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PREREQUISITES FOR THE INTELLECTUALISATION OF INDUSTRY ON THE BASIS OF DIGITAL TRANSFORMATION: ECONOMIC ANALYTICS OF THE IT-INDUSTRY IN UKRAINE

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Trofymenko O. O., Roshchyna N. V., Lazarenko I. S., Kot Ya. V. Prerequisites for the Intellectualisation of Industry on the Basis of Digital Transformation: Economic Analytics of the IT-Industry in Ukraine

The article investigates the prerequisites for the intellectualisation of industry on the basis of digital transformation, using the tools of economic analytics of the IT industry in Ukraine for the period of 2010–2023. The author analyses the key factors of the industry development, including export of IT services, number of enterprises, level of developers' salaries, US dollar exchange rate, share of innovative products and number of employees in the sector. It is found that the IT industry, due to the high dynamics of exports and the growing role of innovative technologies, plays a strategic role in the process of intellectualisation of the economy. In 2022, exports reached their peak, but in 2023, they declined due to the effects of the war, business relocation, and a decrease in demand for digital services. The study confirmed that digital transformation is a critical factor in the modernisation of industrial processes, and the IT industry provides technological solutions for the implementation of intelligent control systems, production automation and big data analysis. Economic and mathematical modelling, including regression and time series methods (Auto ARIMA), helped identify the key factors influencing the dynamics of the IT industry. Among them, the exchange rate, the number of companies, the average salary, the number of employees and the level of innovation activity are of significant importance. Forecasting with the use of the selected models allows to formulate effective strategies to support the IT sector and the digital transformation of industry. It is determined that the intellectualisation of industry based on digital solutions increases productivity and creates high value-added products, which is the basis for competitiveness in the global economy. The developed models can be used to predict and manage technological changes, increasing the effectiveness of strategic decisions in the field of digital transformation. The application of the research results contributes to the formation of an innovative environment, strengthening economic stability and enhancing Ukraine's position in the international IT services market. To ensure sustainable development, it is recommended to strengthen innovation potential, develop human capital, create favourable conditions for investment and support international cooperation. It is concluded that the integration of the IT industry and digital technologies is a key prerequisite for the intellectualisation of industry and economic modernisation of Ukraine.

Keywords: *intellectualisation of industry, digital transformation, IT industry, economic analysis, prerequisites for intellectualisation, forecasting the development of the IT sector, innovative technologies, business relocation, human capital in IT, competitiveness.*
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Трофименко О. О., Рощина Н. В., Лазаренко І. С., Кот Я. В. Передумови інтелектуалізації промисловості на засадах цифрової трансформації: економічна аналітика ІТ-індустрії в Україні

У статті досліджено передумови інтелектуалізації промисловості на засадах цифрової трансформації з використанням інструментів економічної аналітики сфери ІТ в Україні за період 2010–2023 рр. Проаналізовано ключові фактори розвитку галузі, серед яких експорт ІТ-послуг, кількість підприємств, рівень заробітної плати розробників, курс долара США, частка інноваційних продуктів та кількість працівників у секторі. З'ясовано, що ІТ-індустрія завдяки високій динаміці експорту та зростаючій ролі інноваційних технологій відіграє стратегічну роль у процесі інтелектуалізації економіки. У 2022 р. експорт досяг свого піку, але у 2023 р. скоротився через наслідки війни, релокацію бізнесу та зниження попиту на цифрові послуги. Дослідження підтвердило, що цифрова трансформація є критично важливим фактором модернізації промислових процесів, сфера ІТ надає технологічні рішення для впровадження інтелектуальних систем управління, автоматизації виробництва та аналізу великих даних. Економіко-математичне моделювання, включно з методами регресії та часових рядів (Auto ARIMA), допомогло виявити ключові фактори, що впливають на динаміку сфери ІТ. Чимале значення мають курс валют, кількість компаній, середня заробітна плата, кількість працюючих і рівень інноваційної активності. Прогнозування з використанням обраних моделей дозволяє сформулювати ефективні стратегії підтримки сектора ІТ і цифрової трансформації промисловості. Визначено, що інтелектуалізація промисловості на основі цифрових рішень підвищує продуктивність і створює продукцію з високою доданою вартістю, що є основою конкурентоспроможності у світовій економіці. Розроблені моделі можуть бути використані для прогнозування й управління технологічними змінами, підвищення ефективності стратегічних рішень у сфері цифрової трансформації. Застосування результатів дослідження сприятиме формуванню інноваційного середовища, зміцненню економічної стабільності та посиленню позицій України на міжнародному ринку ІТ-послуг. Для забезпечення сталого розвитку рекомендується зміцнювати інноваційний потенціал, розвивати людський капітал, створювати сприятливі умови для інвестицій та підтримувати міжнародне співробітництво. Зроблено висновок, що інтеграція сфери ІТ і цифрових технологій є ключовою передумовою інтелектуалізації промисловості та економічної модернізації України.

Ключові слова: *інтелектуалізація промисловості, цифрова трансформація, сфера ІТ, економічний аналіз, передумови інтелектуалізації, прогнозування розвитку сектора ІТ, інноваційні технології, релокація бізнесу, людський капітал у сфері ІТ, конкурентоспроможність.*
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According to the European Industrial Strategy [1], industry is central to Europe's future progress and prosperity, and industry must be digital, sustainable and competitive, which implies the introduction of digital technologies, artificial intelligence and big data. Today, with the emergence and development of Industry 5.0, industrial intelligence is one of its key components. Since industrial intelligence involves the integration of such advanced technologies as artificial intelligence (AI), the Internet of Things (IoT), Big Data, robotics, automation and other digital tools that allow for the creation of smart production systems capable of self-learning, self-diagnosis and self-regulation, the IT industry is a key factor in ensuring the development of intelligence. This determines the relevance of this study, which involves a study of the IT industry in Ukraine and the identification of key factors for its development, taking into account the needs of industrial intellectualisation, which is critical for economic stability, technological breakthrough and post-war economic recovery in Ukraine.

