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THE USE OF DATA SCIENCE MODELS TO ANALYZE THE DEVELOPMENT STATE OF THE EU AND UKRAINE IT SECTOR

The paper is devoted to the assessment of the development state of the EU and Ukraine's IT sector. For the countries of the EU, the IT market is a priority direction and a strategic goal of the development of the digital economy. Ukraine is also trying to introduce the use of digital technologies in all areas of activity. The purpose of the study is to develop economic and mathematical models for assessing and analyzing the level of development of the IT sector in the EU and Ukraine, which allow for the analysis of the strengths and weaknesses of this sector, to form recommendations. The analysis of the features of the IT sector development was carried out and key indicators were selected. A set of models for assessing the level of development of the IT sector of the economy in the EU has been developed. Classification models of EU countries by the level of development of the IT sector were built using cluster analysis methods. The analysis of the digital development state of Ukraine on the European market was carried out using discriminant analysis. The regression model for forecasting the level of development of the IT sphere in Ukraine has been developed. The results of the research can be used during the implementation of global and regional programs for the development of the IT sector in the EU countries and Ukraine.

Keywords: *IT sector, digital economy, model, cluster analysis, discriminant analysis, multiple regression.*

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ВИКОРИСТАННЯ МОДЕЛЕЙ DATA SCIENCE ДЛЯ АНАЛІЗУ СТАНУ РОЗВИТКУ ІТ-СЕКТОРУ ЄС ТА УКРАЇНИ

Стаття присвячена оцінці стану розвитку ІТ-сектору ЄС та України. Для країн ЄС ІТ-ринок є пріоритетним напрямком і стратегічною метою розвитку цифрової економіки. Україна також намагається запровадити використання цифрових технологій у всіх сферах діяльності. Метою дослідження є розробка економіко-математичних моделей для оцінки та аналізу рівня розвитку ІТ-сектору в ЄС та Україні, які дозволяють аналізувати сильні та слабкі сторони цього сектору, формувати рекомендації. Проведено аналіз особливостей розвитку ІТ-сектору та обрано ключові показники. Розроблено набір моделей для оцінки рівня розвитку ІТ-сектору економіки ЄС. Методами кластерного аналізу побудовано моделі класифікації країн ЄС за рівнем розвитку ІТ-сектору. Аналіз стану цифрового розвитку України на європейському ринку проведено за допомогою дискримінантного аналізу. Розроблено регресійну модель для прогнозування рівня розвитку ІТ-сфери в Україні. Результати дослідження можуть бути використані під час реалізації глобальних та регіональних програм розвитку ІТ-сектору в країнах ЄС та Україні.

Ключові слова: ІТ-сектор, цифрова економіка, модель, кластерний аналіз, дискримінантний аналіз, множинна регресія.

Introduction

The development of the country's IT sector is impossible without the use of the digital economy. After all, the digital economy of the modern world is the demand of the century, since the use of digital technologies covers all spheres of life, and also allows to use of new opportunities. The development of the Internet, mobile communications, and online services is the main tool for the formation of the digital economy and the IT sector of the country as a whole. These processes affect all sectors of the economy and social activity, production, medicine, education, finance, transport, etc.

The expansion of digital infrastructure contributes to the development of the international economy. For the countries of the European Union, the IT market is a priority direction and a strategic goal of the development of the digital economy. Ukraine is also trying to implement the use of digital technologies in all spheres of activity. In the last decade, the IT market has been developing at a tremendous speed. The development of the Internet, mobile communications, and online services is a basic tool for the formation of the IT sector of the country's economy. After all, they affect the socio-economic activity of the enterprise, education, finances, health care, etc.

In the international sense, the digital economy is a networked, systemically organized spatial structure of relationships between business entities. The development of the IT sector is necessary to create convenient platforms for comfortable interactions between the state and citizens, to reduce the administrative burden on business, and to increase the transparency and efficiency of the economy and the entire state administration system. Therefore, the digital economy becomes an impetus for the development of advanced technologies and their platforms. These technologies and platforms include advanced analytics, distributed wireless networks, mobile devices, and social networks.

