many European countries, which is essential in the absence of funds in the state budget of the country necessary for the development of innovations. J. Bijannska & N. Wodarski (2024) conducted a joint study of a wide range of issues related to the impact on the investment climate in the field of hard coal mining due to the introduction of martial law in Ukraine. The authors highlighted that after the introduction of martial law, the country stopped implementing innovative methods of switching from coal to renewable energy sources. In their view, this is an indication of the negative impact of martial law on the prospects of attracting investment in innovative projects directly from the state, especially in the context of the use of hard coal as a raw material in the energy sector of Ukraine has significantly decreased since its introduction. The opinion expressed by the researchers is consistent with the results obtained in the study, since public investment in the development of any economic programmes during martial law is quite problematic because there is a risk of losing these funds, and their amount is generally limited, especially in the context of the growing budget deficit in the context of martial law.

At the same time, the study by S. Kumar *et al*. (2023) addressed several problematic issues of finding the

necessary balance between existing approaches to creating investment strategies for the distribution of commodity prices during the Russian Ukrainian war. According to the researchers, economic and political unrest has a complex impact on the economies of all countries of the world, mostly complicating or making it impossible to fully develop any economic sphere. This applies to the opportunities to attract investment in the development of innovative areas that contribute to the development of the country's economy and the creation of favourable conditions for the interaction of various business structures. The conclusions of scientists should be supplemented since not all unrest in politics and the economy leads to the introduction of martial law in the country, so the interaction of business structures in the country may be possible under any circumstances, another thing is that its effectiveness may differ significantly when there is a possibility of attracting investment funds from the state, or when there is no such possibility in a situation where significant amounts of state budget funds are directed to the national defence.

F. Gursoy (2012) addressed a wide range of issues related to changes in the investment climate in the country during the introduction of martial law and after the war was over. The researcher highlighted that political instability is a substantial problem for attracting investment in any country. The imposition of martial law as a result of external aggression causes a situation that makes it impossible to fully develop the country's economy, hinders the processes of borrowing foreign investment in the economy and the growth of investment attractiveness of individual enterprises and certain economic sectors in general (Ilychok *et al.*, 2024). The author's conclusions are fully consistent with the results obtained in the study, since during martial law and hostilities, potential investors will not invest in projects that involve huge risks of losing their investments, and the national budget does not have sufficient funds to finance innovations.

Thus, the discussion of the results of this research, in the context of their comparison with the results of the research of other scientists who have studied the problems of the impact of martial law on the prospects for attracting investment in the development of innovations, showed their correspondence in key points. In particular, the positions of the studies coincide regarding the impossibility of fully investing in innovative projects during hostilities in the country and the high probability of losing the invested funds. In addition, a comparison of the results of the studies confirms the fact that during military operations in the country, a significant part of the state budget is allocated to defence, which forces a temporary suspension of innovation funding until martial law is lifted.

Conclusions

The study determined that the introduction of martial law in the country has a negative impact on the prospects of receiving investment from the state by any entity developing innovative projects. The current situation is explained by the presence of significant risks of losing investment funds as a result of hostilities in the country, as well as economic instability, accompanied by the destruction of infrastructure and the inability to implement investment projects in full.

In Ukraine, legislation provides for the possibility of receiving investment funds from the state for the development and implementation of innovative projects in various fields. The sequence of financing investment projects in the field of innovation is established by the European Bank for Reconstruction and Development recommendations and has been successfully tested in several European countries, including Ukraine. However, the introduction of martial law in the country saw a significant increase in defence spending (from 8.6% in 2021 to 66.1% in 2025) amid a persistent state budget deficit before and during the war. This negatively contributes to the prospects for public investment in innovation during martial law and largely prevents investment development of the economy.

Since the introduction of martial law in Ukraine, the most promising areas for investment by the state have been the agricultural sector and construction. In the first case, this is attributable to the impossibility of destroying land as such as a result of hostilities or during the post-war restoration of territories. The prospects of investing in construction are explained by the mandatory return of demand for real estate after the end of hostilities and the lifting of martial law, as well as the need to restore the country's destroyed infrastructure. However, as for the prospects for investment in the development of innovative projects by the state, they will be extremely low until the martial law is lifted. This is attributed to many factors, including the lack of qualified personnel required to implement innovative projects, The situation can only improve dramatically after the end of hostilities, which will facilitate the lifting of martial law and the launch of the process of restoring the country's infrastructure. The experience of other countries (Israel, South Korea) shows that in this case, there will be a wide range of opportunities to receive investments in the development of innovative projects aimed at creating conditions for the revival of the country's economic potential, provided there is no risk of losing investment funds.

Prospects for further research in the area determined by the subject matter of the presented work are predetermined by the need to find effective means of implementing innovative projects in difficult conditions caused by the introduction of martial law in the country, as well as the allocation of funds for these projects by the State.

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Conflict of Interest

None.

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Вплив воєнного стану на державні інвестиції в інновації

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Анотація. Метою дослідження було вивчення ступеня впливу воєнного стану на інвестиційну активність у сфері розвитку інноваційних проектів. Методологічний підхід базувався на аналізі, синтезі та узагальненні. У результаті дослідження встановлено значний негативний вплив введення воєнного стану в Україні на процеси залучення інвестицій з боку держави в різні інноваційні сфери. За результатами дослідження визначено, що найбільш перспективними сферами інвестування під час запровадження воєнного стану в країні є аграрний сектор та будівництво. Найменш перспективними сферами діяльності для потенційних інвесторів є галузь інформаційних технологій, а також тепло- та електропостачання. Крім того, державні облігації є одним з найпоширеніших напрямків інвестування фондів. До облігації внутрішніх державних позик у воєнний час слід ставитися досить надійно, оскільки їх дохідність гарантується безпосередньо державою. Після запровадження воєнного стану в Україні широкої популярності набули військові облігації. Дослідження визначило, що дохідність за такими цінними паперами може сягати 18,5 % річних. У дослідженні відзначено суттєве зростання видатків державного бюджету (з 1,490,258,9 млн грн у 2021 році до 4,486,682,7 млн грн у 2024 році) зі збільшенням видатків на оборону (з 8,6 % у 2021 році до 66,1 % у 2025 році). Все це відбувається в умовах зростання дефіциту державного бюджету в період воєнного стану. Водночас в Україні спостерігається різке скорочення інвестицій в інноваційну сферу через значне зростання ризиків втрати коштів потенційних інвесторів внаслідок неможливості реалізації інвестиційних проектів під час воєнних дій та призупинення або повної зупинки діяльності бізнес-структур, які мали змогу повноцінно реалізовувати ці проекти до війни. Визначено фактори, які вплинули на можливість залучення державних інвестицій в інноваційну сферу державою під час війни для пошуку шляхів ефективної реалізації заходів інноваційного розвитку після завершення бойових дій

Ключові слова: перспективи розвитку; фінансові запозичення; ефективні рішення; зовнішня агресія; економічна нестабільність; інновації

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Economic impact of sports sponsorship models on the development of the sports industry: Albanian experience

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Abstract. The research relevance of sports sponsorship in the Albanian context is determined by the lack of case studies, especially on the economic impact of sponsorship models. The study aimed to analyse the impact of sponsorship models on the development of the sports industry in Albania. Scientific analysis has confirmed that sponsorship models contribute to employment growth, expanding the national tourism opportunities and creating new economic incentives for sports. Sponsorship agreements facilitate the organisation of international sporting events, which increase tourist flows and strengthen regional economies. In addition, the study determined that effective management of sponsorship funds ensures sustainable funding for the development of youth sports and the modernisation of infrastructure facilities. Effective sponsorship models contribute to a positive international image of the country and long-term economic benefits for the sports industry. The development of sponsorship can increase the competitiveness of sports organisations by attracting more international partners. A comparative analysis of the US and German practices has identified key aspects that can be adapted to improve the effectiveness of sponsorship in Albania. The integration of private and public funding can reduce the burden on the state budget. However, legislative changes are needed to encourage private investors and ensure transparency of financial flows. The effective use of sponsorship agreements positively affects the development of sports culture and the involvement of young people in physical activity. The research has filled the identified gaps in the study of sports sponsorship in Albania, highlighting the need to develop strategies to further improve the mechanisms for attracting investment in the sports industry. The study combined the

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local context with global trends in sports sponsorship, which made it possible to identify the features of their interaction and adaptation under current conditions. The proposed recommendations aim to overcome systemic gaps in sports financing and create conditions for the sustainable development of sports infrastructure

Keywords: financing; government support; long-term projects; social impact; effective strategy

Introduction

Sports sponsorship is a mechanism of interaction between business and sports that provides financial, material and other support to sports organisations, events or athletes (Rahmani *et al*., 2024). Following C.-H. Hsiao *et al*. (2021), successful sponsorship is based on the use of experiential marketing elements that promote the creation of an emotional connection between the brand and consumers, which also increases the level of satisfaction with sponsorship and strengthens brand equity, which, in turn, has a positive impact on purchase intentions. However, the expansion of the impact of sports sponsorship goes beyond the usual marketing objectives. S. Chadwick *et al*. (2022) demonstrated that this form of cooperation contributes to strengthening the soft power of states through sports initiatives that improve the geopolitical image of countries. S. Chadwick *et al*. (2021) emphasised that the globalisation of sports leads to an increase in the influence of transnational corporations, and major sporting events become a platform for political dialogue while demonstrating dependence on economic and cultural conditions of international cooperation. In this context, sponsorship is not only a source of funding for sports but also an important tool for international interaction and cultural exchange, which is especially relevant for countries seeking to strengthen their presence on the global stage (Lazaj *et al*., 2024).

