Oleksandr Shapurov
Zaporizhzhia National University, Zaporizhzhia, Ukraine
E-mail: 0961779400saa@gmail.com
ORCID: https://orcid.org/0000-0002-4381-4886
ResearcherID: S-6890-2017

The role of technological development, national security and human capital in a country's economic development

Abstract
The purpose of this article is to assess the dynamic relationship between technological development, national security, human capital and economic growth. To find out how Ukraine's economic growth changes during 2013–2020 and which factors are strategically important in this change. *Methodology*. Research objective: to assess the long-term relationship between independent variables (human capital, technological development, national security) based on the Fechner rank correlation coefficient and cognitive analysis; to assess the causal relationship between indicators of human capital, technological development, national security and economic growth based on multiple regression. The method of cognitive modeling, multiple regression and rank correlation allows to find out how the economic growth of Ukraine changes during 2013–2020 and what factors are fundamental for this change. *Results*. The causal relationships of the factors of economic growth were established with the help of the Fechner coefficient. On the basis of cognitive modeling with the use of causal relationships of exogenous and endogenous factors, the impulse impact of each factor on the whole system of economic growth indicators was assessed. It is proved that the most significant scenarios are impulses, which include factors: military expenditures, population in urban agglomerations over 1 million people (% of the total population); domestic public spending on health care per capita. The significance of the factors is confirmed by the construction of a multiple regression of the dependence of GDP per capita on the % of population in urban agglomerations, public health expenditures per capita, military expenditures per capita. It was found that in the situation under study 99.94% of all the variability of GDP per capita is explained by changes in selected factors. *Practical implications.* It consists in the possibility of using the results of the study for scientific developments and practical activities. The proposed cascade approach can be used in forecasting macroeconomic growth of the country and the formation of appropriate strategic development programs. *Value/originality.* A cascade approach to the assessment of the dynamic relationship between technological development, national security, human capital and economic growth, which includes a hierarchical sequence: the establishment of causal relationships of economic growth factors using the Fechner coefficient; assessment of the impulse impact of each factor on the entire system of economic growth indicators using cognitive modeling; proving the significance of factors using the construction of a multiple regression.

Keywords
economic growth, human capital, technological development, cognitive modeling, multiple regression, rank correlation

JEL: O11

DOI: https://doi.org/10.30525/2500-946X/2022-2-5

1 Introduction

In today's complex conditions of the functioning of the world economy, there are many factors that suppress the economic development of countries. Each country should identify effective mechanisms to overcome the formed factors, to prevent prolonged recessions or protracted crises. The concept of sustainable development is one of the effective vectors of overcoming these obstacles. At a time of global present, development must meet the needs of society while not endangering future generations and their opportunities, minimizing the depletion of natural resources and ensuring the innovative development of mankind. Sustainable development of a country's economy has the key components of its formation. Net foreign direct investment, human capital, export of high-tech goods, ensuring national security are the key to the stability and growth of the country's economy.

Human capital reflects knowledge, ideas, health components within the production function of the economy. The main economic categories and components that form human capital are: public spending on health care, education, the level of use of intellectual property, the level of well-being (the inverse of the poverty level and the Gini index characterizing it), the employment level (unemployment), the literacy rate of the population. Thus, improving people's knowledge, skills, abilities, health, and well-being can lead to increased productivity, flexibility, and innovation for sustainable economic growth. Technological development that emphasizes alternative energy sources, the production of high-tech products, and the export of information services reduces carbon dioxide emissions and builds strong urban agglomerations and ecosystems. A very important aspect that affects the economic development of the country is national security, which combines many financial, defense, migration characteristics and indicators.

The purpose of this article is to assess the dynamic relationship between technological development, national security, human capital and economic growth. Specifically, the study aims to: a) assess the long-run relationship between independent variables (human capital, technological development, national security); b) assess the causal relationship between human capital, technological development, national security and economic growth.

2 Theoretical aspects of economic growth modeling

The problem of practical research of economic growth, which determines the relationship between investment, human capital, technology and the development of a country's economy, is now an important debatable issue. Since the 1970s the question of the functional form of the dependence of economic growth on the degree of influence of exogenous and endogenous factors has been one of the most debated issues related to the global economy.

From the perspective of one of Solow's first growth models, human capital is the main and most important component of total factor production, which explains the unaccounted-for residuals in other models. Solow's model is considered the starting point of all modern models of economic growth, to which it provided the necessary mathematical basis for analyzing the rate of change of capital. The model influenced the entire macroeconomic theory, the basis of the model is the production function with endogenous factors (capital, labor and technological progress) (Solow, 1957).

