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Article

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THEORETICAL AND METHODOLOGICAL ASPECTS OF INNOVATIVE-INDUSTRIAL CLUSTER DEVELOPMENT IN THE ERA OF DIGITALIZATION

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Abstract: *This article summarizes the arguments and counterarguments within the scientific debate on the identification of the main theoretical and practical principles of the functioning of innovative-industrial clusters in different countries, as well as the formalization of the impact of digitalization on their activities. The article summarizes scientific approaches to determining the main characteristics and features of the functioning of innovation-industrial clusters. In order to substantiate the theoretical background of the relationship between innovation-industrial clusters' performance and digitalization processes, a bibliometric analysis of the main Scopus publications in this direction is carried out using the VOSviewer toolkit. That made it possible to identify the main essential and contextual clusters of scientific research on relevant topics to characterize the evolutionary patterns of their changes during the analysis period. In order to determine the empirical causality of the impact of digitalization on innovative and industrial development, an integral indicator of innovative and industrial development is developed. The Index considers the measurement parameters and regional features of industrial, entrepreneurial, and innovative development. Indicators were integrated using the principal components analysis and additive convolution. The study modelled the influence proxies of the digital economy on the integrated indicator of innovative and industrial development using panel data regression modelling in the Stata 14.2/SE software. In the paper, it is also identified those determinants of the digital development of the state that depends to the greatest extent on the volatility of the innovative and industrial development of the country using one-factor regression models. The study is conducted for the country sample with 10 countries, including Azerbaijan, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Poland, Romania, and Ukraine. The time horizon of the study covers the period 2009-2021 (or the latest available period). The research results can be useful to scientists, state authorities, and local governments.*
Keywords: industrial and innovative cluster, digitalization, management, panel data, regression modelling.
JEL Classification: C33, E24, J01, O15, O30

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Introduction. In the last few decades, the attention of both representatives of the academic community and practitioners has been focused on studying the advantages and peculiarities of the functioning of innovation-industrial clusters and their role in ensuring economic growth. Clusters, as a rule, are formed based on industrial enterprises existing in the region. Important prerequisites for the development of innovation-industrial clusters were defined by Porter (1998). The scholar emphasized that the existence of a cluster organization of industry allows to increase in labor productivity and stimulates competitiveness, is an activator of innovation processes and also promotes the formation of new businesses within the defined region. As noted by Slaper and Orturaz (2015), «cluster consists of companies, suppliers and service providers, as well as government agencies and other institutions that provide education, information, research and technical support to a regional economy». The same researchers also emphasize that certain industries are characterized by the highest potential for job creation to ensure their functioning. Thus, among those segments of the industry for which cluster formations will provide the largest number of new jobs, scientists (Slaper and Orturaz, 2015) define Upstream Chemical Products, Biopharmaceutical, Music and Sound Recording, Food Processing and Manufacturing, Upstream Metal Manufacturing, Electric Power Generation and Transmission.

Researchers (Yamawaki, 2002; Lines and Monypenny, 2006; Caniels and Romijn, 2005) defined the following advantages of innovative-industrial clusters:

– increasing labor productivity due to the use of outsourcing and vertical integration technologies;

– higher level of quality and increase in the network of coverage of the population with public goods due to the intensification of investment activity;

– activation of the creation of centers of new knowledge and centers of development of creative technologies;

– improvement of organizational and functional characteristics of the economic policy due to closer cooperation of representatives of the academic environment and state authorities;

– increasing the level of loyalty and trust of the population to state and local self-government bodies, which play an important role in the effective functioning of cluster formations;

– ensure the development of human capital through the concentration of high-class personnel and innovative technologies;

– contribute to a more effective solution to the problems of economic and social development arising in the territories of the functioning of innovative industrial clusters, etc.

Thus, scientists note that the cluster approach in the organization of innovative and industrial activity allows for ensuring several positive socio-economic changes, which proves the perspective of this particular form of organization of entrepreneurial activity. Researchers (Lämmer-Gamp et al. 2014) also emphasize a higher level of prospects for creating innovative industrial clusters in emerging industries than traditional ones. Understanding scientists and practitioners of the importance of stimulating the development of innovative-industrial clusters have led to the emergence of special state programs to support their development, especially in stimulating small and medium-sized businesses. According to (Danieles, 2019), in the EU countries, 2.32 billion euros were allocated to finance programs for the development of industrial clusters in the segment of small and medium-sized businesses. According to the same report, «Italy, UK, Germany, Portugal, Poland, France, and Greece are the countries in which funding of above EUR 100 million was envisaged for cluster support in the period 2014-2020». It is worth noting that for EU countries, stimulating the development of industrial clusters is defined as a priority task both at the EU level and at the national level in each country. Since 2008, some state platforms have been created to coordinate efforts to develop innovative industrial clusters (for example, in Austria). At the same time, it is worth noting that most researchers note that one of the main motives for intensifying the development of innovative-industrial clusters is the development of digital technologies and Industry 4.0.

It should be noted that there are a few research aimed at clarification of innovative-industrial clusters development itself (Lämmer-Gamp et al., 2014; Yamawaki, 2002; Lines and Monypenny, 2006; Caniels and Romijn, 2005) and transformation of its functioning in the digital era (Yim et al., 2020; Liu et al., 2022; Lai et al., 2014; Tristão et al., 2013). The lack of empirical studies can be explained by the topic's novelty concerning innovative-industrial cluster development. Moreover, all the existing empirical research on the topic is based on limited analytical data (firms reporting information, questionary results, etc.). Therefore, it does not allow for conducting comprehensive and comparable research. Besides, the digital era started in the late 1980s, but specifically, nowadays, digital technologies have developed dramatically and become an integral part of our personal and business agenda.

Furthermore, the research aims to determine the impact of the determinants of digitalization of the economy on the development of innovative-industrial clusters, but considering the lack of sufficient macro data, the innovative and industrial development of the country will be chosen as a proxy for innovative-industrial clusters development. In order to ensure the sufficiency of measurement indicators, it will be constructed considering the most widely-used indicators of industrial, entrepreneurial, and innovative development. Such an approach allows an understanding of general trends of dependency on innovative and industrial development on digital impetus.