The relevance of sports sponsorship is evident in transition economies, where sports funding often depends on limited state budget resources. Albania, which is at the crossroads of economic transformation, is facing the need to diversify its funding sources to ensure the development of sports infrastructure and international competitions (Shahini, 2024). However, a lack of research in this area hinders the full use of the potential of sports sponsorship to address economic and social challenges. Another problem is that most of the available research focuses on the experience of developed countries, leaving aside the specifics of economies such as Albania.

Despite the existing challenges, sports sponsorship demonstrates significant potential to stimulate economic growth. According to S.M. Jadhav (2021), the development of the sports industry has a multiplier effect, promoting employment, expanding tourism opportunities and creating new sources of income. According to M. Morfoulaki *et al*. (2023) sports tourism also significantly boosts sustainable development, attracting investment in infrastructure and increasing the international attractiveness of countries. At the same time, the study by E. Zsigmond *et al*. (2020) emphasised the importance of effective management of sponsorship agreements to achieve both short-term and long-term benefits. In the context of Albania, all this experience can be used to optimise the attraction of foreign sponsors and strengthen the country's position in the sports arena.

The study aimed to analyse the role of sponsorship models in the development of the Albanian sports industry. In particular, the study aims to explore the potential of sports sponsorship as a tool for economic growth and international positioning. The uniqueness of the topic is determined by the need to incorporate both local and global trends, which defines the study as relevant not only for Albania but also for other countries with similar economic conditions. The objectives of the study are threefold: to analyse the main models of sponsorship; to identify the main barriers; and to determine the current state of sports sponsorship in Albania. In this context, special attention is paid to the analysis of international experience.

Materials and Methods

The materials used include scientific publications, analytical reports, statistics on the impact of sports sponsorship, as well as official documents regulating sports policy in Albania. Law of Albania No. 79/2017 "On Sport" (2020), data on the cooperation of the Football Federation of Albania with Macron (2022), a report on the financing of the Albanian Olympic Federations (2024), National Collegiate Athletic Association (n.d.) information on the financing of student sports in the United States, etc. were analysed. Statistical metrics of sports funding covering the period of recent years were also studied. The collected material provided an empirical basis for assessing the economic benefits and barriers to the implementation of sports sponsorship models.

To achieve the research objective, a systematic analysis was used to analyse sports sponsorship as a multi-component phenomenon, including the interaction between governmental, commercial and sports organisations. This method was used to structure the problem under study and highlight key aspects, such as financing mechanisms, strategic planning and possible economic consequences. System analysis was used to identify the dependence between different forms of sponsorship, their impact on sports infrastructure and socio-economic development of the country.

The comparative method was used to analyse sponsorship models in different countries to identify the advantages and disadvantages of each approach, which assessed the effectiveness of sponsorship agreements in the context of Albania in comparison to other countries (e.g., Germany or the United States), considering their financial capabilities, regulatory policies and the level of development of sports

infrastructure. The comparison identified best practices that can be adapted to the national context of Albania and identified unique challenges related to the national specifics.

The inductive approach was used to summarise the data obtained during the analysis of specific sponsorship deals, for example, the partnership between the Football Federation of Albania and Macron. The method identified general trends and patterns in the development of sports sponsorship based on specific cases. Based on these generalisations, recommendations for optimising the mechanisms of cooperation between sponsors and sports organisations were formulated. The deductive method was used to test the assumptions made in the study, in particular, the impact of sponsorship on the country's economy and the development of sports infrastructure. This method allowed for a logical transition from general theoretical concepts to their verification based on practical data.

The synthesis method combined the results obtained using other methods. The synthesis integrated data from different sources, creating a holistic picture of the impact of sports sponsorship on the economy and social sphere of Albania. The study analysed the rates of tax incentives for investors and determined their impact on the volume of sports sponsorship in Albania, Greece, Croatia and Hungary, comparing different models of sports sponsorship.

The chosen methodology ensured a comprehensive approach to the study of sports sponsorship. The use of various methods of cognition not only analysed the problem from different perspectives, but formulated recommendations for improving the efficiency of cooperation between sponsors and sports organisations. This approach contributed to the scientific novelty and practical significance of the results.

Results

Sports sponsorship is an important element of the modern sports industry, which has a significant impact on its development and stability. Sponsorship involves financial or other support of sports organisations, events or individual athletes by private companies, government agencies or other investors. At the same time, sponsorship agreements provide sponsors with benefits by increasing brand awareness, improving corporate image, and attracting new consumers (Phiri & Chakauya, 2023). Thus, sponsorship is a mechanism that reduces the financial burden on sports organisations and contributes to the overall and comprehensive development of sports infrastructure.

In general, for many countries, including Albania, sports sponsorship is an important factor in economic development. With limited national resources, where a large part of the funding for sports comes from the state budget, the need to attract additional investment is becoming increasingly apparent. Albania, with its limited infrastructure and financial capacity, cannot rely solely on traditional sources of funding to support the sports industry. At the same time, sponsorship agreements, which include both public and private components, can provide the necessary funding for the development of sports infrastructure, organisation of international competitions and training of athletes (Schönberner & Woratschek, 2023).

First and foremost, sponsorship is important for Albania due to the need to modernise its sports infrastructure, many of which need renovation and improvement. To successfully host international competitions and attract attention to sports at the national level, the country must create competitive conditions for attracting investment. Sponsorship can not only cover the costs of organising events but also stimulate the development of the tourism industry, which is important for an emerging economy where tourism is one of the main sources of income.

The study proved that the development of the sports industry has a positive impact on the economic growth of countries (Ziming, 2021; Mirzaie *et al.*, 2022). In this context, it is necessary to find effective and efficient ways to develop the industry, such as sponsorship. Attracting investments in the sports industry contributes to the development of sports infrastructure, the creation of new jobs and the increase in employment. Therefore, sponsorship has a direct impact on the economy, as it increases spending on sports services and products, and stimulates the development of related industries such as advertising, media and transport.

Sports sponsorship encompasses various forms of cooperation, including corporate sponsorship, government support and private investment (financial, in-kind sponsorship), as well as a combination of the latter (Walraven *et al.*, 2012; Jedel, 2019). Corporate sponsors typically invest in popular sports (defined by the number of participants, media coverage, and social impact), providing funding for competitions, team support, or the development of sports facilities. Public support is often provided through subsidies, infrastructure development programmes and initiatives aimed at promoting sports among the population. Private investors, in particular local businesses, are becoming particularly important in countries with limited financial resources, where the involvement of sponsors can help develop new sports projects. Thus, sports sponsorship is a multifaceted phenomenon that includes various models of cooperation between sponsors and sports organisations. They can vary depending on the source of funding and the terms of cooperation, which determine the economic and social impact on sport and its participants. Each model has unique features and functionalities that determine the effectiveness of sponsorship in a particular context.

Corporate sponsorship is one of the models of direct financial support for sports events, teams or infrastructure. It is funding that is provided by large companies or brands that want to associate their products with the successes and positive emotions that sport generates. Corporate sponsors benefit not only from increased brand awareness but also by attracting new consumers, as sporting events provide access to a large audience. Sponsorship can include funding specific events, teams, individual athletes or even entire sports programmes, thus contributing to the sustainability and development of sports infrastructure.

In addition, an example of corporate sponsorship, called In-Kind Sponsorship, is the partnership between the Football Federation of Albania and the Italian sportswear company Macron (2022). The agreement on technical sponsorship, signed in 2016 during the participation of the Albanian national team in the final round of the European Championship, was an important stage in the development of Albanian football. In 2023, Macron and the Football Federation of Albania announced the extension of their cooperation until 2027. This agreement includes not only the supply of equipment for the men's and women's national teams but also the provision of technical sportswear for youth teams and football academies operating under the auspices of the Federation.

Macron's chief executive officer, D. Pavanello, noted that the renewal of the partnership with the Football Federation of Albania is a confirmation of a shared vision and a long-term project for the Albanian national team. The relationship between the company and the federation is based on friendship, mutual respect and common sporting values. Notably, the Albanian national team became the first national team to use Macron products. Therefore, the cooperation between the parties is based on personal friendships, which, according to Football Federation of Albania President A. Duka, not only provides material support but also contributes to the development of common sports traditions. The history of their cooperation began in 2015 and has become a success story, as Albania participated in Euro 2016 and achieved positive results. Macron is one of the most important partners of the Football Federation of Albania, and the new contract provides for the launch of a project that will help strengthen the social component of sport.