In a study of the effects of labor, capital, and government size on economic growth, Shittu et al. use a distributed lag autoregression method based on data from the World Bank and the KOF Institute. The results show a positive relationship between globalization, political governance, and economic growth. Despite inconclusive results on the relationship between direct investment and economic growth, the authors conclude that direct investment stimulates subregional growth and that political governance enhances the positive impact of direct investment on economic growth. Other growth factors include labor, capital, and the size of government (Shittu et al., 2020).

In an endogenous model of economic growth, Wu et al. hint that dynamism and the interaction of other variables besides foreign direct investment and human capital play a background but important role in the pursuit of sustainable economic development. Scholars identify a relationship between renewable energy and economic growth. Renewable energy can theoretically affect the relationship between foreign direct investment, human capital, and sustainable economic growth (Wu J. et al., 2021).

The paper by Radmehr et al. provides panel spatial simultaneous equation models with generalized spatial two-stage least squares (GS2SLS). The main factors used in the endogenous economic growth model are: carbon emissions, renewable energy consumption in EU countries. The data confirmed that the relationship between economic growth and renewable energy consumption is unidirectional. These new empirical results, in the view of the authors, will help policy makers develop appropriate environmental and energy policies to achieve the EU's economic development and sustainable development goals (Radmehr, Henneberrya, 2021).

Noteworthy is the work assessing the degree of correlation between urbanization, population development, energy consumption, GDP per capita, and carbon emissions among the five most populous countries in Asia (China, India, Indonesia, Pakistan, and Bangladesh, using time-series data from 2001 to 2014). The authors' annual study was conducted using three gray Deng GRG ratio models, an absolute GRG, and a second synthetic GRG model, which can be implemented as a viable alternative to existing panel data analysis methods (Rehman, Rehman, 2022).

There is still a significant amount of scientific literature that mentions the empirical relationship between new technologies, knowledge, innovation, human capital and economic growth (Hölzl, Janger, 2014; Das, Drine, 2020), the impact of foreign direct investment and trade on economic growth (Pierucha, Żelazny, 2019) in various economic models and constructions; growth of total factor productivity due to ICT and R&D (Edquist, Henrekson, 2017). In addition, Kim and Loayza consider market efficiency, education, and financial infrastructure to be integral factors of economic growth (Kim, Loayza, 2019).

Thus, the diverging results require additional research and evidence to establish the relationship between economic development, national security, human capital, and economic development of the country.

3 The methodology of causality

At the first stage of the study, the causal relationships of economic growth factors were established using the Fechner coefficient. The Fechner coefficient is also called a distortion index or correlation coefficient. The proposed coefficient is an indicator of the quality of accounting and analytical information and characterizes the absence of significant distortions in it (Osadcha, 2016).

$$Qi = \frac{n_{\text{з}} - n_p}{n_{\text{з}} + n_p}$$

where Q_i – Fechner's coefficient of the i-th indicator;

$n_{\text{з}}$ – the number of coincidences of signs of deviations of the actual value of the characteristic from the base value;

n_p – the number of differences in the signs of deviations of the actual value of the characteristic from the base value.

The main data for the formation of cause-effect relationships are obtained from the World Bank dashboard. All indicators are divided into 3 groups:

- indicators of security (national and financial): (1.1) external debt, state and state-guaranteed (PPG) (DOD), million dollars; (1.2) Net direct foreign investment, million dollars; (1.3) Inflation, consumer prices (annual %); (1.4) Internally displaced persons, total number of displaced persons as a result of conflict and violence, thousand persons; (1.5) Military expenses, million dollars;
- technology and ecology indicators: (2.1) Access to clean fuel and technologies for cooking, city (% of urban population); (2.2) CO_2 emissions (metric tons per capita); (2.3) High-tech exports, million dollars; (2.4) Export of ICT services (balance of payments), million dollars; (2.5) Population in urban agglomerations over 1 million (% of the total population);
- indicators of human capital and social components: (3.1) Internal state spending on health care per capita, PCS, dollars; (3.2) Gini index; (3.3) State expenditure on education, total (% of state expenditure); (3.4) Total unemployment rate (% of total labor force) (simulated ILO estimate); (3.5) Fees for the use of intellectual property, payments, million dollars.

Based on the Fechner coefficient, only moderate and high relationships between economic growth factors were identified and left (k = 0.5-1). The results are presented in Table 1.

In the next stage, based on cognitive modeling, the impulse impact of each factor on the entire system of economic growth indicators was assessed.