Literature Review. In order to identify theoretical patterns of research on the development of innovative-industrial clusters, a bibliometric analysis of Scopus publications (Scopus, 2022) was carried out using Vosviewer (Vosviewer, 2022). The study covered 2,829 documents with the phrase «industrial cluster» in the title, keywords, or abstract. Publications for 1992-2022 were analyzed. Figure 2 presents the dynamics of their changes.

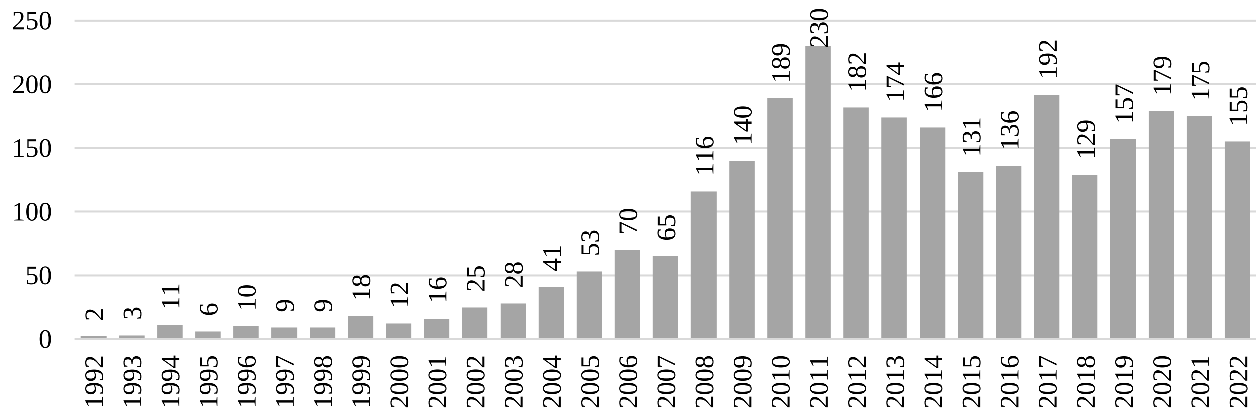

Figure 1. Number of Scopus publications on search request «industrial cluster» for 1992-2022
Sources: developed by the authors on the basis of (Scopus, 2022).

First, it should be noted that during 1992-2007 the interest of scientists in the issue of the development of industrial clusters was quite insignificant (during this period, on average, 23 publications on this topic were published annually). At the same time, during 2008-2022, the intensity of publication activity on this topic increased significantly: during the period, an average of 163 articles were published annually. The maximum number of works on the topic was published in 2011 – 230 publications.

The main substantive and contextual research clusters are revealed based on the bibliometric analysis of 2829 Scopus publications (Scopus, 2022), in the title, keywords or abstracts of with the collocation «industrial cluster». The bibliometric analysis applied the Vosviewer toolkit (Vosviewer, 2022). They can be characterized according to the data in Figure 2.

According to the results of the bibliometric analysis of 2829 Scopus publications (Scopus, 2022) with Vosviewer (Vosviewer, 2022), 275 words/phrases were identified, with which relationships were established within the defined content block of research. According to Figure 2, these words can be combined into 6 contextual clusters, namely:

– red cluster (93 items) – covers scientific studies aimed at determining the influence of the existence of industrial clusters on the development of industry and innovations;

– green cluster (58 items) – includes scientific research aimed at identifying the influence of industrial clusters on solving environmental problems and ensuring sustainable development;

– blue cluster (51 items) – covers scientific research aimed at formalizing the role and prerequisites for the functioning of industrial clusters in the context of ensuring technological development;

– yellow cluster (47 items) – covers scientific studies aimed at identifying the impact of the functioning of industrial clusters on the pollution of water bodies and soils by heavy metals;

– purple cluster (15 items) – covers scientific research aimed at researching logistical aspects in the functioning of industrial clusters;

– turquoise cluster (11 items) – covers scientific studies aimed at determining the branch-specific features of the functioning of industrial clusters.

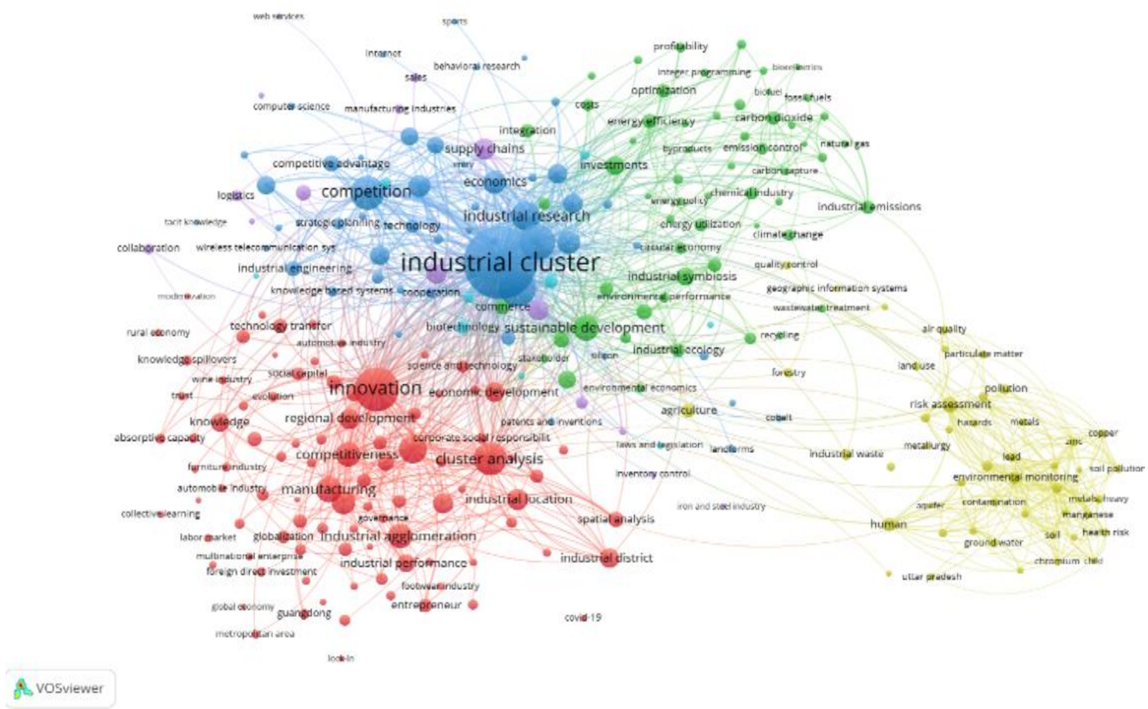

Figure 2. Network visualization on the co-occurrence of keywords in Scopus publications on search request «industrial cluster» for 1992-2022

Sources: developed by the authors on the basis of (Scopus, 2022; Vosviewer, 2022).