The *purpose* of the article is to carry out an economic analysis of the development of the IT industry in Ukraine as a strategic prerequisite for the intellectualisation of industry and to identify the key factors ensuring its development.

Today, studies by Ukrainian and foreign scholars in the field of industrial intellectualisation and the economy in general are devoted to its various components and directions. Study [2], which examines the components of the intellectualisation of real sector enterprises, among other things, determines that stimulating the intellectualisation of enterprises is a promising direction of the present, and the combination of IT and process mechanisation is a promising direction for its provision. An interesting study [3] examines approaches to intelligent manufacturing in the context of Industry 4.0. The author identifies key technologies such as IoT, cyber-physical systems (CPS), cloud computing, big data analysis (BDA), and information and communication technologies (ICT) used to ensure smart manufacturing. Global trends in the development of intelligent manufacturing, including government strategic plans of different countries and strategic plans of large international companies in the European Union, the United States, Japan, and China, are investigated. Study [4] analyses the scientific challenges and key technologies that are crucial for the successful implementation of smart manufacturing in the manufacturing industry. Study [5] analyses the impact of industrial intelligence on changing the industrial structure by building indicators of optimisation, rationalisation and synergy of the industrial structure, as well as modernisation of agriculture, industry and services. Study [6] identifies the need to stimulate the development of the IT industry to achieve the global Sustainable Development Goal 9, which aims to create sustainable infrastructure, promote sustainable industrialisation and innovation. In general, modern studies have identified the key role of intellectualisation for industrial needs, as well as the need to develop IT systems to optimise production processes.

Industrial intellectualisation involves a set of processes of implementation and use of modern information and technological solutions for automation and digitalisation of production processes in order to optimise and improve the efficiency of production processes, and with the development of Industry 5.0, it provides for a harmonious combination of technology and human creativity, personalisation of production, improvement of working conditions and sustainability of production processes, providing new forms of interaction between people, machines and technologies in the industrial sector. Industrial intellectualisation includes the use of advanced technologies such as artificial intelligence (AI), the Internet of Things (IoT), big data, robotics, automation and other digital tools that allow for the creation of smart production systems capable of self-learning, self-diagnosis and self-regulation. That is why the development of the IT industry, which produces these technologies, will increase the potential for industrial intelligence in Ukraine.

The Ukrainian IT industry market covers a wide range of activities, including programming, consulting and support of computer equipment, development of software solutions, training, system administration, software testing, data processing, web publishing, and research on information process automation. The industry is regulated by the laws of Ukraine, including the Law of Ukraine 'On Amendments to Certain Legislative Acts of Ukraine on Ensuring Conditions for the Restoration and Development of Electronic Communication Networks' and the Law of Ukraine 'On Protection of Information in Information and Telecommunication Systems'. These regulations define IT services as activities aimed at providing consumers with software products via electronic communications.

Electronic delivery of software products saves time and money and increases the industry's export potential. Ukrainian IT companies focus mainly on international markets, which indicates a high level of trust in their expertise and ability to solve complex problems. The evolution of Ukraine's IT market has passed through five main stages, reflecting the progressive development of the industry [7; 8].

Until the 1990s (*the first stage*), the scientific basis of IT was being formed in the USSR. The main achievement was the creation of the first digital computer in Europe – MEOM. The Institute of Cybernetics was founded and an automated system for collecting and processing information (OGAS) was developed.

The 90s of the XX century (*the second stage*) were the period of formation of the IT industry in independent Ukraine. Research into artificial intelligence and data processing automation intensified, and educational programmes combining training and practice were introduced. The first business projects were launched, and young people joined the IT sector and learnt English.

The years 2000–2010 (*the third stage*) were marked by informatisation, automation and the transition to cloud services. Despite the 2008 crisis, Ukraine remained attractive for IT outsourcing, consolidating its position as a cost-effective partner.

2011–2019 (*the fourth stage*). The 'IT boom' period was characterised by an increase in the number of certified IT specialists and a qualitative improvement in services. Ukraine became a reliable partner for for-

eign customers in the fields of medicine, finance, logistics, etc. Exports of IT services reached USD 4.17 billion in 2019. The exports of it services reached USD 4.17 billion in 2019.

2020 to date (*the fifth stage*). Despite the COVID-19 pandemic and the war, the IT industry has maintained its development dynamics. In 2020, exports exceeded USD 5 billion. IN 2020, exports exceeded USD 5 billion. In 2023, it totalled USD 6.73 billion. Although it decreased by 14.3% due to global challenges.

Analysing the volume of imports of IT services from Ukraine is of particular importance in the context of the deep crisis the country is experiencing. In 2021–2023, the main importing countries of Ukrainian IT services include the United States, Malta, the United Kingdom, Cyprus, Israel, Germany, and Switzerland (*Tbl. 1*).

Table 1

The largest importing countries of IT services from Ukraine country revenues from export of IT services, mln USD

Country	Revenues from export of IT services, mln USD		
	2021	2022	2023
USA	2728	2973	2677
Malta	481	581	567
United Kingdom	698	693	535
Cyprus	288	314	362
Israel	334	347	293
Germany	369	286	275
Switzerland	285	331	274

Source: compiled based on [9].

Exports of IT services are an important component of Ukraine's economy, making a significant contribution to the country's foreign exchange earnings. An analysis of the dynamics of exports to the largest sectors of importing countries in 2021–2023 demonstrates both the achievements and challenges faced by the Ukrainian IT services market.

Thus, the United States remains the largest importer of Ukrainian IT services, consistently accounting for almost half of all export revenues. In 2022, revenues grew by 9% year-on-year, reaching USD 2.973 million, indicating a high level of confidence in Ukrainian developers. However, in 2023, exports dropped to USD 2677 million (down 10%). This decline is due to the impact of the war, business relocation, and global market uncertainty.

European markets showed mixed dynamics. Malta and Cyprus have a positive growth trend, showing an increase in imports of Ukrainian IT services over the past three years. In 2023, exports to Malta totalled $567 million and to Cyprus $362 million, ensuring Ukraine's successful reorientation to markets with less competition.