Weakly structured socio-economic systems are characterized by a significant number of elements, connections, and structural complexity. A certain dynamics of the system, the complexity of its behavior, integration, integrity, communicativeness, hierarchy – all these characteristics complicate the process of forecasting. Effective and efficient method of research and prediction of their development is modeling, which allows you to display the object (system, problem situation) various classes of models, thereby organizing the gradual process of knowledge and formalization of the problem. It is cognitive modeling, as the main type of simulation models, allows the

TABLE 1 Fechner's coefficient of the assessment of the cause-and-effect relationship of factors of economic growth (Ukraine 2013–2020)

	1.1	1.2	1.3	1.4	1.5	2.1	2.2	2.3	2.4	2.5	3.1	3.2	3.3	3.4	3.5
1.1					0,75	1				1	0,75	0,75			
1.2							0,5	0,5						0,5	
1.3				0,75										0,5	
1.4			0,75												
1.5	0,75					0,75				1	0,5	0,5			0,5
2.1	1				0,75					1	0,75	0,75			
2.2		0,5						0,5							
2.3		0,5					0,5						0,75		
2.4										0,5					1
2.5	1				1	1			0,5		0,75	0,75			
3.1	0,75				0,5	0,75				0,75		0,5			
3.2	0,75				0,5	0,75				0,75	0,5				
3.3								0,75							
3.4		0,5	0,5												
3.5					0,5				1						

full implementation of scenario-based prediction of the impact of factors on the overall system of functioning.

It is the consideration of qualitative fuzzy factors that allows to study the problem (in particular, economic growth) on the basis of an infinite number of components, which are interconnected by the corresponding impulses. Cognitive analysis is defined as sequential causal hierarchical information, which describes the processes taking place in the corresponding economic directions. The identified directions are determined by numerous factors, which are interconnected by causal chains. The influence of some factors on others can be depicted using a cognitive map (graphical approach), which is a weighted directional graph that includes vertices (subject area factors) and edges (causal chains) (Shapurov, 2021).

A balanced undirected graph (cognitive map) of economic growth is shown in formula 1.

$$R=\langle K,L\rangle, K=\{\ k_i \,|\, k_i\in K, i=1,2,....n\ \};$$

$$L=\{\ l_{ij}\ \,|\, l_{ij}\in L, ij=1,2,....n\ \}, \quad (1)$$

where R – is a balanced non-oriented graph (cognitive map) of economic growth;

K – the vertices of the graph are factors of economic growth;

$k_i\in K, i=1,2,....n$ – parameters that characterize factors of economic growth;

L – set of arcs connecting factors of economic growth;

$l_{ij}\in L, ij=1,2,....n$ – arcs reflecting the functional interdependence between factors of economic growth

Thus, to build a cognitive map, we will use the factors of the cognitive model and systematize them into three categories: security (national and financial); technology and ecology; human capital and the social component. The cognitive map of the system of economic development indicators is presented in Figure 1.

Modeling of the system development trends in the future involves determining changes in the values of the graph vertices – factors of economic growth in the corresponding modeling cycles on the basis of the perturbation propagation theorem, according to which:

$$r(t)=r(0)\lfloor F^t \rfloor, H(t)=H(0)+\lfloor I+F+F^2+....+F^t \rfloor, \quad (2)$$

where $r(t)$ – the vector of changes in the values of the parameters of the vertices of the weighted undirected graph at the corresponding simulation cycle;

F – the adjacency matrix for this balanced undirected graph is a table in which both columns and rows correspond to the vertices of the graph – the factors of economic growth.

t – tacts (steps) of modeling t = 0, 1, 2, 3, ... n, which reflect the sequence of changes in the states of the economic growth indicator system;