Literature Review

The issue of digitization in the context of the country's development was raised in many works of foreign scientists Josef-Peter Schöggl, Magdalena Rusch, Lukas Stumpf and Rupert J. Baumgartner [16], Benhamou Salima [3], Bingnan Guo, Yu Wang, Hao Zhang, Chunyan Liang, Yu Feng, Feng Hu [4], Qihang Yang, Huizi Ma [24], Dmitry Plekhanov [5], Ke Rong [17], Gregory Vial [13], and others. Among domestic scientists working on the problems of assessing the state of digital and telecommunications development of Ukraine, should be singled out such as V. V. Apalkova [28], O. V. Dannikov [7], H. H. Golovenchik [12], O. Gudz [14], S. V. Kolyadenko [18], G. B. Sokolova [25], Y. Zelenkov, J. Sharsheeva [29], O. Polous [23], S. Kvitka [19], M. A. Demyanchuk [8], M.V. Rudenko [25], and others. Existing studies and publications in the field of assessing the level of telecommunication progress in the context of modern processes of countries` digitization [10-18, 22-30] helped to identify a number of approaches aimed at researching issues of the countries digitization effectiveness and building their ICT rating. Thus, works [7] [10] proved that the existing models for assessing the level of the country digitization, which are based on the usual indicators of economic welfare based on GDP, do not take into account other important social factors. This led to the creation of a number of special generalizing digital development indicators: the global index of electronic government development, the index of network readiness, and the index of information and communication technologies development. In the study [6] [12], in the context of the innovations spread, the need to improve the existing tools for comparative analysis and rating of e-government was proven, and the strengths and weaknesses of six areas of the e-government index evaluation were presented, it was shown that the areas that include expanding the functions and capabilities of e-government sites have prerogative over others. Josef-Peter Schöggl, Magdalena Rusch, Lukas Stumpf, and Rupert J. [16] analyze the relationship between the development of digital technologies and sustainable development. S. Benhamou [3] analyzes the relationship between artificial intelligence and the future development of the workforce and further explores the possibilities of using big data to change approaches to the provision of public services. Taking into account that the infrastructure of the digital economy is not limited to the information and communication sector (ICT), but also includes such components as human capital, a favorable business climate, and effective management, M. V. Rudenko [25] singled out such subsystems of ensuring the digital economy as technical, information-technological, human resources, normative-legal and financial-economic, and conducted an analysis of digitalization rating indices. H. H. Golovenchik [12] forms an original rating system for evaluating the development of the digital economy, which contains 22 indicators, combined into five sub-indices. In our opinion, among the indicators that should be taken into account for the calculation of the integral indicator of the standard of living state in the country, an important place should be given to such factors as the availability and formation of research competencies, training of specialized personnel, information security, and infrastructure, economic indicators digitalization and the social effect of the digitalization implementation. The author M. A. Demyanchuk [8] proposes to classify the balanced indicators into internal and external, taking into account the influence of external and internal factors on the activity of a telecommunications enterprise and the cost of its business. The integrated index of digital development of territorial grouping, proposed by the authors Kvitka S., Tytarenko O., and Mazur O. [19], is presented as a tool for comparing the degree of development and use of digital technologies in administrative-territorial units. According to their proposal, it should be built on the basis of 63 indicators in 8 areas of digital development, which allows comparison of territories in an administrative section.

Thus, the analysis of modern approaches to assessment allowed us to conclude that there are significant contradictions in approaches to the formation of indicators for assessing the level and state of digital development of the country and its individual territorial units. Achievements in the development of approaches to the assessment of digital development should include detailed analytical reviews of the development of the IT industry of Ukraine by research groups, as well as the prerequisites for the development of the information and telecommunications sector of the economy. In many studies, the need for constant monitoring of the country's positioning among other countries of the world based on global indices of digital development is particularly emphasized, as this makes it possible to conduct a comparative analysis of the pace of the country's digital development and the expediency of intensifying digital transformations and reforms.