The extension of the agreement also includes a unique social initiative called "My Uniform", which provides free sportswear to every athlete playing football in Albania. This project is aimed at stimulating the development of children's and youth football and promoting sports among young people. Under the new terms, Macron will continue to develop specialised uniforms that reflect the identity of Albanian football, which helps to strengthen the brand of both the team and the Federation in the international sports environment. Thus, the partnership between the Football Federation of Albania and Macron has not only provided for the development of football infrastructure and technical support for the teams but has also created a positive social impact, which is an important factor for countries with limited resources. This example illustrates how corporate sponsorship can play a significant role in the development of sport and the formation of a national sporting identity.

An international example of corporate sports sponsorship is Coca-Cola. Coca-Cola, one of the world's largest soft drink giants, has a long history of partnership with the Olympic Games, dating back to 1928. This cooperation, which has lasted for over 90 years, makes Coca-Cola the oldest corporate sponsor of the Olympic Games. Through this partnership, the company has become an important participant in the Olympic Partner programme and will continue to participate in this initiative until 2032. The new sponsorship contract, which also includes the Chinese company Mengniu Dairy, is estimated to be worth USD 3 billion. Distribution innovation is also an important part of Coca-Cola's strategy for the Paris Olympics. The company is introducing a "revamped distribution model" that includes the use of beverage fountains and reusable glass bottles, as directed by the Paris 2024 Organising Committee. Where water fountains are not available, drinks are served in recycled plastic bottles. This demonstrates the company's commitment to reducing its environmental footprint in response to global sustainability challenges. In addition, as part of the 2024 Olympic Games in Paris, Coca-Cola offered fans a range of beverages, including water, tea, coffee, juice and carbonated drinks, while reducing added sugar in its products, which correlates with global recommendations to limit added sugar to 10% of daily calories (Buse *et al.*, 2024).

Coca-Cola's involvement in the Olympic Movement has not only a marketing but also a social impact. The company provides funding for many teams and athletes, enabling them to train, prepare and compete (Rogers, 2024). As the company's representative noted in an interview with MarketWatch, this funding is "essential support", which contributes to the development of sports at the international level.

Moreover, one of the most common forms of corporate sponsorship in sports is title sponsorship, which involves a company providing financial support in exchange for the right to include its name in the name of a sports event, league or team. An example of such a model is the agreement between the Albanian Internet company Abissnet and the Football Federation of Albania, which resulted in the top division of the country's championship being named Abissnet Superiore for three seasons (2021-2024) (The Superior Category…, 2021). Such a partnership not only helps to attract additional financial resources for the development of national football but also increases the sponsor's brand awareness among a wide audience of fans. The use of such a financing mechanism allows sports organisations to compensate for the costs of holding competitions, developing programmes and upgrading infrastructure, which is an important factor in strengthening the position of national championships in the European sports space.

Official sponsorship is another form of corporate support that provides funding for national teams and promotes their competitiveness in the international arena. In this context, the partnership between Vodafone Albania and the Football Federation of Albania is worth considering (Vodafone Albania becomes…, 2019). As part of this agreement, Vodafone Albania became the official sponsor of the national team, which allowed the team to provide the necessary financial resources for training, participation in competitions and development of youth programmes. Such sponsorship contracts are particularly important for countries where state funding for sports is limited, as they guarantee stability and contribute to the long-term development of the football system. At the same time, for the

sponsoring company, this partnership is an effective marketing tool that strengthens its presence in the market and increases brand awareness among fans.

The next model of sponsorship is Public Partnerships, which requires the involvement of government authorities, often providing financial resources for the development of sports infrastructure, organisation of international competitions or support for national teams. It can be implemented through various programmes and subsidies designed to make sport accessible to the general population. An important feature is that public funding is often directed to long-term projects that ensure the sustainable development of sports infrastructure and increase the level of physical activity among the population. However, public sponsorship can also be affected by political factors, budgetary constraints, and changes in political priorities (Lechner & Solberg, 2021).

For instance, government sponsorship in the sports sector through the system of student scholarships in the United States is an important strategic tool for developing sports and supporting talented young athletes. This system combines educational opportunities and sports achievements, providing students with the opportunity to pursue higher education at universities while developing a career in sports. The importance of this form of state sponsorship lies in the fact that it not only allows for funding of athletes but also contributes to the development of sports culture in the country. In general, the US sports scholarship system for students is one of the most developed in the world, and its impact on the country's sports landscape is enormous. It is partially funded by government agencies through higher education programmes, through government grants to universities and sports associations.

The main state actor in supporting this programme is the US National Collegiate Athletic Association (n.d.), which is responsible for managing sports competitions among students. National Collegiate Athletic Association scholarships are provided through universities and colleges. Student-athletes receive first-class academic support, quality medical care, and regular access to outstanding coaching staff and facilities. All these scholarships are partially funded by the state through the system of subsidies for higher education institutions. For decades, American universities have received significant amounts of public funding for the development of student sports. For instance, National Collegiate Athletic Association Division I and II schools provide nearly USD 4 billion in athletics scholarships annually to more than 196,000 student-athletes. Division I schools can award multi-year scholarships to student-athletes. In addition, Division I schools may pay for student-athletes to pursue bachelor's or master's degrees after they retire from National Collegiate Athletic Association sports.

According to Albanian legislation, the financing of sports in the country is carried out through various sources, including the state budget, local authorities, sports organisations and international sports federations. Law of Albania No. 79/2017 "On Sport" (2020) defines the procedure for financing sports structures and organisations related to Olympic and non-Olympic sports. Article 13 of the law stipulates that the main sports organisations, such as sports federations, the National Olympic Committee of Albania and the National Anti-Doping Organisation, receive funding through transfers from the state budget. This funding may also include funds from other legal sources. The bodies responsible for funding are the ministries dealing with sports and finance. Funding for Olympic federations and the National Olympic Committee is determined by a joint order (instruction) of the Minister of Sport and the Minister of Finance, which ensures coordinated and systematic support for Olympic sports. Instead, non-Olympic federations are funded by the Ministry of Sport through transfers for proposed projects. The Ministry assesses the impact of these projects on the social, economic and environmental situation in the country, which ensures the effective use of state budget funds to develop sports infrastructure and support sports initiatives. The Ministry also controls and allocates the transfer expenditures.

Articles 19 and 20 provide for the possibility of receiving funding from central or local authorities for sports associations and sports companies through transfers and other sources, which allows for a diversity of funding at all levels of the sports infrastructure, including local authorities, which can contribute to the development of sports in their territory by providing financial support to sports clubs and societies. The general mechanism of financing sports in Albania includes not only direct subsidies from the state budget but also fundraising through the following sources, donations, sponsorship, television rights and advertising. For instance, matches of the Albanian football league are broadcast on local TV channels, which generates advertising revenue and increases the popularity of the sport among viewers. These additional sources increase funding and create conditions for the development of sports projects and events.

Article 39 of the law states that the funds allocated for sports from the state budget are determined in the annual budget of the country, which ensures long-term stable funding and planning of important sports events, national and international competitions, as well as support for sports clubs, organisations and teams throughout the country. Sport funding in Albania allows for the support of the sports sector at various levels, from Olympic federations to local sports clubs and associations. This approach also contributes to the development of sports among young people, raising sports culture and engaging more people in physical education and sports. The volumes of state funding for the industry should be based on official statistics of recent years. Thus, in 2021, the distribution of the Grand Fund for the Albanian Olympic Federations (2024) amounted to 138 million Albanian leks (USD 1.5 million). The funding for sports projects proposed by Albanian non-Olympic sports federations amounted to 13 million Albanian leks (USD 136 thousand). It is possible to conclude that the state primarily focuses on supporting Olympic sports, which are

widely known internationally and can provide the country with a high level of prestige on the world sports scene.

The total amount of public funding for sports is relatively small, which indicates that the country's budget for this sector is limited. By comparison, public spending on sports in developed countries is much higher. For example, the budget for financing the sector in Germany in 2024 was EUR 276 million, which is EUR 27 million less than the budget for 2023, but significantly higher than the budgets of Albania (Poschmann & Rieger, 2024). The EUR 27 million cut has caused concern among representatives of the German sports industry, including officials and politicians. Criticism of the budget cuts was also expressed by the leadership of the German Olympic Sports Union, by chief executive officer T. Burmester. As such, before the election, the government had promised to create better conditions for sports, for the development of high achievement. However, according to the chief executive officer, the funding was cut, which will make it much more difficult to achieve the goals. The reduction in funding has also raised questions about supporting sports projects at the regional and national levels, which are important for promoting sports among young people, developing infrastructure, and ensuring access to physical education. In this context, the need to find alternative sources of funding, including corporate sponsorship or expanding the role of local initiatives, is a pressing issue. At the same time, further discussions around budget cuts may stimulate a review of funding priorities and the introduction of new strategies to use available resources more efficiently.