According to the results of the analysis of the temporal patterns of research on a certain issue, it can be noted that the vectors of scientific research covered by the yellow and green clusters (2015–2022) are more modern, while the red, blue, purple, and turquoise clusters include thematic directions that are earlier (2014 and earlier). Thus, based on the results of the bibliometric analysis, it can be noted that research concerning the role of innovation-industrial clusters in solving environmental problems (air pollution, water pollution, soil degradation) and ensuring the country's sustainable development has recently attracted the attention of scientists. At the same time, scientists have been dealing with the problems of identifying two-way causal relationships between the functioning of industrial clusters and the innovative and technological development of industries, regions, and the country for more than 30 years. It is fair to note that despite the existence of numerous scientific studies aimed at formalizing the role of industrial clusters in ensuring innovative and technological development of the country, the patterns of transformation of the organizational and functional foundations of the existence of industrial clusters in the conditions of increased digitalization of the economy are insufficiently researched. Considering the above, the empirical research to clarify the relationships between innovative-industrial cluster development and digitalization becomes relevant. As far as there is limited statistical data on specifically innovative-industrial clusters' performance, these relationships could be revealed by using a broader concept – country innovative and industrial development index, which takes into account the main parameters and regional features of industrial, entrepreneurial, and innovative development. In order to realize the research objective on the identification of the influence of the determinants of digitalization on the development of countries' innovative and industrial development (innovative-industrial clusters development), it is necessary to identify measurement indicators of digitalization and countries' innovative and industrial development.

Thus, the first block of the literature review generalizes research results on the measurement of country digitalization. In the report «Toolkit for Measuring the Digital Economy» (OECD, 2018) as a proxies of digital development are considered as follows: broadband subscriptions per 100 inhabitants; mobile broadband subscriptions per 100 inhabitants; the speed of Internet connection (megabits per second); M2M SIM card penetration per 100 inhabitants; the number of secured servers; the proportion of households with a computer; households with Internet connections; Internet users; individuals who purchased online in the last 12 months; tertiary graduates in the natural sciences, engineering, and ICTs; individuals with ICT skills; patents in artificial intelligence technologies; business enterprise expenditure on R&D and information industries; employment in information industries; value added of information industries; ICT investment; ICT contribution to labor productivity growth; ICT goods as a percentage of merchandise trade, etc. It should be noted that the indicators mentioned above, to some extent, concerns both country's digital and innovative development. Considering the research objective, there is the necessity to split these indicators for measurement separately digital development and innovative development. In turn, UNCTAD (2022) consider as digital economy measurement such indicators as ICT producing sector core indicators; bilateral trade flows by ICT goods categories; share of ICT goods as a percentage of total trade; core indicators on ICT use in business by location type, annual; core indicators on ICT use in business by location type/size class/industrial classification of economic activity; international trade in digitally-deliverable services; international trade in ICT services. As far as it can be seen, UNCTAD considers only trade operations of ICT goods as quantitative measures of digital development. In turn, OECD Going Digital Toolkit (OECD, 2022) considers 37 indicators to measure digitalization within seven perspectives (market openness, trust, access, society, jobs, use, and innovation). Indicators from the report «Toolkit for Measuring the Digital Economy» (OECD, 2018), UNCTAD (2022) «Digital economy» collection, and OECD Going Digital Toolkit (OECD, 2022) represent the most commonly used indicators for assessing progress in a country's digital development. Scientists also use these indicators to provide empirical research. Thus, Milosevic et al. (2018) used 13 indicators to measure the digital economy in European countries: Computer Internet Connections used by Employees in Enterprises; Use of Cloud Services by Individuals; Mobile Internet Connections used by the Employees in Enterprises; Level of Internet Access in Households; Mobile Internet Access by Individuals; Internet Use by Individuals; Internet Purchases by Individuals; E-commerce Purchases of Enterprises; Enterprises that have a Website; Internet Advertising of Enterprises; E-commerce Sales of Enterprises; Enterprises that Employ ICT Specialists; Value of E-Commerce Sales of Enterprises. Kotarba (2017) realized scientific research on generalizing digital performance KPIs. The author mentioned that there are more than 100 KPIs of digital measurement that leads to a more complicated approach to sufficient indicators selection.

Concluding this block of literature review, it is fair to note that some of the digital measurement indicators are informative and effective. Still, there is no sufficient data for providing comprehensive empirical research (limitation on country coverage, time coverage, or both). Some indicators characterize mostly innovation but not digital development. Thus, based on the literature review within this research it will be chosen such indicators of a country's digital development as: Fixed broadband subscriptions; Fixed telephone subscriptions; Mobile cellular subscriptions; Individuals using the Internet; Secure Internet servers; High-technology exports; Communications, computers, % of service exports; Communications, computer, % of service imports. These indicators have sufficient both country and time coverage. They illustrate the specifically digital but not innovative perspective of country development (for example, it is considered only ICT service but not goods trade because the last proxy is responsible for hardware but not software).

Consequently, the second block of the literature review generalizes research results on measuring the country's innovative and industrial development. Upadhyaya (2013), while developing a composite measure of industrial performance, is considered proxied of country industrial development indicators such as manufacturing value-added and manufacturing export ratio. The UNIDO (2019) report «Statistical Indicators of Inclusive and Sustainable Industrialization» also mentioned manufacturing value-added as a core proxy of industrialization. The report also mentions that the measurement of industrialization can't be realized without considering the employment perspective. Manufacturing value-added and employment in manufacturing are considered as KPIs within the target of SDG 9 (9.2 «Inclusive and sustainable industrialization» (UNCTAD (2022)). Raghupathi and Raghupathi (2017) also mentioned patent applications as an indicator of the innovative and industrial (economic) development of the state. Considering this block of literature review results, it becomes obvious that value-added, employment rate and patent application in the industry are the best and most commonly used proxies of industrial development. It is also proposed to consider within industrial development such traditional economic growth models' control variables as GDP per capita; inflation; consumption of fixed capital, and trade (Doumbia, 2016; Zhang et al., 2022). And also use new business density as an indicator of entrepreneurial development. As a proxy of a country's innovative development, it is considered to choose industry-related components of the Global Innovation Index.