At the same time, the Ukrainian IT services market faced significant difficulties in traditional markets such as the UK, Germany and Switzerland. Exports to the UK decreased from $698 million in 2021 to $535 million in 2023, which can be explained by the effects of Brexit and increased competition from other countries. Germany and Switzerland also recorded a decrease in imports by 25% and 4%, respectively, during the analysed period.

Israel, an important partner, also reduced its exports of Ukrainian IT services from $347 million in 2022 to $293 million in 2023, reflecting local economic challenges and changes in the structure of demand for IT services.

Thus, Ukraine's IT sector continues to adapt to changes in global markets, demonstrating resilience and the ability to diversify. Export growth in certain markets confirms an effective reorientation strategy, but the decline in volumes in key markets indicates the need to strengthen competitive advantages and introduce innovations to maintain its position in the global IT industry.

To obtain more objective results of the study, we will conduct a comparative analysis of the IT industry market, in particular, the exports of IT services in Ukraine and other countries. Poland, India, Brazil, and the Czech Republic were selected for the analysis, given their high level of competitiveness, significant human resources in the field of technology, favourable business environment, and developed infrastructure (*Tbl. 2*). These countries are leading participants in the international IT services market and demonstrate the pace and level of development of the IT industry comparable to that of Ukraine.

An analysis of the exports of IT services by Ukraine, India, Brazil, Poland, and the Czech Republic in 2021–2023 shows significant differences in the dynamics of this sector. India has consistently held a leading position in the world in terms of IT services exports. Over three years, exports have grown from USD 87.9 billion in 2021 to USD 102.9 billion in 2022. USD in 2021 to 102.9 billion USD in 2023. In 2023, this corresponds to an absolute increase of USD 15 billion (17.1%). (17.1%). The annual growth rate remains consistently high, reflecting the country's well-developed infrastructure, large human resources and favourable business climate. Brazil demonstrates high relative

Table 2

Analysis of IT services exports of Ukraine. India. Brazil. Poland and the Czech Republic in 2021–2023

Country	Exports of IT services, billion USD			Absolute deviation, +/–			Relative deviation, %		
	2021	2022	2023	2022/2021	2023/2022	2023/2021	2022/2021	2023/2022	2023/2021
India	87.9	95.5	102.9	7.6	7.4	15	8.6	7.7	17.1
Brazil	4.1	5.3	6.2	1.2	0.9	2.1	29.3	17.0	51.2
Poland	9	12.2	13.8	3.2	1.6	4.8	35.6	13.1	53.3
Czech Republic	5.3	6.3	6.8	1	0.5	1.5	18.9	7.9	28.3
Ukraine	6.9	7.3	6.7	0.4	–0.6	–0.2	5.8	–8.2	–2.9

Source: compiled based on [9].

growth rates of IT services exports, which amount to 51.2% over three years. Export volumes increased from USD 4.1 billion in 2021 to USD 6.2 billion in 2020. USD in 2021 to 6.2 billion USD in 2023. USD in 2023. In 2022, the growth rate reached 29.3%, although in 2023 it slowed to 17%. This may be due to the growing demand for IT services in Latin America and the active development of international markets. Poland is also showing steady growth. In 2021, the volume of exports of IT services amounted to USD 9 billion. In 2023, it increased to USD 13.8 billion. USD. The absolute growth was USD 4.8 billion. (53.3%). The highest growth rate was observed in 2022 (35.6%), although it slowed down slightly in 2023 (13.1%). This indicates the effective integration of the Polish IT sector into the European market and favourable business conditions. The Czech Republic demonstrates moderate but stable growth in the export of IT services. During the analysed period, its volume increased from USD 5.3 billion in 2021 to USD 6.8 billion in 2022. USD in 2021 to 6.8 billion USD in 2023. USD in 2023, which corresponds to an increase of USD 1.5 billion. USD (28.3%). Although the growth rate was 18.9% in 2022, it dropped to 7.9% in 2023. This may be due to the saturation of the local market and high competition in the region.

Ukraine, despite a slight increase in exports in 2022 (+5.8%), showed a decline of 8.2% in 2023 compared to the previous year. In total, the volume of IT services exports in 2023 amounted to USD 6.7 billion. This is slightly lower than in 2021 (USD 6.9 billion). These results reflect the impact of external factors, including the military conflict, which creates significant obstacles to business development.

Thus, the analysis confirms India's leading role as a global leader in IT services. Poland and Brazil demonstrate high relative growth rates, which indicates their active development and competitiveness. The Czech Republic maintains stable but lower growth rates. Ukraine, despite its challenges, retains significant potential for recovery and further growth once its internal and external conditions stabilise.

The next step in the economic analysis of the IT sector is to analyse the share of IT services exports in the total exports of countries. This stage allows us to assess the role of the IT industry in the economy, its level of competitiveness and the degree of economic diversification. The results of such an analysis are an indicator of the economic efficiency of the IT sector and its ability to ensure stable growth in the face of changes in international markets (*Tbl. 3*).

Based on the data presented in the table regarding the analysis of the share of IT services in the total export of services from Ukraine, India, Brazil, Poland, and the Czech Republic during 2020–2022, it can be stated that overall, there are significant differences in the dynamics of this indicator among the countries. These differences are determined by varying levels of IT industry development, the structure of service exports, and the specifics of economic processes.