Today, there is a problem of the lack of a systematic and unified methodology for assessing the digital development of the country at different levels of the hierarchy, and the assessment of the state of digitalization of the country also requires detailed justification from the point of view of system analysis and mathematical modeling. As often as possible, separate systems of unrelated or mutually complementary indicators are used, which do not allow for the comprehensive assessment of the level and analysis of the state of digitization of the country in all sectors.

Desynchronization during the formation of statistical bases of indicators for the assessment of the state of digitalization and telecommunication development of the countries of the European Union, its associated members, other European countries and the world is a significant obstacle to conducting an up-to-date assessment of the state of digitalization of the country. In addition, on the one hand, the lack of a comprehensive approach, and on the other hand, the insufficient information base of the evaluation indicators of telecommunications development, digital development in general, which are provided by the State Statistics Service of Ukraine, create obstacles for assessing the modern realities of digitalization of the country. This is a significant obstacle in harmonizing the national methodology for assessing the country's digital development and global approaches.

Problem Formulation, Methods

The purpose of the work is to develop economic-mathematical models of assessment, analysis, and forecasting of the level of the IT sector development in Europe and Ukraine at different levels of the management hierarchy, which allows for analysis of the weak and strong sides of this sector, to formulate recommendations. In order to achieve the set goal, the work proposes to implement the following tasks: analyze the features and trends of the development of the IT sector; develop a set of models for assessing the state of development of the IT market in countries by machine learning and Data Science methods; to build classification models of European countries according to the level of IT development; develop models for assessing the interrelationship of IT industry indicators; assess Ukraine's position on the European IT market and offer recommendations for improving the IT sphere. The following conceptual scheme of modeling the development of the IT sector of the economy of EU countries and Ukraine is proposed.

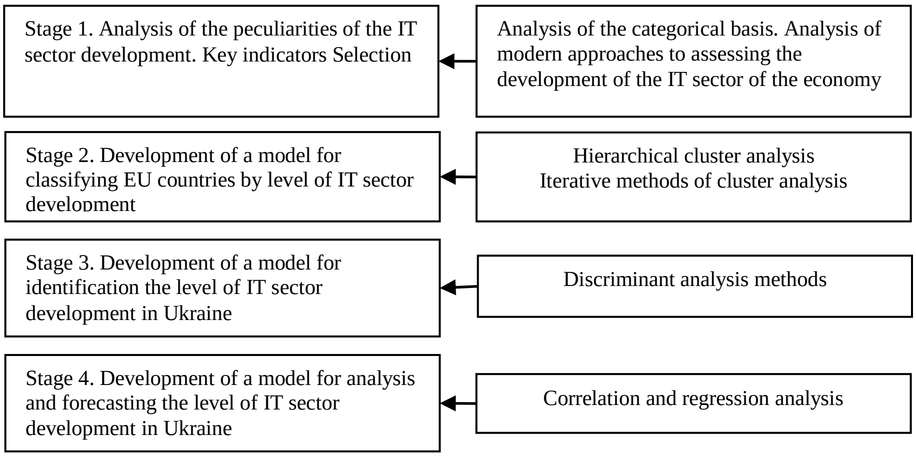

Fig. 1. Conceptual scheme of modelling the development of the IT sector of the economy of EU countries and Ukraine

According to the proposed conceptual scheme, the first stage involves a thorough analysis of the IT sector development peculiarities, as well as the selection of key indicators reflecting the development of IT technologies in the countries. In the second stage of the study, the EU countries are classified according to the level of IT sector development. The third stage of the study determines the level of IT sector development in Ukraine in comparison with European countries. At the fourth stage of the study, the level of the IT sector development in Ukraine is analyzed and forecasted by the methods of correlation and regression analysis.