Methodology and research methods. The main task of this study is to determine the influence of the determinants of digitalization of the economy on the development of innovative and industrial clusters. However, considering the lack of an opportunity to form an optimal set of statistical data that comprehensively characterized the development of innovative-industrial clusters in different countries, it is proposed to carry out indirectly through the developed integrated indicator of innovative industrial development of the country. In particular, parameters characterizing the features of industrial, entrepreneurial, and innovative development were taken into account when forming the dataset to ensure the maximum closeness of the connection between the development of innovative industrial clusters and the country. Empirical research was conducted for 10 countries, such as Azerbaijan, Estonia, Georgia, Kazakhstan, Kyrgyz Republic, Latvia, Lithuania, Poland, Romania, and Ukraine, from 2009 to 2021. These countries are chosen because of common historical development trends (post-socialistic countries, countries of Eastern partnership, and some European countries). It also considers Asian and European perspectives on the relationship between digital development and a country's innovative-industrial development. The limitation of the observation period results from statistical data availability (pillars of the Global Innovation Index (2022) are calculated and reported starting from 2009). The research involves the sequential implementation of several stages:

1) formation of an integral indicator of innovative and industrial development of the country;

2) preliminary selection of determinants of digitalization of the economy according to the level of relevance of their influence on the integrated indicator of innovative industrial development of the country by building a correlation matrix;

3) determination of the most appropriate model of regression modelling on panel data (with fixed or random effects) for modelling the influence of the determinants of digital development on the integrated indicator of the innovative and industrial development of the country. These two options are chosen as the most commonly used options in panel data regression modeling. Besides, it is also considered linearity in the relationship between variables. Thus it does not require the application of any alternative approach;

4) direct modeling of the causality of relationships between the parameters of digital development and innovative industrial development of the country using fixed or random effect panel data regression model and the interpretation of the obtained results;

5) identifying those determinants of digital development on which the innovative and industrial development of the country has the greatest impact by building a system of one-factor regression models on panel data.

Panel data regression analysis is chosen as it is the most commonly used approach in economic growth models (Xu and Li, 2022; Zhang et al., 2022).

So, to form an integral indicator of innovative and industrial development of the country, the following indicators were selected from open databases:

– Institutional capacity of innovative development (GII_I) – pillar «Institutions» of the Global Innovation Index (Global Innovation Index Reports, 2022) that considers such proxies as Political Environment (Political Stability; Government Effectiveness), Regulatory environment (Regulatory quality, Rule of law, Cost of redundancy dismissal) and Business environment (Ease of starting a business, Ease of resolving insolvency);

– Human Capital Capacity of innovative development (GII_HC) – pillar «Human capital and research» of the Global Innovation Index (Global Innovation Index Reports, 2022) that considers such proxies as Education (Expenditure on education, Government funding/pupil, School life expectancy, Assessment in reading, mathematics, and science, Pupil-teacher ratio), Tertiary Education (Tertiary enrollment, Graduates in science and engineering, Tertiary inbound mobility) and Research and Development (Researchers, full-time equivalent, Gross expenditure on R&D, Global R&D companies, average expenditure, top 3, QS university ranking score of top 3 universities);

– Business Environment Capacity of innovative development (GII_BS) – pillar «Business sophistication» of the Global Innovation Index (Global Innovation Index Reports, 2022) that considers such proxies as Knowledge workers (Knowledge-intensive employment, Firms offering formal training, Gross expenditure on R&D performed by business enterprise, Gross expenditure on R&D financed by business enterprise, Females employed with advanced degrees), Innovation linkages (University/industry research collaboration, State of cluster development, Gross expenditure on R&D financed by abroad, Joint venture/strategic alliance deals, Patent families filed in two offices) and Knowledge absorption (Intellectual property payments, High-tech imports, ICT services imports, Foreign direct investment net inflows, Research talent in business enterprise).

The methodology of the Global Innovation Index considers that all pillars are assessed with a score, which varies in the range of 0–100, where a higher score illustrates the better performance of the pillar (Global Innovation Index Reports, 2022). Therefore, these three complex indicators are considered to measure the innovative perspective of country development within this research.

In order to measure a country business and industrial development, it is also collected a subset of indicators from the «World Development Indicators» collection of the World Bank Group (World Bank DataBank, 2022):

– Employment in industry, % of total employment (Empl_ind);

- Industrial design applications, nonresident (IDA_non);
- Industrial design applications, resident (IDA_res);
- Industry (including construction) value-added, % of GDP (VA_ind);
- GDP per capita, current US$ (GDPpc);
- Inflation, consumer prices, annual % (CPI);
- Adjusted savings: consumption of fixed capital, % of GNI (CFC);
- Trade, % of GDP (Trade);
- New business density, new registrations per 1,000 people ages 15-64 (Bus).

Within the first stage of the research, it is developed Innovation and Industrial Development Index (IID). For integration into a single composite indicator, all the indicators mentioned above are reduced to a comparative form using a minimax approach. After applying the method of relative normalization of data series, all indicators belong to the range [0; 1]. At the next stage, all the normalized values of indicators for assessing the level of innovative and industrial development of the country are processed using one of the tools of multivariate analysis (principal components analysis (PCA)) using the Stata 14.2/ SE software product. After running PCA, it is chosen the amount of principal components. As Zhang et al. (2022) mentioned, selecting only those components that explain more than 70% of the total variation is necessary. In the next step, loadings in the absolute value of selected components are averaged for ranking the indicators concerning their relativity (higher averaged loading value explains higher relativity of the indicator in Index). By dividing the rank of a curtain indicator by the total ranks' sum for the set of innovative and industrial development proxies, it is determined the weighting coefficients for each of the individual indicators in the integral. Integrating individual indicators in the IID will be carried out using additive convolution.