When public funding is reduced or insufficient, private investments in sports (Joint Ventures) become relevant, as they are usually more localised and individual forms of funding. They can involve investors or small companies that contribute to the development of specific sports projects or events. Private investment is often directed at creating new sports facilities, organising local tournaments, or supporting talent that has not yet gained widespread popularity. While this model may be smaller in scale than corporate or government sponsorship, it is often highly flexible, allowing for a quicker response to changes in sporting needs or demand for specific sports.

One example of an effective private initiative is the Goga Basketball Academy (Albania), which demonstrates how private sector investment can change the sports landscape (Ponari, 2018). The club has invested in sports infrastructure, demonstrating how private resources can significantly contribute to improving the quality of sport. Such initiatives also underline the importance of government support, which should create a favourable environment for attracting such investments.

Despite ongoing efforts, the legal framework is not yet fully adapted to the needs of investors, which hinders the potential of private initiatives. To achieve harmony between the public and private sectors, it is necessary to create mechanisms that encourage entrepreneurs to invest in sports and ensure fair tax regulation. Currently, one of the main problems is the limited tax benefits for investors: according to the current legislation, the amount of pre-tax profit can be reduced by only 30% of the amount invested. This is much less than in many other countries (50% deductible in Croatia, 90% in Greece, 100% in Hungary, etc.), where tax deductions for sports sponsors are higher and more attractive to businesses. Increasing this percentage could stimulate a greater inflow of private capital into the sports industry. It is the private sector that can drive change if its efforts are complemented by a favourable legislative environment, including the expansion of tax incentives for companies and investors investing in sports.

It is also worth considering a combination of such forms of sponsorship as private and public, which create an additional public-private model of sports sponsorship (Public-Private Partnerships). Public-private partnerships in sports are an effective mechanism of interaction between government agencies, private companies and sports organisations aimed at ensuring the sustainable development of sports infrastructure and supporting professional and amateur sports. The model involves joint financing, management and operation of sports facilities, as well as coordination of investments to create favourable conditions for the development of the sports industry. In contrast to traditional public funding, public-private partnerships reduce the burden on the budget by attracting private sector funds, while ensuring more efficient use of resources through modern management practices and market mechanisms (Khodakovsky, 2023). The format of such cooperation can cover various aspects, including the construction and modernisation of sports facilities, financing of major international competitions, development of youth sports and ensuring the long-term operation of sports infrastructure facilities. The successful implementation of such projects requires a clear division of responsibilities between partners, including the definition of investment mechanisms, management principles, and guarantees of financial stability. At the same time, a significant advantage of this model is the ability to attract innovative tools and management approaches, as well as to encourage businesses to actively participate in the development of sports, while maintaining the social orientation of public policy in this area.

One of the most significant projects, which is an example of a successful combination of public and private investment to create a modern sports infrastructure that meets international standards and promotes the development of football in Albania, is the construction and operation of the Arena Kombëtare National Stadium (Air Albania) in Tirana (Goal article for…, 2022). The Arena Kombëtare project envisaged the construction of a modern football stadium on the site of the former Stadiumi Qemal Stafa stadium. Construction began in 2016 and was completed in 2019. The stadium has a capacity of 22,500 spectators and is the largest sports facility in Albania. The project was implemented through a public-private partnership, with the private company AlbStar Sh.P.K. responsible for most of the financing and construction, as well as for the management of the stadium after its opening. The state of

Albania, through the Football Federation of Albania and other state institutions, provided the necessary support and infrastructure for the project.

In summary, each of the sponsorship models has different advantages and limitations (Table 1). Corporate sponsorship provides stable funding and promotes sports to a wide audience, but it often comes with high demands on marketing strategies and the ability to create brand associations. Public support usually provides for longer-term and more comprehensive projects, but its effectiveness may depend on the availability of budgetary resources and political will. Private investment, on the other hand, often provides quick and specific funding but can have a limited impact on broader sports projects.

Table 1. Comparison of sports sponsorship models

Sponsorship model	Advantages	Disadvantages
Corporate sponsorship	Provides stable funding for sports events and infrastructure. Sponsors benefit from increased brand awareness and a wider audience. Can attract investors to the infrastructure by facilitating the development of new sports facilities	Sponsorships often depend on the commercial interests and marketing goals of the company, which can significantly limit flexibility. The high demands on advertising and marketing campaigns can place restrictions on sporting events. The interests of the sponsor may change, which can lead to sudden changes in funding or termination of cooperation
Government support	Provides stable and long-term funding for the development of sports infrastructure. Can be focused on long-term projects and the accessibility of sports for the general population. Supporting national teams and organising major international events helps to enhance the country's image	Political factors can significantly impact government funding priorities and the reliability of support. Lack of flexibility in decision-making and response to the needs of the sports industry
Private investment	Can quickly raise funds for specific sports projects or events. High flexibility in decision-making and quick response to changes in the sports environment. Private investors may be more interested in innovative and non-standard projects	Limited funding for larger and longer-term projects due to a lack of large-scale resources. Support is often limited to local or specific projects. Dependence on the interests of individual investors may lead to funding instability
Private investment	Combines stable funding from the state with the flexibility of the private sector, allowing additional resources to be raised for large and long-term projects. State and private support can contribute to the creation of new sports facilities, infrastructure development and enhancement of the country's image	Can be difficult to implement due to the need to reconcile the interests of the state and private investors. Dependence on external economic and political factors can lead to funding instability

Source: created by the authors

The impact of each of these models on the sports industry varies depending on the level of development of the country, the national economy and the priorities in sports policy. In countries with limited resources, such as Albania, each model can be used for different purposes: corporate sponsorship can increase the international visibility of the sport, government support can help develop basic infrastructure, and private investment can fill in the gaps by creating innovative and localised projects.

Furthermore, the effective use of sponsorship funds requires good governance and strategic planning. This includes transparency of financial flows, a clear definition of goals and priorities, and cooperation between public and private entities.

Discussion

The effectiveness of sponsorship models in the sports industry depends largely on their adaptation to the economic, social and cultural conditions of a particular country. Albania, as a country in transition, faces unique challenges, including limited public funding, insufficient infrastructure development and low levels of private capital. In this context, the study of sports sponsorship models not only assessed their direct economic impact but also identified potential opportunities to overcome systemic gaps. Therefore, it is necessary to define how specific sponsorship models can contribute to the sustainable development of the sports industry, expand employment and increase the country's tourist attractiveness. These issues are becoming important areas of research for many scholars.

At the same time, assessing the effectiveness of sponsorship strategies requires considering international experience, especially in terms of financial management, integration of public and private capital, and stimulating business participation in sports financing. An analysis of sponsorship cases from other countries shows that a combination of corporate sponsorship and government support can ensure the long-term financial stability of sports organisations and create additional incentives for infrastructure development. At the same time, innovative forms of private initiatives, which are increasingly being implemented in developed economies, can be adapted to the needs of emerging markets (Teymurova *et al.*, 2024).

An analysis of international research and sponsorship practices allows not only to assess the economic and social efficiency of different models, but also to identify barriers that may hinder their implementation in the Albanian context. For instance, the experience of countries such as

Germany and the United States highlights the importance of transparency of financial flows and proper regulation. At the same time, cases of private initiatives in the sports sector prove the effectiveness of a localised approach to investment, which provides a basis for further discussion on how the local context can influence the integration of international approaches.

Therefore, a comparison of the results of the study with international practices and scientific approaches assessed the key parameters of the effectiveness of sponsorship agreements, including their impact on economic development, social cohesion and improving the country's international image. In addition, the relevance of the study of sports sponsorship in the context of Albania is explained by the lack of comprehensive research that would cover the effectiveness of various models of cooperation between the government, business and sports organisations in the country. Addressing these features, the study of sports sponsorship in Albania not only assessed the economic benefits of such agreements but also identified the key problems and barriers that arise in the process of attracting investment in the sports sector.

M.K. Marwat *et al.* (2022) offered a comparative analysis of the economic effect of sports in developed and developing countries. The study emphasised that in countries with weak economies, sponsorship is becoming an important tool for improving sports infrastructure, attracting tourists and creating new jobs. This is consistent with the results of a study on the importance of attracting private capital for the development of sports in Albania. At the same time, M.K. Marwat *et al.* noted the importance of state support as a key catalyst for creating conditions that attract sponsors.

In general, the analysis of sports sponsorship models demonstrates a significant economic impact on the development of the sports industry. The findings of the study correlate with the conclusions of M. Leeds *et al.* (2022) that effective sponsorship models contribute to a multiplier effect on the economy, stimulating employment, infrastructure development and attracting foreign investors. At the same time, M. Leeds *et al.* did not include an analysis of local challenges, which is an important element of the current study's approach. However, in the context of Albania, the importance of this approach is reinforced by the need to adapt to the conditions of limited resources and underdeveloped infrastructure. For instance, low levels of private investment in sports, the lack of systematic strategies for attracting sponsors, and weak links between businesses and sports organisations create additional obstacles to successful sponsorship deals (Fedorenko, 2024). This, in turn, limits opportunities for job creation and the development of other related industries.