Thus, the proposed complex of models for analysis and forecasting the level of the IT sector development based on the methods of multidimensional analysis and regression analysis allows to assess the country's belonging to one of the clusters, to analyze the influence of the main indicators on the development of information and communication technologies in the country, and to forecast the level of the IT sector development in the country.

Findings

In accordance with the proposed conceptual research scheme, we will consider the implementation of each of the models. Thus, at the first stage of the study, among the set of indices reflecting the level of digital technologies development in the country, the following indicators were selected as key indicators of the IT sector development: The ICT Development Index (IDI) [15]; The Networked Readiness Index (NRI) [22]; Global Innovation Index (GII) [11]; E-Government Development Index (EGDI); Global Competitiveness Index (GCI) [27]. These indicators characterize the state of the IT sector by the ratio of the number of scientific organizations, the amount of financing of scientific and innovative works, and the results of activities in the form of the final finished product and technologies. The data was collected as of 2021. Statistica and R-Studio programs were used to implement the proposed models.

At the second stage of the research, a classification model of EU countries by the level of IT sector development based on cluster analysis methods was implemented. Step 2.1 involves determining the optimal number of clusters. For this, the "rock scree" method was used (see Fig. 2).

According to fig. 2, it was hypothesized that the optimal number of clusters is 4, since the graph is smoothed on the fourth cluster. In step 2.2, Ward's hierarchical method was used to visualize the distribution and test the hypothesis about the number of clusters. The output data was standardized, and the Euclidean distance was chosen as the measure of distance. The dendrogram is shown on Fig. 3.

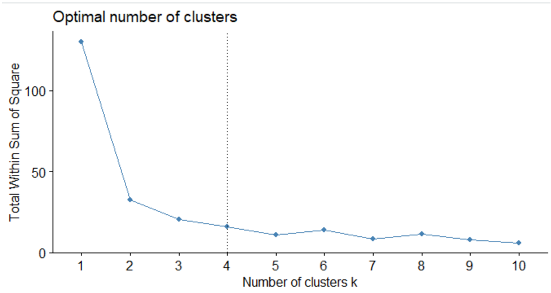

Fig. 2. The "rock scree" graph

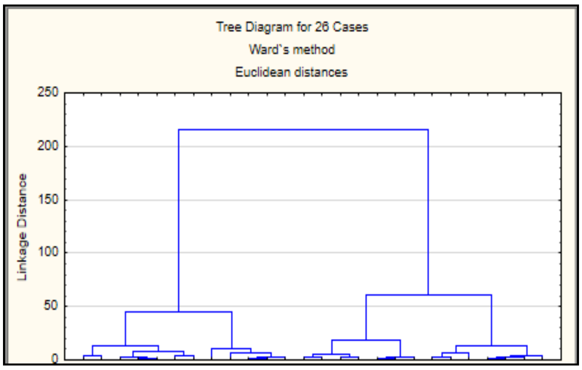

Fig. 3. Ward's method dendrogram

The optimal number of clusters according to constructed dendrogram is 2 or 4. It should be noted that the division into only 2 clusters is uninformative. Therefore, the hypothesis of division into 4 clusters accepted. Further, in step 2.3, the EU countries were grouped into 4 clusters according to the level of IT sector development based on the iterative method of clustering – the k-means method.

At step 2.4, the quality of the performed grouping was evaluated by calculating the values of intergroup and intragroup variances. The results of the dispersion analysis of the assessment of the indicators quality are shown in Fig. 4.

	Analysis of Variance (Spreadsheet104)					
Variable	**Between SS**	df	Within SS	df	F	signif. p
The ICT Development Index	14,151	3	2,6413	22	39,2888	0,000000
The Networked Readiness Index	2850,009	3	189,9793	22	110,0124	0,000000
Global Inovation Index	2128,490	3	182,9737	22	85,3069	0,000000
E-Government Development Index	0,110	3	0,0372	22	21,5919	0,000001
Global Competitiveness Index	8,516	3	0,6509	22	95,9478	0,000000

Fig. 4. Table of dispersion analysis

These descriptive statistics make it possible to carry out a meaningful analysis of the obtained groups of countries and to determine their main characteristics (Table 1).