India demonstrates a decline in the share of IT services in its total export of services, decreasing from 32.2% in 2020 to 30.9% in 2022. This trend may indicate increased competition between service sectors influencing the country's export structure. Brazil, in contrast, exhibits stable growth in the IT service share, rising from 7.5% in 2020 to 10.1% in 2022. The absolute change over three years amounted to 2.6%, while the relative increase was 34.67%. Notably, significant growth in 2021 (+1.1%, or 14.67% relative increase) indicates a gradual strengthening of the IT sector's position in the country's export structure, representing a positive signal for economic development. Poland shows consistent growth in the share of IT services within total exports, increasing from 12.3% in 2020 to 12.8% in 2022. The dynamics reflect steady progress, with annual increments of +0.4% in 2021 and +0.1% in 2022, suggesting sustainable development of the IT

Table 3

Analysis of the share of IT services exports in total services exports of Ukraine. India. Brazil. Poland and the Czech Republic in 2020–2022

Country	Share of IT services exports in total exports of services, %			Absolute deviation, +/–			Relative deviation, %		
	2020	2021	2022	2021/ 2020	2022/ 2021	2022/ 2020	2021/ 2020	2022/ 2021	2022/ 2020
India	32.2	32.7	30.9	0.5	–1.8	–1.3	1.55	–5.50	–4.04
Brazil	7.5	8.6	10.1	1.1	1.5	2.6	14.67	17.44	34.67
Poland	12.3	12.7	12.8	0.4	0.1	0.5	3.25	0.79	4.07
Czech Republic	16.3	16.4	15.8	0.1	–0.6	–0.5	0.61	–3.66	–3.07
Ukraine	32.3	37.8	44.2	5.5	6.4	11.9	17.03	16.93	36.84

Source: compiled based on [9].

sector within the country's export structure. The Czech Republic, however, recorded a decline in the share of IT services, decreasing from 16.3% in 2020 to 15.8% in 2022. The most significant reduction occurred in 2022 (–0.6%, or –3.66% relative decline), indicating a shift towards other types of services in the country's foreign economic activity.

Ukraine shows the most substantial growth in the share of IT services among the analysed countries, increasing from 32.3% in 2020 to 44.2% in 2022. The absolute change during this period was 11.9%, with a relative increase of 36.84%. A particularly notable rise occurred in 2021 (+5.5%, or 17.03% relative growth), highlighting the effective integration of the IT sector into the national export strategy despite challenging economic conditions.

Overall, it can be concluded that Ukraine and Brazil exhibit the highest growth rates in IT service exports, confirming the dynamic development of their IT sectors and their significant role in the structure of service exports. Poland is characterised by stable growth, whereas the Czech Republic and India experience a reduction in IT service shares, potentially necessitating adjustments to industry development strategies to maintain competitiveness.

Thus, a comprehensive approach to economic analysis of the IT market not only determines its current state but also enables forecasting future trends, taking into account factors of digital transformation and industrial intellectualisation. Summarising the obtained results, it is evident that the current stage of IT industry development in Ukraine is closely aligned with global trends of digital transformation and the widespread implementation of smart technologies in industry. Forecasting the sector's further development requires consideration of both internal factors (growth in the number of IT enterprises, wage levels for developers, and innovation activity) and external influences – demand for digital solutions, global market trends, and challenges associated with business relocation.

Economic and mathematical modelling, particularly through regression analysis and time series methods, allows for predicting key parameters of the IT sector. Digital transformation acts as a catalyst for the intellectualisation of production processes, including the implementation of automated control systems, big data analytics, and artificial intelligence. In this context, the development of the IT industry is strategically vital for enhancing economic stability and improving the country's competitiveness.

Enhancing the level of industrial intellectualisation promotes the creation of high-tech products with greater added value, stimulates demand for innovative IT solutions, and expands the role of IT services in the structure of national exports.

The implementation of forecasting strategies should rely on the development of human capital, the improvement of infrastructure for digital innovations, and should foster international cooperation within global technological ecosystems.

To strengthen Ukraine's position in the international IT services market, despite major external challenges, it is advisable to create a favourable investment climate, develop educational programmes for training professionals, and support the introduction of new technologies.

One of the key results of the conducted study is the development of an economic and mathematical framework, which enables the forecasting of further development of the IT sector in Ukraine.

Moreover, the proposed models facilitate the analysis of relationships between identified param-

eters and determine their impact on the state and prospects of IT industry development, considering current requirements and challenges. The models are based on the analysis of five key indicators that significantly influence industry growth under contemporary conditions. The first indicator is the number of IT enterprises, reflecting the institutional base and scale of the industry. The second parameter is the average developer salary in the market, serving as an indicator of the attractiveness of professions and the competitiveness of human resources in the sector. The third indicator is the USD exchange rate, which affects pricing policies and profitability levels, particularly in export-oriented operations. The fourth measure is the proportion of innovative products implemented, indicating the sector's technological level and its ability to create competitive advantages. The fifth parameter is the number of IT specialists, demonstrating the availability of qualified personnel and the potential for market expansion.

For forecasting IT service export volumes – a key market indicator – and assessing the current state of the IT industry, two models were selected: multiple linear regression and an autoregressive integrated moving average (Auto ARIMA) model [10]. The Auto ARIMA model offers high accuracy and accounts for seasonal fluctuations when forecasting quarterly data for 2023, as well as 2024–2025. In contrast, the multiple regression model enables the analysis of various factors influencing the current state of the IT market in Ukraine. The efficiency and accuracy of these models depend on several factors, including the quality and availability of indicator values, the correct choice of independent variables, result interpretation, and limitations in selecting parameters.

When constructing a multiple linear regression model, it is crucial to adhere to a defined sequence of actions. Therefore, the initial step involves collecting the necessary data for modelling the market conditions of the IT industry. For this model, the values of key economic indicators were gathered for the period from 2010 to 2023 (*Tbl. 4*).

After data collection, it is essential to proceed with analysis, recognising that these indicators serve as industrial markers of market conditions and reflect structural transformations driven by both internal and external factors.

The export of IT services demonstrated stable growth throughout most of the analysed period, peaking in 2022. This trend highlights Ukraine's strengthening position as a provider of intellectual services in the global market. However, the decline in export volumes in 2023 signals new challenges related to global economic instability and the domestic situation.

During the analysed period, the number of IT enterprises increased until 2021, reflecting market expansion and growing interest in the sector. Nevertheless, the subsequent decline may indicate adverse effects on market competition, increasing concentration, or the impact of economic crises. The peak in the number of enterprises in 2021 illustrates rising market demand and interest in the sector, driven by growing demand for IT services and the implementation of innovative technologies.