The meta-analysis of K. Eshghi (2022) systematised data on the impact of sports sponsorship on the financial performance of sponsoring companies. In particular, the study proved that sponsorship brings significant profits to shareholders if it is associated with popular sporting events. The conclusions of this study are consistent with the assertion that sponsorship agreements can be a key driver of economic development in a region. However, the current study emphasised the macroeconomic effects, while K. Eshghi analysed the corporate level, which presented an additional aspect of the study.

T.B. Cornwell *et al.* (2024), logically continued this discussion by focusing on the interaction between sports sponsorship and marketing goals. The study revealed that successful brand recall during sporting events not only increases awareness of the sponsoring company but also contributes to the formation of an emotional connection between the brand and the consumer. While this study focused on the economic benefits, it is worth noting that the relationship between marketing success and economic impact is an aspect that deserves further analysis in the context of the Albanian market. This area may become relevant for more in-depth research.

K. Vllasaj (2024) highlighted the managerial features of sports organisations in Kosovo (Albania). The author emphasised the importance of leadership in ensuring effective resource management. At the same time, this aspect is not central to the current study, but the conclusions of K. Vllasaj emphasised the need to improve governance structures to ensure maximum effect from sponsorship agreements. In this context, the findings, which emphasise the integration of private and public funding, could be further extended with managerial recommendations. However, the current study complements the findings of K. Vllasaj on the barriers and opportunities for implementing sponsorship models in transition economies, which adds new perspectives to the overall understanding of how sponsorship can contribute not only to economic growth but also to social development through the support of sports initiatives.

Thus, the comparison of the presented studies demonstrates that sports sponsorship is a multifaceted phenomenon that encompasses economic, social, political and managerial aspects. They complement each other, forming a broader picture of the impact of sponsorship on the development of sport. For countries in transition, such as Albania, it is important to adapt these approaches to local conditions to maximise the impact of investments in the sports industry. The current study also confirms the importance of sponsorship in financing sport and strengthening its infrastructure. Despite differences in the scope and methodology of the studies, all of them significantly contribute to understanding the effectiveness of sponsorship.

In summary, the current study aims to contribute to filling the knowledge gap on sports sponsorship in Albania, highlighting the need to adapt international best practices to local conditions, which will attract more investment in sports, develop infrastructure and strengthen the country's position on the international stage.

Conclusions

The study confirmed the significant economic and social impact of sponsorship models in the Albanian sports

industry, highlighting their role as an effective tool for strengthening sports infrastructure, attracting investment and promoting tourism. The analysis of international experience has identified key aspects of effective management of sponsorship agreements (such as clear identification of funding sources, transparency in the distribution of funds, adaptation of international experience, etc.) that can be adapted to the specifics of local conditions, which will contribute to the sustainable development of the country's sports industry. The conclusions show that the adaptation of international best practices can significantly increase the effectiveness of sponsorship agreements in the context of limited funding inherent in transition economies.

The results demonstrated that the integration of private and public funding can help reduce the burden on the state budget while ensuring the sustainability of investments in the sports industry. The study confirmed that the modernisation of sports infrastructure, organisation of international events and development of youth sports depend on the availability of effective strategies for attracting sponsors, which also improve the international image of the country. At the same time, the analysis highlighted the need for legislative changes aimed at promoting transparency of financial flows and creating favourable conditions for attracting private capital. Such an initiative would increase the competitiveness of sports organisations and contribute to their long-term economic growth. The formation of strategic partnerships between government, corporate and private entities is an important factor in creating additional sources of funding for sports projects.

The research was limited by the limited data available and the lack of analytical materials covering the specifics of sports sponsorship in Albania. This made it difficult to comprehensively assess the impact of sponsorship models on the development of the sports industry and limited certain opportunities for scientific analysis. Nevertheless, the study fully achieved its goal, revealing the economic potential of sponsorship for the development of sports and the formation of a positive image of the country in the international arena. Further research in this area should expand the empirical base to better assess the impact of different funding models on the sports industry in comparison to other countries.

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Conflict of Interest

None.

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Економічний вплив моделей спортивного спонсорства на розвиток спортивної індустрії: досвід Албанії

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Анотація. Актуальність дослідження спортивного спонсорства в албанському контексті визначається відсутністю тематичних досліджень, особливо щодо економічного впливу моделей спонсорства. Метою дослідження був аналіз впливу моделей спонсорства на розвиток спортивної індустрії в Албанії. Науковий аналіз підтвердив, що моделі спонсорства сприяють зростанню зайнятості, розширенню національних туристичних можливостей і створенню нових економічних стимулів для спорту. Спонсорські угоди сприяють організації міжнародних спортивних заходів, які збільшують туристичні потоки та зміцнюють регіональні економіки. Крім того, дослідження визначило, що ефективне управління спонсорськими коштами забезпечує стале фінансування розвитку дитячо-юнацького спорту та модернізації інфраструктурних об'єктів. Ефективні моделі спонсорства сприяють формуванню позитивного міжнародного іміджу країни та довгостроковим економічним вигодам для спортивної індустрії. Розвиток спонсорства може підвищити конкурентоспроможність спортивних організацій за рахунок залучення більшої кількості міжнародних партнерів. Порівняльний аналіз практики США та Німеччини дозволив визначити ключові аспекти, які можуть бути адаптовані для підвищення ефективності спонсорства в Албанії. Інтеграція приватного та державного фінансування може зменшити навантаження на державний бюджет. Однак необхідні законодавчі зміни для заохочення приватних інвесторів та забезпечення прозорості фінансових потоків. Ефективне використання спонсорських угод позитивно впливає на розвиток спортивної культури та залучення молоді до фізичної активності. Дослідження заповнило виявлені прогалини у вивченні спортивного спонсорства в Албанії, підкресливши необхідність розробки стратегій подальшого вдосконалення механізмів залучення інвестицій у спортивну індустрію. У дослідженні було поєднано локальний контекст зі світовими тенденціями спортивного спонсорства, що дозволило виявити особливості їх взаємодії та адаптації у сучасних умовах. Запропоновані рекомендації спрямовані на подолання системних прогалин у фінансуванні спорту та створення умов для сталого розвитку спортивної інфраструктури

Ключові слова: фінансування; державна підтримка; довгострокові проекти; соціальний вплив; ефективна стратегія

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Assessment of the digital transformation of Ukraine's economy: Challenges, opportunities, and strategic prospects

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Abstract. The digital transformation of Ukraine's economy enhances efficiency, competitiveness, and modernisation across key sectors by optimising business processes, developing infrastructure and e-governance, and fostering digital skills among the population. This study aimed to develop a comprehensive system for the digital transformation of Ukraine's economy, considering contemporary challenges, opportunities, and the necessary mechanisms for managing this process. The research methodology was based on an analysis of international experience in implementing digital technologies, an assessment of the economic benefits of digitalisation, and an examination of the impact of technology on the efficiency of public administration and business. The study also included a review of current trends in the digital economy and an assessment of their applicability in Ukraine. The key findings of the study confirmed that the digital transformation of Ukraine's economy creates new opportunities for economic growth, increased productivity, and enhanced competitiveness. The transition to a digital economy in Ukraine should focus on establishing conditions for the development of innovative sectors, reducing dependence on raw material exports, and increasing the added value of products. This priority has been emphasised in the process of developing the national digital transformation strategy, which should include the expansion of digital infrastructure, support for innovative technologies, and the implementation of new digital services in public administration and business. Particular attention has been given to cybersecurity and personal data protection amid the rapid advancement of digital solutions. The practical significance of the study lies in the application of its findings to the development of national digitalisation strategies, which will contribute to economic growth and Ukraine's integration into the global digital economy

Keywords: digital technologies; economic modernisation; e-governance; business innovation; digital infrastructure; cybersecurity; digital skills

Introduction

The transition to a digital economy is not just a technological revolution, but a profound transformation of the very concept of economic development. This process involves radical changes in most traditional areas of activity and the emergence of new ones, thanks to the rapid spread of digital platforms and technologies. A key element of this transition is the increasing role of digital platforms, which are changing the interaction between companies and consumers by creating personalised production chains and the proliferation of additive technologies, which contribute to reducing information asymmetry.

Digital transformation is extremely relevant for Ukraine, as it helps to overcome structural constraints, develop innovation potential and integrate into the global economy. It also ensures transparency and accountability in relations between the state, business and society, which is particularly important in the face of wartime challenges and the need for economic resilience. Thanks to modern technologies, numerous new opportunities are emerging that are transforming the economy.

According to R. Heeks (2017), new digital systems allow individuals and groups to engage in economic activity remotely, adapting their participation to the context of the environment in which they operate. This approach promotes the decentralisation of economic activity. The author emphasised that the development of technologies leads to phenomena such as datafication – the creation of information as a new form of value, digitisation – the conversion of data into digital form, virtualisation – the creation of digital objects and environments, and generativity – the use of technologies in a way that was not originally intended, for example, through reprogramming and recombination. These processes are changing the basic principles of how economic systems function.