Table 1

The results of the EU countries grouping by the IT sector development level

Cluster, elements and distance to cluster center	**Characteristics of countries**
First cluster (A): Austria (0.242), Belgium (1.326), France (1.531), Iceland (1.376), Norway (2.742)	Progressive countries. This cluster characterizes the economies of countries with limited but rapidly developing digital infrastructure.
Second cluster (B): Great Britain (1.71), Germany (1.862), Netherlands (0.712), Switzerland (2.852), Denmark (1.382), Finland (1.256), Sweden (1.714)	Highly developed countries characterized by potentially and actually the strongest IT development in Europe. This zone includes countries whose economies are distinguished by both a high level of digitalization and a powerful pace of development of the IT industry.
Third cluster (C): Hungary (1.777), Poland (1.729), Slovakia (2.077), Czech Republic (2.509), Spain (1.983), Italy (1.002), Portugal (0.412)	Moderate development. This cluster includes countries with fairly good development of digital systems. But countries need to pay attention to the growth of IT.
Fourth cluster (D): Bulgaria (2.013), Moldova (2.982), Romania (0.519), Greece (1.054), Serbia (0.753), Croatia (1.440), Montenegro (1.181)	Underdeveloped. This cluster is characterized by a low growth rate of the IT sector. The countries of this zone should take an example from the countries with promising economies in the use of IT technologies as a tool of economic stability

As can be seen from Table 1, the closest to the center of the first cluster is Austria, the minimum distance to the center of the second cluster is the Netherlands, the third is Portugal, and the fourth is Romania. In order to maintain the proper condition of the first cluster countries (progressive countries in terms of development), the following possible directions should be followed, with which many scientists agree: strengthening mobile Internet access, and intensifying its availability and quality to support a high degree of involvement in online business processes; increasing the degree of attracting investments in domestic IT companies, financing digital development projects, training IT personnel and developing applications to create jobs. Countries from the second cluster are highly developed countries that can develop directions: support the implementation of various digital tools for consumers, such as online shopping, digital payments, entertainment, etc.; support and development of digital startups; provision of a fast and affordable Internet connection both on the ground (for example, using a fiber optic connection) and mobile communication. Countries from the third cluster (with a moderate development of the IT sector) should make the following tasks a priority: protecting against digital lag by investing in strong institutional pillars, regulatory environment and capital markets to support new innovations; identifying new technological niches and creating ecosystems that will promote innovation in these areas. Countries from the fourth cluster (underdeveloped) should choose the following priorities for further development: creating an institutional environment that will facilitate the safe and widespread adoption of digital products and services for consumers, especially those that will help improve productivity and create new jobs; support for the development of applications that solve current problems and can become catalysts for the spread of digital tools, for example, digital payment platforms.

At the third stage of the study, a model was implemented to identify the level of the IT sector development in the EU countries and Ukraine based on discriminant analysis. Let's consider the result of the implementation of step 3.1. Thus, linear discriminant functions have the following form:

$$y_1 = -739{,}957 + 68{,}818x_1 + 1{,}73x_2 - 4{,}774x_3 + 195{,}078x_5$$

$$y_2 = -784{,}127 + 64{,}544x_1 + 2{,}285x_2 - 3{,}512x_3 + 189{,}189x_5$$

$$y_3 = -548{,}930 + 58{,}949x_1 + 1{,}545x_2 - 4{,}086x_3 + 167{,}5x_5$$

$$y_4 = -483{,}188 + 61{,}033x_1 + 0{,}443x_2 - 4{,}554x_3 + 168{,}093x_5$$

Using the classification matrix, the number and percentage of correctly classified observations in each of the groups were determined. In step 3.2, was carried out an evaluation of the quality and statistical significance of the discriminant model. Fig. 5 shows the indicators of the discriminant model quality.