Alongside the increase in enterprises, a gradual rise in the average salary of developers was observed, indicating heightened demand for skilled professionals in the IT industry.

The exchange rate dynamics of the hryvnia against the US dollar significantly influenced IT sector development. Exchange rate increases created additional opportunities for higher foreign currency revenues, particularly through higher export values, but simultaneously complicated operational stability by introducing financial risks related to inflationary processes and exchange rate volatility [14; 15].

Special attention should be given to the analysis of the volume of innovative product sales. The data reveal a stable increase in this indicator only in recent years, signalling a gradual shift from traditional services towards the development of high-tech products with greater added value. This shift strengthens the sector's strategic position and underscores its focus on innovation-driven growth.

The number of employees in the IT sector consistently grew, confirming its high attractiveness to the workforce. Labour market expansion in this domain further indicates its dynamic growth and promising prospects.

Thus, the analysis of key indicators of the Ukrainian IT industry demonstrates its resilience and potential, as well as its adaptability to external challenges. Growth in exports, innovation development, and increased employment create a foundation for further strengthening the sector. However, ensuring long-term stability requires considering the impact of macroeconomic and global factors, as well as implementing both tactical and strategic planning for the IT sector's development.

Hence, the obtained data and conducted analysis confirmed the relevance and validity of constructing a multiple linear regression model to simulate the market conditions of the IT industry.

The general form of the multiple linear regression model equation can be expressed as follows:

$$y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5, \quad \textbf{(1)}$$

where y – the volume of IT service exports;

x_1 – the number of IT enterprises;

Table 4

Values of input variables for modelling the market conditions of the IT industry, 2010–2023

Year	IT services export, million UAH	Number of enterprises, units	Average developer salary, USD	Exchange rate (1 USD), UAH	Share of innovative product sales, %	Number of employees, persons
2010	3215.84	4684.00	1662.00	7.96	3.8	44792
2011	5296.90	5148.00	2000.00	8.05	3.8	53832
2012	7533.48	5220.00	1900.00	8.04	3.3	73791
2013	10607.32	6070.00	2000.00	8.21	3.3	90712
2014	24405.00	5633.00	2000.00	16.27	2.5	114609
2015	40699.20	5961.00	1750.00	24.4	1.4	110254
2016	52930.00	5350.00	1600.00	26.8	4.0	123263
2017	68958.75	6264.00	1800.00	27.75	0.7	139866
2018	88110.00	7003.00	2000.00	27.5	0.8	164656
2019	98900.10	8063.00	2250.00	23.7	1.3	195354
2020	141481.90	8433.00	2500.00	28.15	1.9	214576
2021	188710.74	8822.00	3300.00	27.18	4.80	257581
2022	294694.90	6556.00	3400.00	40.1	5.80	265577
2023	256433.24	6795.00	3300	38.12	6.30	271699

Source: compiled based on [11–16].

x_2 – the average developer salary in the market;
x_3 – the exchange rate of 1 US dollar;
x_4 – the share of innovative product sales;
x_5 – the number of IT specialists employed;
b_0, b_1, b_2, b_3, b_4, b_5 – model parameters.

Quarterly data on IT service exports are crucial for analysis and determining future trends in the development of the IT industry, especially for constructing Auto ARIMA models for forecasting export volumes based on historical data. Breaking the data down into quarters will allow for more accurate predicted values of IT service exports, which is essential for modeling the dynamic and rapidly changing IT sector.

For the calculation of model parameters, data were collected for modeling the IT industry market conditions for the years 2010–2023. Based on the collected indicators, an input data matrix was constructed (*Tbl. 5*).

The results of constructing the model, including the coefficients of determination and statistical significance, are presented in *Fig. 1*. Based on the obtained results, it can be concluded that the coefficient of determination is 0.985, meaning that 98.5% of the variation in variable Y is explained by the model used. The significant variables are X_2 and X_3, i. e., the average salary of developers and the exchange rate of 1 USD, as their p-values are below the standard significance level of 0.05. Overall, it can be stated that the model itself is also significant, as its p-value is below 0.05.

Table 5

Input data matrix for the construction of the multiple linear regression model

Y	X_1	X_2	X_3	X_4	X_5
3215.84	4684.00	1662.00	7.96	3.8	44792
5296.90	5148.00	2000.00	8.05	3.8	53832
7533.48	5220.00	1900.00	8.04	3.3	73791
10607.32	6070.00	2000.00	8.21	3.3	90712
24405.00	5633.00	2000.00	16.27	2.5	114609
40699.20	5961.00	1750.00	24.4	1.4	110254
52930.00	5350.00	1600.00	26.8	4.0	123263
68958.75	6264.00	1800.00	27.75	0.7	139866
88110.00	7003.00	2000.00	27.5	0.8	164656
98900.10	8063.00	2250.00	23.7	1.3	195354
141481.90	8433.00	2500.00	28.15	1.9	214576
188710.74	8822.00	3300.00	27.18	4.80	257581
294694.90	6556.00	3400.00	40.1	5.80	265577
256433.24	6795.00	3300	38.12	6.30	271699

Source: compiled based on [11–16].

To eliminate multicollinearity, we will apply the principal component analysis (PCA) method to the independent variables. Fig. 1 shows the values of the

```
Standard deviations (1, .., p=5):
[1.8953074429544328 1.1239940694373376 0.6775456955978386 0.24812288434190233 0.0918110985082994]

Rotation (n x k) = (5 x 5):
          PC1       PC2       PC3       PC4       PC5
X1  0.417796 -0.482468  0.557682  0.448037  0.284473
X2  0.508230  0.249391  0.285209 -0.727335  0.262957
X3  0.464191 -0.150070 -0.770227  0.113598  0.394780
X4  0.239916  0.820479  0.091188  0.507070  0.061795
X5  0.542325 -0.096547 -0.077986  0.014898 -0.830818
Importance of components:
                            PC1       PC2       PC3       PC4       PC5
Standard deviation      1.895307  1.123994  0.677546  0.248123  0.091811
Proportion of Variance  0.667121  0.234624  0.085256  0.011433  0.001565
Cumulative Proportion   0.667121  0.901746  0.987001  0.998435  1.000000
```

Fig. 1. Values of obtained indicators when applying the PCA method

Source: developed by the authors.