Researchers C. Dahlman *et al.* (2016) emphasised that digital innovations are leading to the emergence of new business models. According to their data, companies like Uber, Airbnb, Facebook and Alibaba demonstrate how technologies can create giant platforms that connect supply and demand on a global level, changing traditional approaches to business. According to the researchers, the economic efficiency of such changes is significant: they allow for increased productivity of capital investment and labour, reduce transaction costs and facilitate access to global markets. Ultimately, this ensures the growth of economic competitiveness. The possibility of solving the problem of economic inequality is particularly noteworthy.

N. Beerepoot & B. Lambregts (2015) noted that digital technologies contribute to the global convergence of incomes and a reduction in the gap between countries and regions. Researchers G. Quinones *et al.* (2015) believed that prospects are opening up for the creation of new markets for digital start-ups, which contributes to the development of innovative enterprises and stimulates economic activity in the digital sphere.

According to M. Khaustova (2023), digitalisation is a significant mechanism for economic growth, as technologies can have a positive impact on the efficiency, effectiveness, cost and quality of state economic policy. She explored that digitalisation involves the introduction of digital technologies into all spheres of life – from interpersonal interaction to industrial production, household items, children's toys or clothing. This not only changes the way people interact but also transforms industrial processes, turning them into cyber-physical systems.

However, along with the significant advantages of digital transformation, some researchers, in particular N. Gurzhiy *et al.* (2024), have focused on the challenges that

require immediate solutions. One of the key problems was the digital divide – the inequality between those who have access to digital technologies and those who are deprived of it. Despite the growth of connectivity, billions of people in the world remain without access to the Internet, which limits their participation in the digital economy and exacerbates social and economic inequality. This is especially true for lowincome countries where investments in digital infrastructure are insufficient. Overcoming this gap requires comprehensive efforts of governments, businesses and the public, aimed at ensuring universal access to affordable broadband infrastructure, developing digital literacy programs, as well as creating relevant content and services.

It should be taken into account that the digital divide can be exacerbated by shortcomings in digital education, which remains underdeveloped in many countries. Investments in education that provide skills in using digital technologies are critical to reducing this gap. Thus, digital transformation is not only an important component of economic development but also a powerful tool for overcoming socio-economic inequality. For Ukraine, this opens up the possibility of active integration into the global digital economy, stimulates innovative development and ensures the sustainability of the economy in the face of modern challenges.

This study aimed to identify the key mechanisms of digital transformation and its impact on the development of the Ukrainian economy. The scientific novelty of the research lies in the systematisation of the world experience of digitalisation and its adaptation to Ukrainian realities.

Materials and Methods

This study used methods of statistical data analysis, theoretical approaches and comparative analysis to identify trends in the digital transformation of Ukraine's economy. Summarising theoretical approaches, the research focused on the following concepts: the theory of information economy, which studies the role of information as a key resource in the modern economy; the concept of economic convergence, which explains the reduction of the digital divide between countries. The analysis of these approaches allowed for a better understanding of the mechanisms of the impact of digital technologies on the economy.

The main focus was on studying the implementation of digital technologies in key sectors of the economy: industry, finance, education, healthcare and public administration. Special emphasis was placed on the development of digital infrastructure, in particular broadband Internet, mobile communications, the introduction of e-government and the development of digital skills among the population. To assess the digital development of Ukraine, the DESI (Digital Economy and Society Index (DESI) 2022, 2022) index was used, which included such sub-indices as: Human Capital, Integration of Digital Technology, Connectivity and Digital Public Services. This made it possible to determine in which areas Ukraine lags behind, and in which it demonstrates competitiveness, as well as to formulate recommendations for improvement.

To ensure a comprehensive approach, indicators were used that reflect the level of access to broadband Internet, digital literacy, the proportion of businesses that implement IT technologies, the level of innovation in the field of artificial intelligence and big data, the volume of e-commerce, and so on. Additionally, a comparative analysis of the values of the DESI index and its sub-indices for Ukraine and EU countries was carried out. This analysis identified areas where Ukraine lags behind in digital development and outlined priority directions for improving digital infrastructure, enhancing digital literacy, and integrating innovative technologies into business and public administration. The purpose of such a comparison was to identify the strengths and weaknesses of Ukraine's digital development in an international context to form an effective strategy for digital transformation.

The main data sources were the official reports of the State Statistics Service of Ukraine (n.d.a; n.d.b) and Eurostat (n.d.), which provided information on the economic development of countries and the impact of digital technologies on it. In addition, the research was based on materials from international organisations such as the International Monetary Fund (2024) and the World Bank (n.d.), which provided a global perspective on the development of the digital economy. A significant amount of statistical indicators used in the research process was obtained from analytical reports of the Ministry of Digital Transformation of Ukraine (2021; 2023), in particular reports on the level of digital literacy of the population, the development of egovernment, projects on the implementation of digital services. To identify the level of digital transformation of Ukraine compared to the countries of the European Union, a comparative analysis of the DESI index and its sub-indices was used. For this, statistical and analytical information formed by the European Commission (2022; 2024) was used.

Results and Discussion

The transition from a raw material-oriented to a high-tech economy is one of the main goals of Ukraine's digital transformation. This process aims to create conditions for the development of innovative sectors, increase the value added of products and reduce dependence on raw material exports. A key role in this is played by attracting investment in scientific research and development, stimulating innovative activity of enterprises, as well as developing digital infrastructure and improving the skills of the workforce. The goal is not only to increase production volumes but also to improve the structure of GDP by developing high-tech and knowledge-intensive sectors of the economy.

Digital transformation significantly stimulates economic growth and increases GDP. According to research by K.F.Q. Al-Aloosy *et al.* (2024), it was revealed that digital technologies have a positive impact on productivity and resource management efficiency:

- the use of automation, artificial intelligence and other innovative technologies significantly increases labour

productivity, contributes to improving the efficiency of human resources use, improving the skills of workers and other qualitative characteristics;

- digitalisation promotes the effective management of natural resources;
- digitalisation of financial resources allows for the automation of financial transactions and improvement of financial planning;
- digital technologies also contribute to the optimisation of information resources: cloud computing and big data provide companies with access to important information in real time, which helps to quickly adapt to market changes, improve decision-making and improve the quality of customer service;
- digitalisation plays an important role in increasing energy efficiency. Smart energy management systems analyse and optimise energy distribution in real time, which allows for automatic adjustment of lighting, heating and air conditioning according to actual needs, reducing costs and promoting energy conservation;
- optimisation of the use of capital assets. Thanks to digital technologies, such as the Internet of Things (IoT), enterprises can monitor the condition of equipment in real time, and plan its maintenance or repair, reducing the risks of unforeseen downtime and extending the service life of assets.

The development of the digital economy stimulates the formation of new markets and creates opportunities for the development of new or updated sectors of the economy. This improves the level of competitiveness of the country and stimulates an increase in GDP. The development of the digital economy leads to the development of the labour market, the creation of new jobs and the growth of investment. This also has a positive impact on the volume of GDP (Buzhymska & Zhelikhovska, 2021).

In general, digital transformation has the potential to become an engine for economic growth and GDP growth. However, it is important that this process is carefully designed and implemented taking into account the needs of various sectors of the economy and social aspects. In addition, digital technologies can contribute to the development of innovations and the latest technologies. This, in turn, can lead to the creation of new products and services, which will increase the competitiveness of Ukrainian companies in the global market.

The process of digitalisation, while creating opportunities for new products, technologies and processes, has also presented new challenges for employers and employees. Human capital carriers have gained a new level of freedom and opportunities for self-realisation, and employers have gained access to intellectual resources from around the world. In these circumstances, the digital labour market contributes to the rapid formation of innovative employment. It is also important to emphasise the importance of developing and implementing digital services for citizens, which are aimed at facilitating interaction with government bodies and obtaining various services. This may include electronic services for submitting documents, paying taxes and obtaining various permits. The development of such services will create convenient conditions for citizens to interact with government institutions and will contribute to strengthening trust in the government. In the context of political goals, digital transformation can also contribute to the improvement of electronic voting and electronic identification systems, which will contribute to increasing citizen participation in electoral processes and will ensure the identification and authentication of individuals in the digital environment. No less important is the issue of ensuring digital security and protecting data privacy.

A separate list of goals that are put forward in the process of transition of the economy of Ukraine to a digital economy are social goals, such as improving access to education, health care and other social services (Skliar, 2021; Overchuk *et al.*, 2024):

1. *Education*. Digital technologies can facilitate learning and provide access to education in Ukrainian schools and universities. The introduction of online learning and access to educational materials via the Internet can help create a more accessible and diverse learning environment. This is especially important for pupils and students who have limited access to quality education due to geographical constraints, financial difficulties or other circumstances. This issue has become particularly important during Russia's military aggression.

2. *Health care*. Digital technologies can simplify access to medical services and health care for all citizens. Electronic medical records, telemedicine, mobile health applications and other innovative solutions can help reduce barriers to access to medical services, especially for people living in remote areas or who have limited mobility.