Discriminant Function Analysis Summary (Spreadsheet1111)
No. of vars in model: 4; Grouping: class (4 grps)
Wilks' Lambda: ,01752 approx. F (12,50)=15,217 p< ,0000

N=26	Wilks' Lambda	Partial Lambda	F-remove (3,19)	p-value	Toler.	1-Toler. (R-Sqr.)
ICT	0,026742	0,655258	3,332079	0,041467	0,729854	0,270146
NRI	0,026021	0,673419	3,071415	0,052651	0,605505	0,394495
GII	0,029800	0,588025	4,437182	0,015909	0,541652	0,458349
GCI	0,028724	0,610053	4,048276	0,022072	0,550789	0,449211

Fig. 5. Discriminant analysis results

As can be seen from fig. 8 values of the Wilks lambda indicators are close to zero, so a high quality of discrimination is claimed. According to Fisher's criterion, the most significant variables for discrimination are The ICT Development Index, and Global Innovation Index. Next, we calculate the distances between the groups.The groups closest to each other are countries from groups A and B (a cluster of highly developed countries and a cluster of progressive countries), and countries from groups C and D are also close to each other. It is absolutely logical that the most distant groups are countries from groups D and B .During the implementation of step 3.3, it was determined that the IT sector of Ukraine belongs to the relevant group of EU countries. The recognition results are shown in Fig. 6.

Case	Posterior probabilities				
	Observed Classif.	D p = 0.269	C p = 0.269	A p = 0.192	B p = 0.269
Italy	C	0.000209	0.999791	0.0	0.0
Portugal	C	0.000259	0.999741	0.0	0.0
Serbia	D	0.999463	0.000537	0.0	0.0
Croatia	D	0.979496	0.020504	0.0	0.0
Montenegro	D	0.999882	0.000118	0.0	0.0
Ukraine	--	0.999901	0.000099	0.0	0.0

Fig. 6. Recognition results

From the results of the calculations, we can see that Ukraine belongs to the group of underdeveloped countries in the IT sphere. But in Ukraine, there are very large opportunities for the development of this industry, if the country pays attention to the expansion of the IT environment that supports the safe and widespread distribution of digital products and services among consumers – especially if these products contribute to productivity and the creation of new jobs.

At the next stage of the research, regression analysis was used to analyze and forecast the development level of the IT sector of Ukraine. In step 4.1, The ICT Development Index (IDI) was chosen as an endogenous variable, one of the two indices that turned out to be the most statistically significant in the discriminant analysis. The following indicators were selected as exogenous variables: X1 – innovation costs (mln.UAH), X2 – export of services in the field of telecommunications, computer and information services (mln.UAH), X3 – number of IT specialists (mln.UAH), X4 – number of Individual entrepreneurs in the field of IT. At step 4.2, a hypothesis was put forward about the existence of a linear relationship between exogenous and endogenous factors based on the calculated pairwise correlation coefficients. In step 4.3, based on the initial data for the period from 2002 to 2021, estimates of the multiple regression coefficients were found based on the least squares method. The coefficient of multiple correlation R=0.96, which confirms the high closeness of the linear relationship between dependent and independent variables. The value of the coefficient of determination R2 is quite high (0.9266), which means that the forecast is sufficiently accurate. Fisher's test confirms the statistical significance of the regression equation in general, since the calculated value is 47.382 (p-value<0,05). Thus, the built model is adequate, it can describe the input processes with a projection on the output variable. Analyzing the statistical significance of individual exogenous factors of the model using the t-criterion, we see that only X1 and X4 are statistically significant. Analysis of the cyclic autocorrelation coefficient value (0.25) made it possible to conclude that there is no autocorrelation of the residuals. Next, the presence of multicollinearity was checked. There is a very close linear relationship between X1 and X2, which leads to partial multicollinearity. In order to improve the quality of the model, in step 4.5, the specification of the model was refined based on the methods of stepwise inclusion and stepwise exclusion of exogenous factors (Fig. 7).