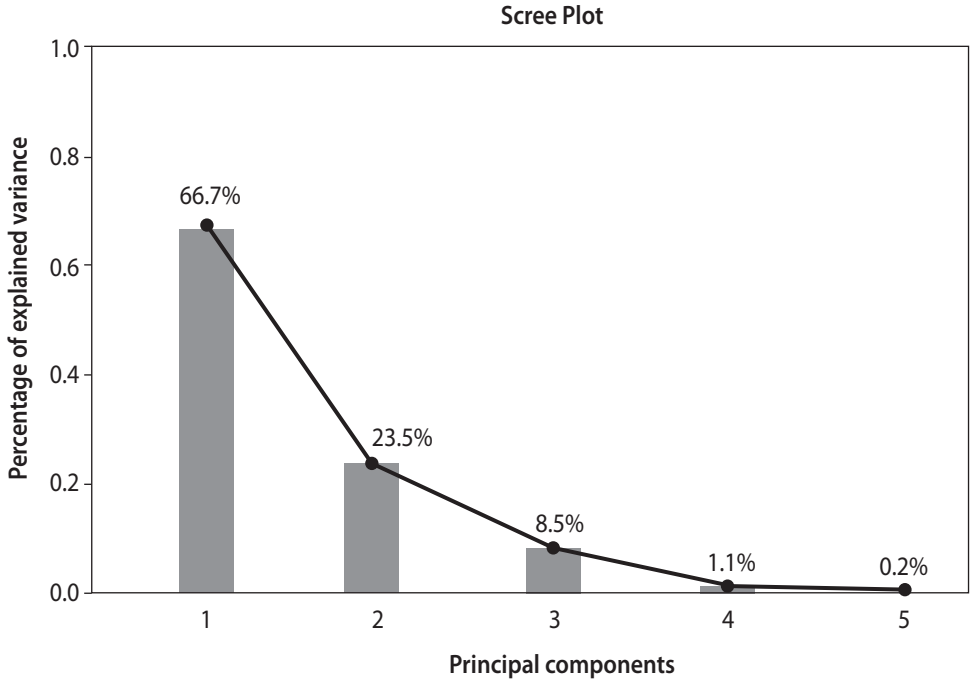

Fig. 2. Visualization of obtained data when applying the PCA method

Source: developed by the authors.

standard deviation indicators, the variance share, and the cumulative share.

Thanks to the visualization of the obtained data, it can be concluded that the first component (PC1) explains 66.71% of the total variation, the second component (PC2) explains 23.46%, and the remaining components (PC3, PC4, PC5) account for a negligible portion (8.53%, 1.14%, and 0.16%, respectively). Together, the first two components explain 90.18% of the total variation (*Fig. 2*). Therefore, for further analysis and model construction, we retain the first two components, as they preserve the majority of the information from the original variables and significantly reduce the dimensionality of the data set.

It is possible to roughly estimate the contribution of each factor to the final model. Therefore, we will build component models represented by their coefficients in the decomposition through the initial independent variables.

The equation of the first principal component model:

$$PC_1 = 0.417796 \cdot X_1 + 0.5082230 \cdot X_2 + \\ + 0.464191 \cdot X_3 + 0.239916 \cdot X_4 + 0.5423252 \cdot X_5. \quad (2)$$

The equation of the second principal component model:

$$PC_2 = -0.482468 \cdot X_1 + 0.249391 \cdot X_2 - \\ 0.150070 \cdot X_3 + 0.820479 \cdot X_4 - 0.096547 \cdot X5. \quad (3)$$

A new data frame will be created with the components and dependent variable, and the results are shown in *Fig. 3*.

	PC1	PC2	target
0	-2.385838	1.109171	-0.960747
1	-1.876982	1.052974	-0.938118
2	-1.862693	0.719371	-0.913798
3	-1.361356	0.403090	-0.880374
4	-1.094483	0.046663	-0.730340
5	-1.019014	-0.820238	-0.553159
6	-0.788998	0.549495	-0.420163
7	-0.611513	-1.338693	-0.245869
8	-0.012194	-1.526794	-0.037621
9	0.679936	-1.586084	0.079708
10	1.432542	-1.429884	0.542736
11	2.904947	0.090182	1.056295
12	2.985650	1.303055	2.208751
13	3.009995	1.427690	1.792699

Fig. 3. Data of components and dependent variable

Source: developed by the authors.

Let us now proceed to constructing the multiple linear regression model based on the first two component models (*Fig. 4*).

Based on the obtained results, we construct the general equation of the multiple linear regression model based on the two component models, which will be used for economic-mathematical modeling of the IT industry market:

$$Y = 0.5287 \cdot PC_1 + 0.1303 \cdot PC_2. \quad \textbf{(4)}$$

According to the obtained results, the coefficient of determination equals 0.952, meaning that 95.2% of the variation in the dependent variable is explained by the model used. The significance coefficients for PC_1 and PC_2 are below the standard significance level of 0.05, indicating that these components show a high quality of the linear relationship found.

Next, we proceed to calculate the modeled values of the dependent variables to assess the current state of the IT industry market, obtained through economic-mathematical and computer modeling.

First, the new calculated values of the indicators are computed in standardized form, and then we transition from standardized data to absolute values in the initial units of measurement.

Given the result, the modeled values of IT service exports differ from the actual values; however, the difference between them is moderate. The modeled and actual IT service export data will be represented through graphs (*Fig. 5*).

The graph illustrates the dynamics of actual and modeled values of IT services export in millions of hryvnias from 2010 to 2023, allowing a visual assessment of the accuracy of the proposed forecasting model at various stages. Let us examine in detail each of the obtained modeled values to evaluate the effectiveness and reliability of the model.