The next stage of the research is the preliminary selection of the determinants of digitalization of the economy according to the level of relevance of their impact on the integral indicator of the innovative industrial development of the country. In particular, it is worth noting that, taking into account the report «Toolkit for Measuring the Digital Economy» (OECD, 2018) as determinants of digital development within the scope of this study, the following were chosen:

- Fixed broadband subscriptions, per 100 people (FBS);
- Fixed telephone subscriptions, per 100 people (FTS);
- Mobile cellular subscriptions, per 100 people (MCS);
- Individuals using the Internet, % of population (Internet);
- Secure Internet servers, per 1 million people (Servers);
- High-technology exports, % of manufactured exports (HTE);
- Communications, computer, % of service exports (ComEx);
- Communications, computer, % of service imports (ComIm).

All these digital development measurement indicators were also collected from the «World Development Indicators» collection of the World Bank Group (World Bank DataBank, 2022).

A correlation matrix will be built to select those characterized by the greatest influence on IID among the given indicators. Those indicators that are characterized by a weak relationship with the dependent variable (correlation coefficient less than 0.3) will not be selected for the models.

The Hausman test will be used to determine the most appropriate panel data regression model. If, according to the results of the Hausman test, the value «Prob > chi 2» is statistically significant ($p<0.05$), then a regression model with fixed effects is more appropriate for this sample, otherwise - with random effects.

Results. The first stage of the realization of the main task of this study is the formation of an integral indicator of the innovative industrial development of the country (IID). For its implementation, one of the multivariate analysis tools of the Stata 14.2/ SE software product was used. Table 1 presents the results of the principal component analysis.

The shadowed cell in Table 1 highlights the number of components, the consideration of which will be sufficient to obtain reliable results regarding the determination of the importance of the contribution of each of the individual determinants of innovative industrial development to its integral level. Table 2 presents the results of determining the weighting coefficients. Determination of the weight coefficients of the components of the Innovation and Industrial Development Index (IID involves: 1) determination of the averaged absolute eigenvalues, calculated according to the Eigenvector parameters of the number of components that will allow obtaining reliable results (in this case, 4 components explain a satisfactory scale of the indicator variation); 2) ranking of the parameters calculated at stage 1 by growth (a higher level of averaged absolute eigenvalues corresponds to a higher rank, and accordingly, a higher weight of the individual indicator in the IID); 3)

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calculation of weighting coefficients as a ratio of the rank of the corresponding indicator to the total value of the ranks for all indicators.

Table 1. Principal components analysis results

Component	Eigenvalue	Difference	Proportion	Cumulative
Component 1	4.726	2.444	0.394	0.394
Component 2	2.282	1.115	0.190	0.584
Component 3	1.167	0.233	0.097	0.681
Component 4	0.934	0.137	0.078	0.759
Component 5	0.797	0.153	0.067	0.826
Component 6	0.644	0.189	0.054	0.879
Component 7	0.455	0.067	0.038	0.917
Component 8	0.388	0.112	0.032	0.950
Component 9	0.275	0.127	0.023	0.972
Component 10	0.148	0.024	0.012	0.985
Component 11	0.124	0.066	0.010	0.995
Component 12	0.059	.	0.005	1.000

Sources: calculated by the authors.

Thus, taking into account the data in Table 2, the general formula (1) for calculating Innovation and Industrial Development Index (IID) will have the following form:

$$IID = 0.077 \cdot GII_I + 0.103 \cdot GII_{HC} + 0,115 \cdot GII_{BS} + 0,128 \cdot Empl_{ind} + 0.090 \cdot\cdot IDA_{non} + 0.026 \cdot IDA_{res} + 0.141 \cdot VA_{ind} + 0.051 \cdot GDPpc + 0.154 \cdot CPI + 0.064 \cdot CFC + 0.013 \cdot Trade + 0.038 \cdot Bus \quad (1)$$

where IID – Innovation and Industrial Development Index; GII_I – institutional capacity of country's innovative development; GII_{HC} – human capital capacity of country's innovative development; GII_{BS} – business environment capacity of country's innovative development; $Empl_{ind}$ – employment in the industry; IDA_{non} – industrial design applications, nonresident; IDA_{res} – industrial design applications, resident; VA_{ind} – industry value added; *GDPpc* - GDP per capita; *CPI* - inflation, consumer prices; *CFC* - consumption of fixed capital; *Trade* - trade openness;*Bus* – new business density.

Table 2. Results of identification of weighting coefficients for measurement indicators of country innovative and industrial development

Variable	Eigenvector 1	Eigenvector 2	Eigenvector 3	Eigenvector 4	AE	Weight
GII_I	0.306	-0.228	-0.145	-0.244	0 . 231	0 . 077
GII_HC	0.285	0.293	0.370	0.032	0 . 245	0 . 103
GII_BS	0.347	0.181	0.295	0.179	0 . 251	0 . 115
Empl_ind	0.299	0.253	0.223	0.230	0 . 251	0 . 128
IDA_non	-0.187	0.544	-0.100	-0.105	0 . 234	0 . 090
IDA_res	-0.101	0.596	-0.018	0.021	0 . 184	0 . 026
VA_ind	-0.242	-0.264	0.564	0.291	0 . 340	0 . 141
GDPpc	0.389	-0.147	0.247	0.018	0 . 200	0 . 051
CPI	0.139	-0.052	-0.379	0.792	0 . 341	0 . 154
CFC	0.315	0.081	-0.402	0.110	0 . 227	0 . 064
Trade	0.333	0.065	0.017	-0.286	0 . 175	0 . 013
Bus	0.362	-0.101	-0.102	-0.191	0 . 189	0 . 038

Notes: AE – average eigenvalue of absolute values for Eigenvectors 1–4.
Sources: calculated by the authors.

Figure 3 illustrates the IID dynamics within the country sample in 2009-2021. According to Figure 3, Estonia makes the best use of its innovation and industrial potential, where the IID value is 50-60% of the reference value. The group of countries with an average level of IID is formed by Latvia, Lithuania, Poland, Romania, and Ukraine, where the available potential is used by 40-50%. On the other hand, Azerbaijan, Georgia, Kazakhstan, and Kyrgyzstan use only 30-40% of their existing innovation and industrial potential.