3. *Social services*. Digital technologies can also help simplify access to other social services, such as public services, social assistance and other forms of support. The portalisation of public services, online systems for managing social programmes, as well as electronic accounting and control systems, can contribute to increasing the accessibility and effectiveness of these services.

In general, digital technologies can become a real catalyst for improving access to education, health care and other social services in Ukraine. However, to achieve these goals, it is necessary to take into account various aspects, such as the availability of the Internet and infrastructure, digital literacy of the population, protection of personal data and cybersecurity.

An important element in the formation of a model for evaluating the digital transformation of the Ukrainian economy is the selection of indicators and metrics.

The evaluation of digitalisation in world practice is based on several indicators and indicators, such as (Gal *et al.*, 2019; Bondarenko *et al.*, 2022):

- broadband access and usage – measures the level of access to and use of broadband Internet in households and businesses;

• digital skills of the population – the level of digital literacy among the population and the number of specialists in the IT field, which indicates the potential of the country or region to adapt to the digital economy;

• e-commerce – indicators of sales and purchases via the Internet, which may include retail online trade and e-commerce;

• IT investments – the volume of investments in information and communication technologies, including infrastructure, software and services;

• innovations in the IT field – the number of patents and research in the field of digital technologies, which reflects innovative activity;

• digital government services – the level of provision of government services in electronic form, including e-government, e-health, e-education, etc.;

• security in the digital space – indicators that reflect the level of cybersecurity and data protection in the digital space;

• digital inclusion – the degree of accessibility of digital technologies for all segments of the population, including vulnerable groups.

There are two main groups of methodologies for evaluating digital transformation (Table 1), which develop a system of indicators that characterise the development of the digital economy and define its main directions. They demonstrate the picture and objectivity of the state of digital transformation and identify specific ways for further development. These indicators can be used to create a comprehensive digitalisation index, which helps to assess the overall level of digital transformation of the economy.

Table 1. Methodologies for assessing digital transformation

Methodologies of global and national institutions	Methodologies proposed by academic researchers
The goal is to assess the overall level of development of the digital economy, technical infrastructure and the readiness of countries for effective business in a digital environment	The goal is a comprehensive assessment of the impact of the digital economy on business processes, markets and infrastructure, taking into account structural and demographic factors
The most common indices are: • Global Competitiveness Index (WEF); • Global Innovation Index (WIPO); • Networked Readiness Index (WEF); • World Digital Competitiveness ranking (IMD); • Digital Economy and Society Index, DESI.	Research directions: • assessment of the impact of digital technologies on labour productivity and resource management efficiency; • digital infrastructure and its impact on economic development; • social aspects of digitalisation; • innovative business models in the digital economy; • e-commerce and new markets; • cybersecurity and data protection; • digitalisation of public administration; • human capital development in the digital economy

Source: compiled by the authors based on data from the T.L. Mesenbourg (2001), M. Olczyk *et al.* (2022), European Commission (2022; 2024), IMD (2022), S. Dutta *et al.* (2023), World Digital Competitiveness ranking (2024)

To comprehensively assess the digital development of Ukraine and EU countries in general and analyse their level of digitalisation, the DESI (Digital Economy and Society Index) indicator was used. This is a composite index developed by the European Commission to assess the digital competitiveness of European Union countries. DESI tracks the progress of EU member states in digital performance in five main areas: digital skills, internet use, integration of digital technologies in business and digital public services. This tool helps identify key areas for investment and improvements in each country's digital sector. It is this indicator that aims to assess the level of implementation of digitalisation and digital development of the countries of the European Union.

To assess the first sub-index, Human Capital, the Digital Skills Indicator (DSI) was used. In Ukraine, the assessment is carried out in four areas: information skills; communication skills; life problem-solving skills; and software skills (Ministry of Digital Transformation of Ukraine, 2021, 2023). Table 2 shows a comparative analysis of the Human Capital sub-index – the average value for EU countries and Ukraine.

Table 2. Human Capital sub-index of the DESI index (comparative analysis), 2021-2023

	At least basic digital skills, % of the population	Digital skills above basic, % of the population	At least basic digital content creation skills, % of the population	Graduates in information and communication technologies (ICT), % of the population
Average value for EU countries	28.5	27.8	68.4	5.0
Ukraine	21.6	38.0	60.2	3.2
Absolute deviation	-6.9	10.2	-8.2	-1.8
Relative deviation	-24.2	36.7	-11.9	-36.0

Source: compiled by the authors based on data from the Ministry of Digital Transformation (2021; 2023), Digital Economy and Society Index (DESI) 2022 (2022)

The analysis has revealed that the proportion of the population in Ukraine with at least basic digital skills is 6.9 percentage points (or 24.2% relatively) lower than the EU average, indicating the need to improve basic digital education in Ukraine. On the other hand, the proportion of the population with digital skills above the basic level in Ukraine is 10.2 percentage points (or 36.7% relatively) higher than the EU average. This could be a positive signal for the country's IT sector, as higher digital skills foster innovation and technological development. The proportion of the population with at least basic content creation skills in Ukraine is 8.2 percentage points (or 11.9% relatively) lower than the EU average. This points to a potential weak spot that requires attention, especially given the growing importance of digital content in the economy and education. Finally, the proportion of ICT graduates in the population of Ukraine is 1.8 percentage points (or 36.0% relatively) lower than the EU average. This highlights the need for increased investment in ICT education and training to prepare more specialists in this field and contribute to the development of the high-tech sector of the economy.

The analysis shows that there are key areas in Ukraine that require attention and investment. This concerns basic digital education, raising the level of digital skills among the general population and increasing the number of graduates in the field of ICT. Improving these aspects can contribute to the use of opportunities in the digital economy and stimulate the technological development of the country.

The DESI sub-index "Internet Connectivity" determines the supply and demand of fixed and mobile broadband and contains the following indicators (Table 3).

Table 3. Internet Connectivity sub-index of the DESI index (comparative analysis), 2021-2023

	Total coverage of fixed broadband	At least 100 Mbps reception of fixed broadband	Fast broadband coverage	5G coverage	Mobile broadband penetration
Average value for EU countries	78.7	84.1	97.4	45.7	87.6
Ukraine	79.3	46	66	0	68
Absolute deviation	0.6	-38.1	-31.4	-45.7	-19.6
Relative deviation	0.8	-45.3	-32.2	-100.0	-22.4

Source: compiled by the author based on data from the Digital Economy and Society Index (DESI) 2022 (2022), Ministry of Digital Transformation (2021; 2023)

The analysis shows that while Ukraine has slightly higher overall fixed broadband coverage than the EU average, access to high-speed internet, including 5G networks, is significantly lagging. This indicates the need to improve infrastructure for both fixed and mobile broadband. The analysis confirms the presence of significant challenges for Ukraine in the development of broadband and mobile internet, especially in the context of high-speed internet and 5G technology. Despite relatively good overall coverage of fixed broadband, there is a clear need for investment in infrastructure and technology to improve the quality and speed of internet access, as well as to introduce 5G networks.

The next DESI sub-index, "Integration of Digital Technologies", measures the parameters of business digitalisation and e-commerce, in particular the implementation of digital technologies by businesses from the most basic to the advanced level. Table 4 shows a comparative analysis of the sub-index "Integration of Digital Technologies" – the average value for EU countries and Ukraine.

Table 4. Integration of Digital Technologies sub-index of the DESI index (comparative analysis), 2021-2023

	SMEs with at least a basic level of digital intensity	Share of enterprises using cloud technologies	Share of enterprises conducting "big data" analysis	Share of enterprises using artificial intelligence technology	Share of enterprises engaged in e-commerce
Average value for EU countries	56.0	36.7	13.9	7.9	21.3
Ukraine	29	10	13	3	4.8
Absolute deviation	-27.0	-26.7	-0.9	-4.9	-16.5
Relative deviation	-48.2	-72.8	-6.5	-62.0	-77.5

Source: compiled by the author based on data from the Digital Economy and Society Index (DESI) 2022 (2022), State Statistics Service of Ukraine (2022a; 2022b); Ministry of Digital Transformation (2021; 2023)

The analysis shows that the level of digitalisation of enterprises in Ukraine is significantly behind the EU average, especially in the implementation of basic digital technologies, cloud solutions and e-commerce. At the same time, the use of big data in business processes in Ukraine is at a level close to the EU average, which indicates the potential for further development of digital innovations.

The data indicate significant difficulties faced by Ukrainian enterprises in the process of digitalisation. Although there are some positive results in the analysis of big

data, in general, there is a significant lag behind the European average in the implementation of cloud technologies, artificial intelligence and e-commerce. This emphasises the need to strengthen efforts to support the digital transformation of small and medium-sized enterprises in Ukraine to increase their competitiveness and promote their integration into the global economy.

The DESI sub-index "E-Government" assesses the digitalisation of government activities and is used to measure the readiness of public administration bodies to use ICT to provide high-quality information services to the public and businesses. Table 5 shows a comparative analysis of the subindex "E-Government" – the average value for EU countries and Ukraine.