In 2010, there is a significant discrepancy between the actual (3,215.84 million UAH) and modeled (–11,142.78 million UAH) export values, indicating a substantial inaccuracy of the model in forecasting. In 2011, the situation improves considerably, although

OLS Regression Results

Dep. Variable:	target	R-squared:	0.952
Model:	OLS	Adj. R-squared:	0.944
Method:	Least Squares	F-statistic:	109.8
Date:	Sat, 18 May 2024	Prob (F-statistic):	5.38e-08
Time:	15:58:34	Log-Likelihood:	1.4371
No. Observations:	14	AIC:	3.126
Df Residuals:	11	BIC:	5.043
Df Model:	2		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	0	0.066	0	1.000	-0.145	0.145
PC1	0.5287	0.036	14.666	0.000	0.449	0.608
PC2	0.1303	0.061	2.144	0.055	-0.003	0.264

Omnibus:	1.488	Durbin-Watson:	2.521
Prob(Omnibus):	0.475	Jarque-Bera (JB):	0.160
Skew:	-0.073	Prob(JB):	0.923
Kurtosis:	3.502	Cond. No.	1.83

Fig. 4. General results of building the model based on component models

Source: developed by the authors.

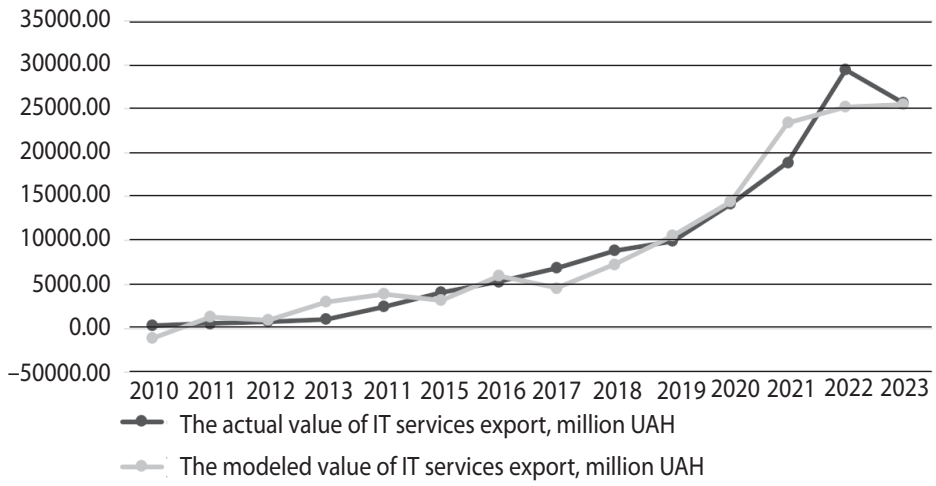

Fig. 5. Comparison of the modeled and actual values of IT services export in Ukraine

Source: compiled based on [11].

the modeled value still significantly exceeds the actual export volume, with the model's trend becoming more realistic compared to the previous year. Between 2012 and 2015, a growth trend in modeled values is observed, with the modeled value for 2012 being quite close to the actual one, while in 2013–2015, the model significantly overestimates the volume of IT services exports. In the period from 2016 to 2019, the modeled values are closer to the actual values in 2016 and 2019, while in 2017, there is some underestimation of exports, and in 2017 and 2018, there is a gradual increase in the modeled value, which noticeably differs from the actual one. In 2020 and 2023, the model nearly exactly reproduces the actual export of IT services, while in 2021 and 2022, deviations in the modeled values are observed.

Thus, the analysis of the modeling results and actual values suggests that the proposed model is adapted to changes in market conditions. The calculated values for the first years of the period significantly differ from the actual values, with large errors. However, for the subsequent years, the model demonstrates high accuracy and low error values, which allows us to conclude that the model is effective. Nonetheless, further improvements and regular data updates are necessary to enhance the accuracy of the forecasted values when modeling the export volume of IT services in the future.

The evaluation of the quality of the econometric modeling allows us to draw conclusions about the feasibility of using the constructed model to obtain forecasted values of the IT services export indicator.

Now, let us calculate the value of the coefficient of determination:

$$R^2 = \sqrt{\frac{112756876056.80}{118402727361.79}} = 0.952. \qquad (5)$$

Considering the obtained result, it can be concluded that the constructed model explains 95.2% of the total variance of the studied variable, meaning it accurately describes the relationship between the data.

The construction of the Auto ARIMA model will be based on the actual values from 2016 to 2022 (*Tbl. 6*).

Table 6

Input data for building the Auto ARIMA model

Year	Quarter	Export, million UAH
1	2	3
2016	1	11926
	2	12542.4
	3	13426.8
	4	15034.8
2017	1	14874
	2	16539
	3	17177.25
	4	20368.5
2018	1	19085
	2	21175
	3	22577.5
	4	25272.5
2019	1	21330
	2	23865.9
	3	25122
	4	28582.2
2020	1	33217
	2	32625.85
	3	35384.55
	4	40254.5

End of the Table 6

1	2	3
2021	1	39247.92
	2	43623.9
	3	48625.02
	4	57213.9
2022	1	80159.9
	2	69894.3
	3	69814.1
	4	74826.6
2023	1	63851.00
	2	64880.24
	3	62745.52
	4	64956.48

Source: compiled based on [11–16].

We will conduct a comparative analysis of the actual and forecasted values of IT services export volume (*Fig. 6*).

The forecasted values are overestimated compared to the actual values, particularly in the third and fourth quarters of 2023. This is because not all factors that could influence the export of IT services, such as changes in the global economy and the political situation in Ukraine, were taken into account. In addition, it is important to note that the Auto ARIMA model was built based on data from the export of IT services between 2016 and 2022. However, in 2022, the full-scale invasion of Russia into Ukraine began, which significantly affected the value of the examined indicator.

We will forecast the export volume of IT services for the four quarters of 2024–2025 by building an Auto ARIMA model using Simple ML for Sheets based on the actual data from 2016-2023.