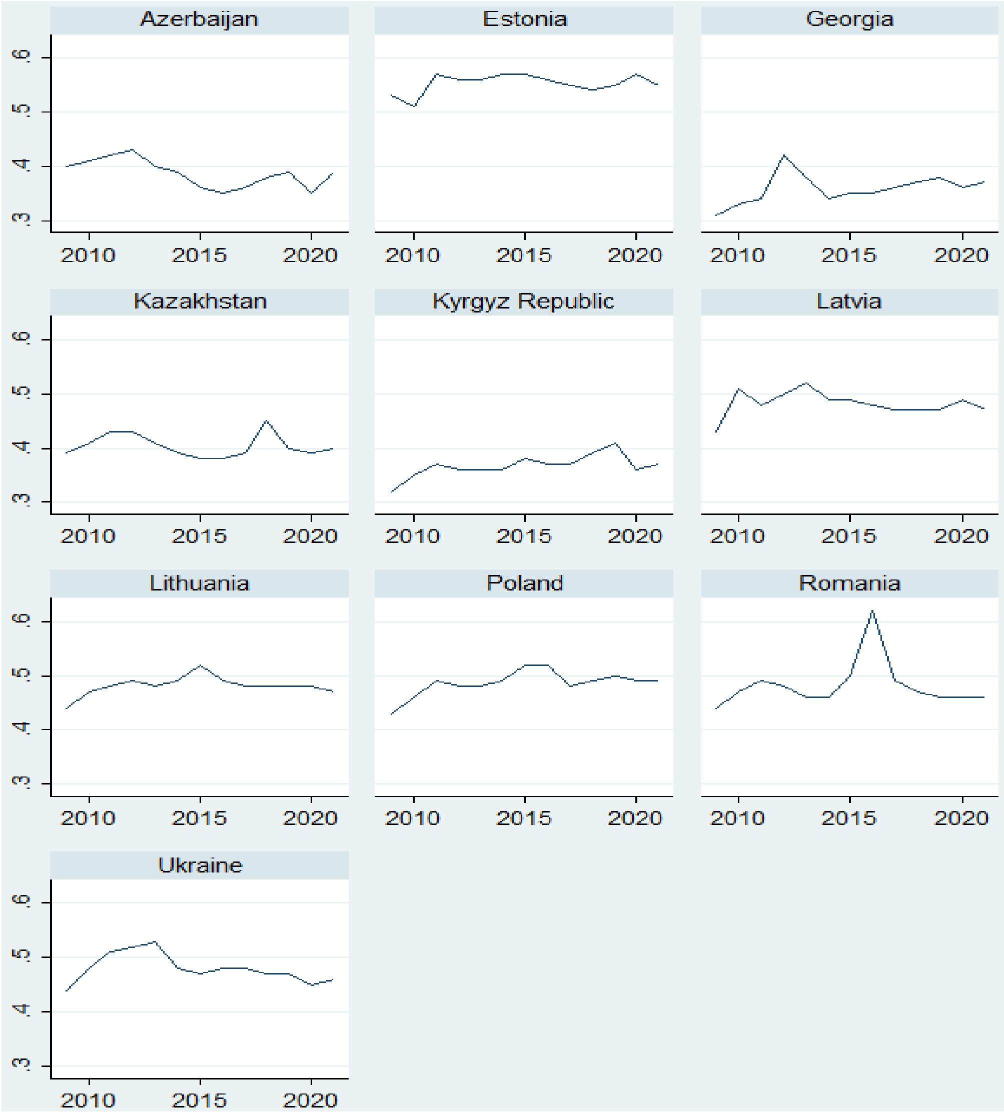

Figure 3. Innovation and Industrial Development Index (IID) for 10 analyzed countries in 2009–2021, units

Sources: developed by the authors.

The next stage of the research involves the preliminary selection of model variables based on the construction of a correlation matrix (Table 3).

Table 3. Correlation analysis results

Variables	IID	FBS	FTS	MCS	Internet	Servers	H T E	ComEx	ComIm
IID	1.000								
FBS	0.614	1.000							
FTS	0.439	0.226	1.000						
MCS	**0. 232**	0.264	0.190	1.000					
Internet	0.438	0.845	0.053	0.316	1.000				
Servers	0.387	0.519	-0.051	0.155	0.449	1.000			
H T E	**0.209**	0.170	0.212	0.457	0.346	0.153	1.000		
ComEx	0.580	0.213	-0.008	-0.139	0.071	0.356	-0.106	1.000	
ComIm	**0.240**	0.186	0.216	-0.129	0.346	0.165	0.421	0.383	1.000

Sources: calculated by the authors.

First, in the context of the task, the correlation coefficients between the dependent variable (IID) and independent variables (determinants of digital development) are of interest. Based on the results of this stage, 3 potential independent variables were eliminated, as they are characterized by a weak connection with the resulting variable (highlighted in bold in 2 columns). Hausman test at the next stage of the empirical study made it possible to obtain the value «Prob>chi2 = 0.0568». Thus, it is more appropriate to use a model with random effects for this sample of data. Table 4 summarizes regression modeling results to identify the impact of digital determinants on IID.

Table 4. Regression analysis results on the identification of digital determinants impact on country innovative and industrial development for 10 countries

IID	Coef.	St. Err .	t-value	p-value	95% Confidence interval		Sig
FBS	0.002 83	0.00114	2.48	0.0132	0.00059	0.00506	**
FTS	0.00268	0.00069	3.89	0.0001	0.00133	0.00402	***
Internet	-0.00005	0.00039	-0.13	0.8995	-0.00082	0.00072	
Servers	$-1.18 \cdot 10^{-7}$	$2.31 \cdot 10^{-7}$	-0.51	0.6091	$-5.71 \cdot 10^{-7}$	$3.35 \cdot 10^{-7}$	
ComEx	0.00111	0.00034	3.30	0.0009	0.00045	0.00177	***
Constant	0.31247	0.03126	10.00	0.0000	0.25120	0.37374	***
Overall r-squared		0.68186Prob > chi2					0.00002

Notes: *** p<0.01, ** p<0.05, * p<0.1

Sources: calculated by the authors.