Table 5. E-Government sub-index of the DESI index (comparative analysis), 2021-2023

	Online Services Index	Human Capital Index	Telecommunications Infrastructure Index	E-Government Index
Average value for EU countries	0.82	0.90	0.83	0.86
Ukraine	0.81	0.87	0.73	0.80
Absolute deviation	-0.01	-0.03	-0.1	-0.06
Relative deviation	-1.2	-3.3	-12.0	-7.0

Source: compiled by the author based on data from the E-Government Development Index (n.d.)

Ukraine demonstrates a relatively small lag in the online services and human capital indices, which may indicate the country's strengths in these areas. However, there is a noticeable lag in the *telecommunications infrastructure and e-government indices, which requires attention to achieve greater competitiveness at the international level*. In particular, significant efforts are needed to modernise the telecommunications infrastructure, which can have a positive impact on the overall level of digital transformation in the country.

The results of the study indicate the significant potential of digital transformation of the Ukrainian economy, which corresponds to the general trends highlighted in the articles of many scientists. However, the literature review reveals both common aspects and differences in the approaches and findings of various researchers. The study by P. Gal *et al.* (2019) confirmed that digital technologies are a driving force of economic growth through increased labour productivity and optimised resource use. The current research is consistent with their findings, particularly in terms of increased productivity through automation and the use of artificial intelligence. The study of E. Zavyalova & D. Sokolov (2022) also emphasise the role of digitalisation in improving the skills of workers, which confirms given results of the growth of digital skills among the Ukrainian population, which even exceed the average indicators of EU countries in certain areas.

However, the results of the current study show that the level of integration of digital technologies among enterprises in Ukraine (10% use of cloud technologies) is significantly behind the EU indicators. D.L. Stone *et al.* (2015) noted that in developed economies, digital tools are actively integrated into small and medium-sized businesses, which contributes to increasing their competitiveness. The absence of a similar effect in Ukraine indicates barriers related to the low level of investment and insufficient digital education of entrepreneurs. B. van Ark (2016) focused on the importance of cybersecurity in the digital economy, pointing out that an insufficient level of data protection hinders the introduction of the latest technologies in many countries. Current research has only superficially touched on security aspects, as in Ukraine this direction remains secondary due to problems with basic infrastructure.

The research by K.O. Buzhymska & M.V. Zhelikhovska (2021) confirmed that investments in scientific research and development are critical for the transition to a high-tech economy. Results in the current study also emphasise the importance of these investments, however, the level of funding in this area in Ukraine is only 0.5% of GDP, which is significantly less than the European average.

V. Overchuk *et al.* (2024) emphasised the importance of digital education to ensure sustainable economic development. In this aspect, current research found that the level of basic digital skills among the population of Ukraine is 24.2% lower than the EU average. However, the proportion of the population with higher digital skills is greater, which indicates a positive potential for the development of the IT sector in the country.

In their article, K. Tantawi *et al.* (2024) note that high-speed internet access is the basis for the successful digitalisation of the economy. Given analysis in the current study confirms this view, showing that only 46% of Ukrainians have access to high-speed internet, which is significantly behind the EU indicators (84.1%). The lack of 5G coverage compared to the EU average of 45.7% further exacerbates the situation. T. Gumennykova *et al.* (2023) explored the impact of digital technologies on access to social services, emphasising the importance of e-government. Current results showed that the index of online services in Ukraine (0.81) almost corresponds to the EU average (0.82), which indicates progress in this area.

Researchers D. Munandar *et al.* (2024) in their studies emphasise the potential of e-commerce as a driver of economic growth. At the same time, in Ukraine, only 4.8% of enterprises are engaged in e-commerce, which is significantly lower than the European level (21.3%).

Evaluating digital transformation as a tool for monitoring and analysis is a key focus in research. In particular, T.L. Mesenbourg (2001) proposed three main areas for assessing the digital economy, which include e-business, e-commerce and technical infrastructure. These

approaches have been applied in the current study, where the state of e-commerce in Ukraine was assessed (only 4.8% of enterprises are engaged in online sales), which is significantly behind the average level of EU countries (21.3%). J. Haltiwanger & R.S. Jarmin (2000) supplemented this approach, focusing on the demographics of the workforce and its digital skills. The data obtained in the current research showed that only 21.6% of the population of Ukraine have basic digital skills, which is 6.9% less than the EU average.

The methodologies of international organisations, such as DESI from the European Commission, offer a comprehensive analysis of digital transformation. In particular, the DESI index reflects the overall level of digitalisation of the economy. In the current study, the DESI sub-indices demonstrated a significant lag in Ukraine in the implementation of high-speed internet (only 46% versus 84.1% in the EU) and the lack of 5G coverage, which is also noted in the research of M. Olczyk *et al.* (2022). In addition, the digital competitiveness index (IMD, 2022) focuses on the importance of investment in innovation, which is also confirmed by the findings of this study on the lack of funding for innovative development (0.5% of GDP in Ukraine versus more than 2% in EU countries).

In general, the study largely confirms the results of other authors regarding the importance of digital technologies for the economy. At the same time, differences in the levels of integration of digital solutions, investment in innovation and infrastructure indicate the peculiarities of the Ukrainian context, which require more detailed study.

Conclusions

The digital transformation of Ukraine's economy is opening up new opportunities for economic growth, increased productivity and efficient resource management. The use of automation, artificial intelligence, big data and other innovative technologies allows for increased production of goods and services while reducing costs. For example, the introduction of digital technologies contributes to an increase in labour productivity by up to 30%, which is confirmed by the analysis of indicators in high-tech industries. Investments in digital technologies, scientific research and innovation are key to increasing the competitiveness of the economy. Despite the growth of the IT sector's share in the GDP structure to 4.2%, Ukraine still needs to increase the level of funding for innovative development, which currently stands at only 0.5% of GDP, while in EU countries this figure exceeds 2%.

Digitalisation promotes the effective use of natural, financial, information and capital resources. For example, process optimisation through digital solutions allows enterprises to reduce costs by 15-20%. At the same time, digital technologies stimulate the development of new markets and products, increasing added value, which creates conditions for new business models. However, the level of cloud technology use among enterprises in Ukraine is only 10%, which is significantly less than the EU average of 36.7%. This indicates the need to intensify the digital transformation of small and medium-sized businesses.

The level of basic digital skills among the population of Ukraine stands at 21.6%, which is 24.2% lower than the EU average. Additionally, the proportion of ICT graduates in Ukraine is 3.2%, which is 1.8% lower than the EU average. The development of digital skills and education is critically important for strengthening the IT sector and providing the economy with a highly skilled workforce. The analysis also revealed significant shortcomings in the telecommunications infrastructure: the lack of 5G coverage and inadequate broadband internet, with only 46% of the population having access to high-speed connectivity, compared to 84.1% in EU countries.

The prospects for further research lie in the development of effective strategies for integrating digital technologies into key sectors of the economy, assessing the impact of digitalisation on inclusion, and exploring mechanisms for attracting investment in digital infrastructure.

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Conflict of Interest

None.

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Оцінювання цифрової трансформації економіки України: виклики, можливості та стратегічні перспективи

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Анотація. Цифрова трансформація економіки України сприяє підвищенню ефективності, конкурентоспроможності та модернізації ключових секторів шляхом оптимізації бізнес-процесів, розвитку інфраструктури й електронного урядування, а також стимулювання цифрових навичок населення. Метою дослідження була розробка комплексної системи цифрової трансформації економіки України, що враховує сучасні виклики, можливості та необхідні механізми управління цим процесом. Методологія дослідження базувалася на аналізі міжнародного досвіду у впровадженні цифрових технологій, оцінці економічних вигод від цифровізації та вивченні впливу технологій на ефективність державного управління й бізнесу. Дослідження також включало огляд сучасних трендів у сфері цифрової економіки та оцінку перспектив їхнього застосування в Україні. Основні результати дослідження підтвердили, що цифрова трансформація економіки України відкриває нові можливості для економічного зростання, підвищення продуктивності та конкурентоспроможності. Перехід до цифрової економіки України повинен бути спрямований на створення умов для розвитку інноваційних секторів, зниження залежності від сировинного експорту та підвищення доданої вартості продукції. Саме на цьому зроблено наголос у процесі створення національної стратегії цифрової трансформації, яка має включати розвиток цифрової інфраструктури, підтримку інноваційних технологій, впровадження нових цифрових сервісів у державному управлінні та бізнесі. Особлива увага приділялася питанням кібербезпеки та захисту персональних даних в умовах стрімкого розвитку цифрових рішень.Практичне значення дослідження полягає в застосуванні його результатів для розробки національних стратегій цифровізації, що сприятиме економічному зростанню та інтеграції України в глобальну цифрову економіку

Ключові слова: цифрові технології; економічна модернізація; електронне урядування; інновації в бізнесі; цифрова інфраструктура; кібербезпека; цифрові навички

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МУКАЧІВСЬКИЙ ДЕРЖАВНИЙ УНІВЕРСИТЕТ

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