	Regression Summary for Dependent Variable: Y (Spreadsheet73) R= ,94270783 R?= ,88869805 Adjusted R?= ,87560370 F(2,17)=67,869 p<,00000 Std.Error of estimate: ,44562					
N=20	b*	Std.Err. of b*	b	Std.Err. of b	t(17)	p-value
Intercept			2,363567	0,201962	11,70303	0,000000
X1	0,341839	0,104773	0,000082	0,000025	3,26267	0,004585
X4	0,687827	0,104773	0,000015	0,000002	6,56495	0,000005

Fig. 7. Regression model by stepwise exclusion method

Both obtained models demonstrate high quality and statistical significance, but in the model from fig. 13, multicollinearity remains, therefore, as the final type of regression equation for forecasting the development level of the IT sector in Ukraine, we choose a model obtained on the basis of the stepwise exclusion method:

$$\hat{Y} = 2{,}3636 + 0.000082 X_1 + 0.000015 X_4.$$

In the last step, the IDI value for 2022 was predicted based on the predicted values of X1 and X4. With a probability of 95%, the confidence interval will be as follows:

$$6{,}181 \le 6{,}718 \le 7{,}256.$$

According to the results of the calculations, it can be confidently said that The ICT Development Index is significantly influenced by the costs of innovation and the number of IT-entrepreneurs. The built model provided a fairly tight confidence interval for the predictive value of the IDI. The forecast value of The ICT Development Index is 6.718, which gives the opportunity to hope for growth in the IT sector in 2022. But it is clear that the war has become a tangible shock for the IT sphere in Ukraine, it has also become a great stress for foreign customers and investors. Although most Ukrainian IT specialists continue to work even after the February 24, 2022 invasion. This forecast gives hope that the country's IT sector will gradually grow after the war due to the successful development of Ukraine's digital potential.

Discussion and Conclusion

The work proposes a conceptual model of research that accumulates the main techniques and methods of studying issues in the IT sector, its management and forecasting. A set of models for assessing the development level of the IT sector of the economy in EU countries and Ukraine has been developed. A ranking comparison was made, classification models of European countries were built according to the level of IT development, an analysis of the state of the IT sphere of Ukraine on the European market was carried out, and a forecasting model of the IT sphere of Ukraine was developed.

With the help of cluster analysis methods, it was possible to classify the EU countries according to the development level of the IT sphere. The identification model based on discriminant analysis made it possible to establish that Ukraine belongs to the class of underdeveloped countries in the IT sphere. But in Ukraine, there are very great opportunities for the development of this industry, if the country pays attention to the expansion of the IT environment, which supports the safe and unlimited distribution of digital products and services among consumers. Also, the method of correlation-regression analysis was used in the model part of the work. The constructed multiple regression makes it possible to assess the influence of various exogenous factors on the development of digitalization in Ukraine, which is necessary for the development of an adequate and effective digital policy. The growth of The ICT Development Index is a key factor for ensuring the sustainable development of the IT sphere of the country's economy. The results of the calculations give an opportunity to hope for the growth of the IT sector in the future. It is clear that the war became a tangible shock for the IT sphere in Ukraine, it also became a great stress for foreign customers and investors. But the forecast gives hope that the country's IT sector will gradually grow after the war due to the successful development of Ukraine's digital potential.

Thus, after conducting such a detailed and responsible investigation, it should be recognized that the issue of studying the IT sector of the country's economy remains interesting for new observations and the emergence of scientific, theoretical and practical innovations on this topic.

Prospects for further research include the possibility of developing strategies and trajectories of the digital development of countries groups according to its various components and the study of these groups' behavior, the assessment of the unevenness of their development and the asymmetry of the countries distribution in macroclusters.

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