To visually present the actual and forecasted values, we will create a graph showing the dynamics of IT services export in Ukraine for 2016–2023 and present the forecasted values for the four quarters of 2024–2025 (*Fig. 7*).

According to the forecast, it is expected that the export of IT services from Ukraine will continue to grow in 2024–2025, with the highest forecasted values observed for the 4th quarter of 2024 and accordingly in 2025.

CONCLUSIONS

The study of the preconditions for the intellectualization of industry based on digital transformation demonstrated the strategic importance of the IT industry for the Ukrainian economy. The analysis showed that the IT sector exhibits high growth rates in exports, business development, and employment growth, creating a foundation for technological modernization of production processes. However, in 2023, a decrease in export volumes by 14.3% was observed due to the impact of the war, business relocation, and reduced demand for digital services, highlighting the need to adapt the industry's development strategy to new conditions.

The applied economic-mathematical models, including regression analysis and time series models, allowed for the identification of key factors influencing the dynamics of the IT industry. Among them, the most significant influences are the exchange rate, number of enterprises, average wage, employment, and share of innovative products. The forecasting results confirmed the importance of a comprehensive

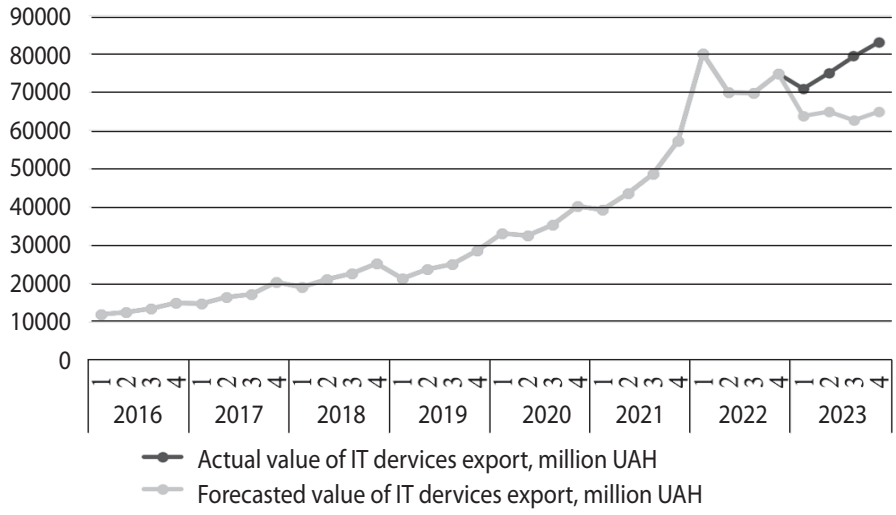

Fig. 6. Actual quarterly values for 2016–2023 and forecasted values of IT services export for the 4th quarters of 2023

Source: compiled based on [11].

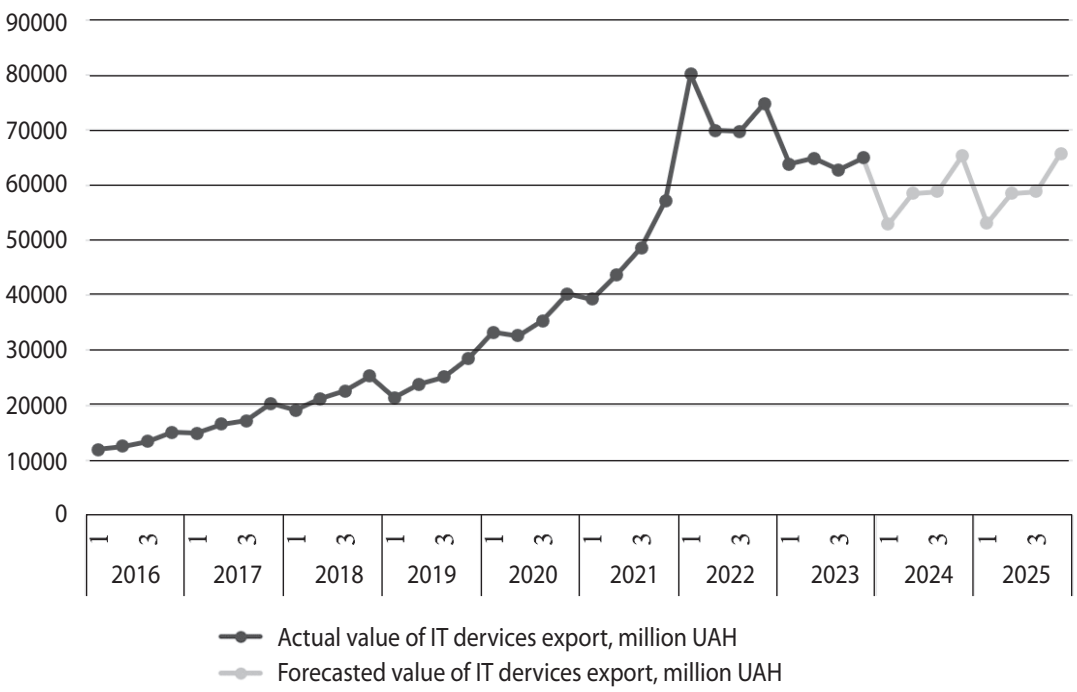

Fig. 7. Actual quarterly values for 2016–2023 and forecasted values for IT services export for the four quarters of 2024–2025

Source: compiled based on [11–16].

approach to managing the IT sector to ensure its stable development.

Digital transformation is a key precondition for the intellectualization of industry, contributing to the adoption of high-tech solutions, automation, artificial intelligence, and big data analytics. This ensures the creation of high added value products, achieves global market competitiveness, and promotes the modernization of the economy.

To accelerate the intellectualization of industry in Ukraine, efforts should focus on developing human capital, stimulating innovation, creating favorable conditions for investment in digital technologies, and supporting international cooperation. The integration of the IT industry and digital technologies should become a key component of the national strategy for economic modernization and enhancing its resilience amid global challenges. ■

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