Thus, based on the results of determining the causality between the innovative and industrial development of the country and the determinants of digitalization for the studied 10 Asian and European countries, it is possible to note:

– an increase in the network of broadband users by 1 unit leads to an improvement in Innovation and Industrial Development Index by 0.003 units with 95% confidence probability;

– the growth of Innovation and Industrial Development Index by 1 unit affects growth of the network of telephone users by 0.003 units with a 99% confidence probability;

– a slightly stronger positive effect on the Innovation Change and Industrial Development Index has an increase in communications and computer export that service export ratio: a 1% increase in the explanatory variable leads to an increase in IID by 0.001 units;

– instead, for this sample of countries, no statistically significant influence of such determinants of digital development on IID as Individuals using the Internet as a percentage of the population, Secure Internet servers per 1 million people.

Table 5 presents the results of similar modeling exclusively on the example of Azerbaijan.

Table 5. Regression analysis results on the identification of digital determinants impact on country innovative and industrial development in Azerbaijan

IID	Coef.	St. Err .	t-value	p-value	95% Confidence Interval		Sig
FBS	0.0004	0.0056	0.07	0.9438	-0.0128	0.0136	
FTS	0.0277	0.0140	1.98	0.0880	-0.0054	0.0607	*
Internet	-0.0013	0.0017	-0.77	0.4670	-0.0052	0.0026	
Servers	0.0002	0.0001	2.09	0.0748	0.0000	0.0004	*
ComEx	0.0016	0.0011	1.43	0.1954	-0.0010	0.0043	
Constant	-0.0807	0.2632	-0.31	0.7682	-0.7031	0.5418	

Sources: calculated by the authors.

According to the results of regression modeling on the identification of the impact of digitalization on the innovative and industrial development of the country in the example of Azerbaijan, slightly different patterns were established compared to the results of the sample as a whole. Thus, in particular, a statistically significant impact on Innovation and Industrial Development Index was empirically confirmed for two determinants of digital development, namely: an increase by 1 unit of the network of telephone users leads to an increase in the dependent variable by 0.027 (the influence of this indicator for Azerbaijan is much higher than the influence of a sample of 10 countries); increase by 1 unit Secure Internet servers per 1 million people leads to an increase of Innovation and Industrial Development Index by 0.0002 units. The statistical significance of both parameters is confirmed with a 90% confidence level. The rest of the digital determinants are not relevant factors for ensuring the innovative industrial development of Azerbaijan.

In turn, Table 6 illustrates the results of reverse causality modeling for the sample as a whole, that is, determining the direction and strength of the influence of the Innovation and Industrial Development Index on the determinants of the country's digital development.

According to the results presented in Table 6, it can be noted that the innovative and industrial development of the country has a positive effect on all determinants of digitalization. However, a statistically significant relationship between IID and high-tech exports and imports of communications and computers has not been confirmed. With a 90% confidence probability, IID growth's positive impact on expanding the broadband, telephone, Internet users and communications, and computer export to service export ratio is confirmed. Instead, the positive impact of the growth of the Innovation and Industrial Development Index on Secure Internet servers per 1 million people and Mobile cellular subscriptions per 100 people was confirmed with 99% confidence probability.

Table 6. Regression analysis results on identification country innovative and industrial development impact on digital determinants for 10 countries

Variable	Coefficient	Standard Error	t-value	p-value	95% Confidence Interval		Sig
			IID →FBS				
IID	26.8792	14.3414	1.87	.0609	-1.2293	54.9877	*
Constant	5.8334	6.687	0.87	.383	-7.2729	18.9397	
Overall R^2	0.3768						
			IID →FTS				
IID	27.0418	14.2227	1.90	.0573	-.8342	54.9179	*
Constant	7.276	6.542	1.11	.2661	-5.5461	20.0981	
Overall R^2	0.1932						
			IID →MSC				
IID	129.2211	37.4897	3.45	.0006	55.7426	202.6997	***
Constant	70.4983	17.334	4.07	0	36.5242	104.4724	***
Overall R^2	0.1105						
			IID →Internet				
IID	66.3529	41.3375	1.61	.1085	-14.6672	147.3729	
Constant	33.2321	18.9511	1.75	.0795	-3.9114	70.3755	*
Overall R^2	0.1917						
			IID →Servers				
IID	77406.259	22015.014	3.52	.0004	34257.625	120554.89	***
Constant	-28174.913	9978.7113	-2.82	.0048	-47732.828	-8616.9987	***
Overall R^2	0.1501						
			IID →HTE				
IID	10.1247	12.0013	0.84	.3989	-13.3973	33.6468	
Constant	7.5407	6.0534	1.25	.2129	-4.3239	19.4052	
Overall R^2	0.0439						
			IID→ ComEx				
IID	21.3981	25.7714	0.83	.4064	-29.1129	71.909	
Constant	23.7274	12.1582	1.95	.051	-.1022	47.5569	*
Overall R^2	0.3369						
			IID→ ComIm				
IID	1.2094	17.328	0.07	.9444	-32.7529	35.1717	
Constant	38.1124	9.217	4.14	0	20.0475	56.1773	***
Overall R^2	0.0575						

Sources: calculated by the authors.

Summarizing the modelling results, it can be noted that the expansion of the broadband and telephone users network is both a driver of the innovative industrial development of the country and a derivative of its improvement. At the same time, the growth of communications and computers export-to-service export ratio contributes to the improvement of the Innovation and Industrial Development Index. However, in the reverse direction, this relationship is not statistically significant. In addition, it is worth noting that the national patterns of causality between variables may differ significantly from those of the sample as a whole, which is vividly illustrated by the example of Azerbaijan.

Conclusions. The problems of forming and developing innovation-industrial clusters have been the focus of representatives of the academic environment and state and local self-government bodies for several decades. Still, this topic has become widespread over the past 10-15 years. Scientists and practitioners note that the cluster organization of industry has several positive aspects, including an increase in labor productivity, the dissemination of new knowledge and the concentration of creative ideas, better satisfaction of the public needs of the population, faster and more effective resolution of local problems, etc. In some countries, special state support programs are even initiated to develop a network of innovation-industrial clusters (specially to support small and medium-sized enterprises).

According to the results of the bibliometric analysis of 2829 Scopus publications (Scopus, 2022), the title, keywords or abstracts of which contain the phrase «industrial cluster» (Vosviewer, 2022), it was established that during 1992-2022, scientific research on a certain topic was published more intensively during 2008-2022. In total, according to the results of the bibliometric analysis, 6 contextual clusters were identified, aimed mainly at identifying the influence of industrial clusters in the development of industry and innovations, solving environmental problems, ensuring sustainable development, ensuring technological development, determining logistical aspects and industry specifics of the functioning of industrial clusters. It is worth noting that despite the existence of numerous scientific studies aimed at formalizing the role of industrial clusters in ensuring innovative and technological development of the country, the regularities of changes in the basic principles of the existence of industrial clusters in the conditions of increased digitalization of the economy are insufficiently researched. Taking into account the fact that it is currently impossible to accumulate a sufficient set of relevant statistical information to characterize the activity of innovation-industrial clusters, it is developed Innovation and Industrial Development Index. This index considers the parameters of the development of innovations, the business environment, and industry, which also characterizes the prerequisites for developing innovation-industrial clusters. Analysis of Innovation and Industrial Development Index dynamics during 2009-2021 allows noting that among the 10 studied countries, Estonia uses its innovation and industrial potential best (by 50-60% of the reference value), followed by Latvia, Lithuania, Poland, Romania and Ukraine (40-50%), and this rating is closed by Azerbaijan, Georgia, Kazakhstan and Kyrgyzstan with an indicator of 30-40%. Based on the results of determining the causality between the innovative and industrial development of the country and the determinants of digitalization for the studied 10 Asian and European countries, it was established that the growth of the network of broadband users, telephone users, and communications and computer s export to service export ratio has a positive effect on the performance indicator. In contrast, the influence of the rest of the studied determinants of digitalization is statistically not relevant. According to the results of regression modeling on the identification of the impact of digitalization on the innovative and industrial development of the country, somewhat different patterns have been established using the example of Azerbaijan: the most relevant for the country are the growth of users of telephone communication and Secure Internet servers per 1 million people. The modelling results also made it possible to establish that such determinants of digitalization as the growth of the network of users of broadband communication, telephone communication, mobile communication, and Secure Internet servers per 1 million people. It should be noted that research results are in a queue with other scientific findings. Specifically, in the paper (Xu, Li, 2022) it was also proved that digital development has a positive influence on industrial development. In turn, Zhang et al. (2022) also pointed out that digitalization contributes to a country's industrial and economic development. The authors highlighted that for specific country samples (similar to the research country sample), the strength of this relationship might be even higher than in more developed countries. Polder et al. (2010) also gained similarities to the curtain research results: they revealed that the growth of the network of broadband users contributes to economic and industrial growth. Gaglio et al. (2022) concluded that «internet surfing has a positive and statistically significant effect on both product and process innovation». Yoo and Yi (2022), based on the existing empirical results on the influence of digitalization on innovation, concluded that digital technologies positively impact innovative development, industry performance, and product cost. Andreoni et al. (2021) also mentioned that digitalization (specifically, Internet broadband and mobile broadband) could significantly contribute to manufacturing and industrial yield. Concluding the research results, it should be noted that the obtained results are similar to the existing ones. Still, most of the research focuses on identifying digitalization's economic and productivity consequences. In contrast, this research focuses on identifying the impact on industrial and innovative development and vice versa. Moreover, as it is argued by Yoo and Yi (2022), the active stage of Industry 4.0 was started in 2016 and triggered a digitally-driven transformation in all spheres of public life. Therefore, it becomes crucially important to realize comprehensive empirical results to reveal regionally-specific patterns of digital impact and adapt to its business and regulatory framework. That is why this particular research supports earlier empirical findings and generates new knowledge.

The obtained empirical results could be useful for scientists in deepening this study. The representatives of government authorities could benefit from the development or adjustment of state strategies for innovative and industrial development, taking into account the challenges of the digital environment, as well as in the context of the development of strategies for state support and stimulation of innovative-industrial cluster development.

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Теоретико-методологічні аспекти розвитку інноваційно-промислових кластерів в умовах цифровізації

Ця стаття узагальнює аргументи та контраргументи в рамках наукової дискусії з питань визначення основних теоретичних та практичних засад функціонування інноваційно-промислових кластерів у різних країнах світу, а також формалізації впливу цифровізації на їх діяльність. У статті узагальнено наукові підходи до визначення основних характеристик та особливостей функціонування інноваційно-промислових кластерів. З метою обґрунтування теоретичних закономірностей взаємозв’язку між діяльністю інноваційно-промислових кластерів та процесами цифровізації, у роботі здійснено бібілометричний аналіз основних публікацій Scopus за означеним напрямком з використанням інструментарію Vosviewer. У ході дослідження визначено головні змістовно-контекстуальні кластери наукових досліджень з релевантної тематики, охарактеризовано еволюційні закономірності їх зміни за досліджуваний період. З метою визначення емпіричних закономірностей впливу цифровізації на інноваційно-промисловий розвиток, авторами розроблено інтегральний показник інноваційно-промислового розвитку. Індекс враховує основні параметри та регіональні особливості промислового, підприємницького та інноваційного розвитку. Інтегрування індикаторів проведено з використанням методу головних компонент та адитивної згортки. У роботі здійснено моделювання впливу параметрів цифровізації економіки на інтегральний показник інноваційно-промислового розвитку з використанням інструментарію регресійного моделювання панельних даних у програмному продукті Stata 14.2/SE. У дослідженні застосовано однофакторні регресійні моделі для визначення детермінант цифрового розвитку держави, які найбільшою мірою залежать від волатильності інноваційно-промислового розвитку країни. Об’єктом дослідження є 10 країн, серед яких Азербайджан, Естонія, Грузія, Казахстан, Киргизстан, Латвія, Литва, Польща, Румунія та Україна. Періодом дослідження обрано 2009-2021 рр. (чи останній доступний період). Результати проведеного дослідження можуть бути корисними науковцям, органам державної влади та місцевого самоврядування.

Ключові слова: інноваційно-промислові кластери, діджиталізація, панельні дані, регресійне моделювання.