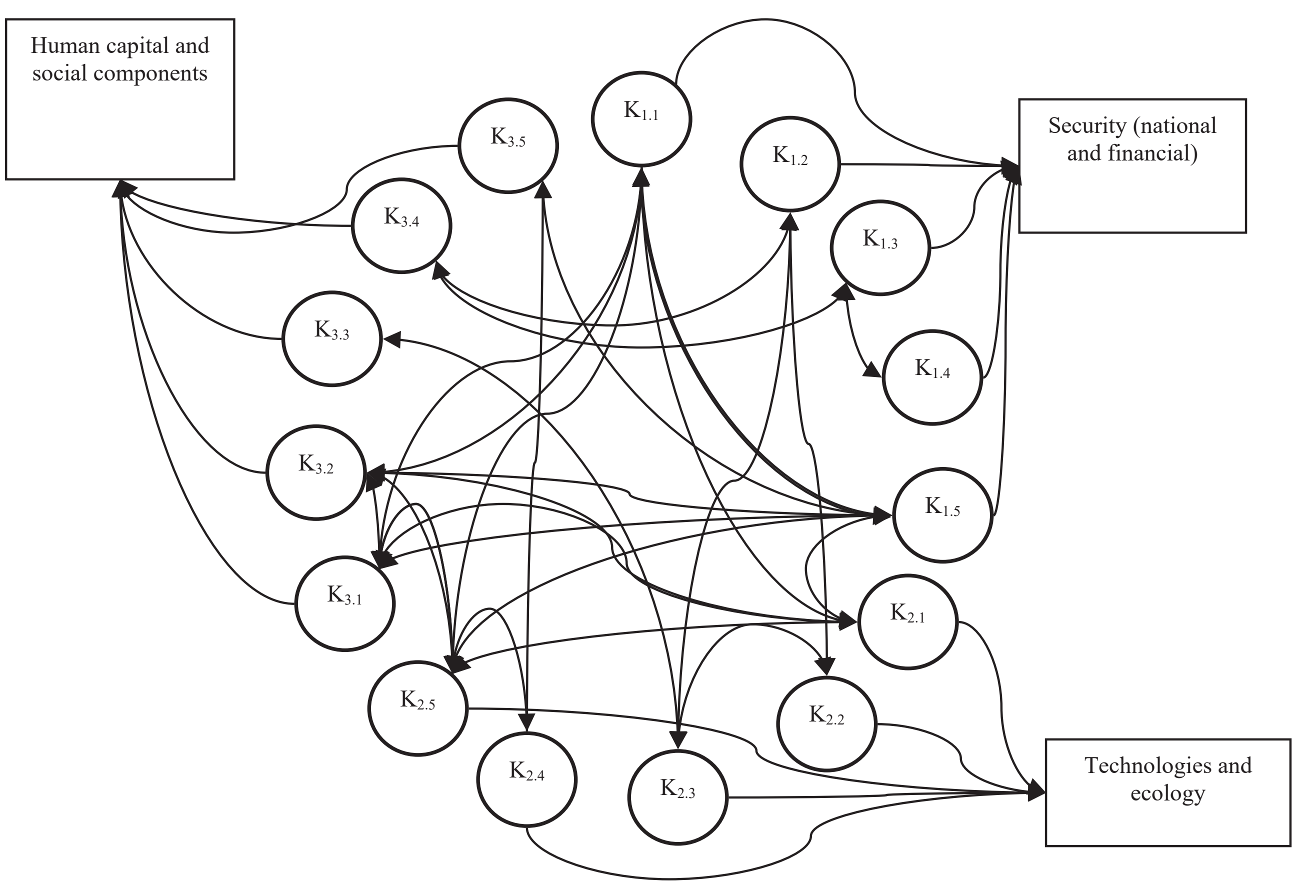

FIGURE 1 Cognitive map of the economic growth indicator system

TABLE 2 The results of the simulation of the impulse process corresponding to the scenario of introducing disturbances to the vertex of K3.1

	n1	n2	n3	n4	n5	n6	n7	n8
1.1	0	1	5	25	127	645	3279	16669
1.2	0	0	0	1	6	33	172	884
1.3	0	0	0	0	0	1	6	35
1.4	0	0	0	0	0	0	1	6
1.5	0	1	5	26	132	672	3416	17368
2.1	0	1	5	25	127	645	3279	16669
2.2	0	0	1	5	26	133	678	3451
2.3	0	0	0	1	6	33	172	883
2.4	0	0	1	6	32	164	836	4252
2.5	0	1	5	26	132	672	3416	17368
3.1	1	1	5	25	127	645	3279	16669
3.2	0	1	5	25	127	645	3279	16669
3.3	0	0	0	0	1	6	33	172
3.4	0	0	0	0	1	6	34	178
3.5	0	0	1	6	32	164	836	4252

H(*t*) – the value of the parameters of the vertices at the simulation cycle;

H(0) – value of the parameters of the vertices at the initial cycle of the simulation;

I – unit matrix

Set L = (0,0,0,0,0,0,0,0,0,0,+1,0,0,0,0), i.e., introduce a positive change in element 3.1 of the system – "Domestic government spending on health care per capita". The specified number of simulation cycles is 8 (n = 8).

The new values of the parameters of the peaks of the cognitive model calculated on the basis of impulse processes in separate simulation cycles n1, n2, ... n8 are presented in the Table 2, on the basis of which a graph (Figure 2) of the change in pulses at the vertices was constructed.

The abscissa axis (Figure 2) shows the simulation cycles (n), and the ordinate axis shows the change in the values of economic growth factors in relative units.

4 Findings

Based on the cognitive model, it can be argued that the most significant scenarios are pulses that include the following factors: 1.5 military spending, 2.5 population in urban agglomerations over 1 million (% of total population); 3.1 per capita domestic government spending on health care.

It is possible to fully agree with this result, because during 2013–2020, the lion's share of Ukraine's GDP came from metallurgical products, which are concentrated in the main old industrial agglomera-

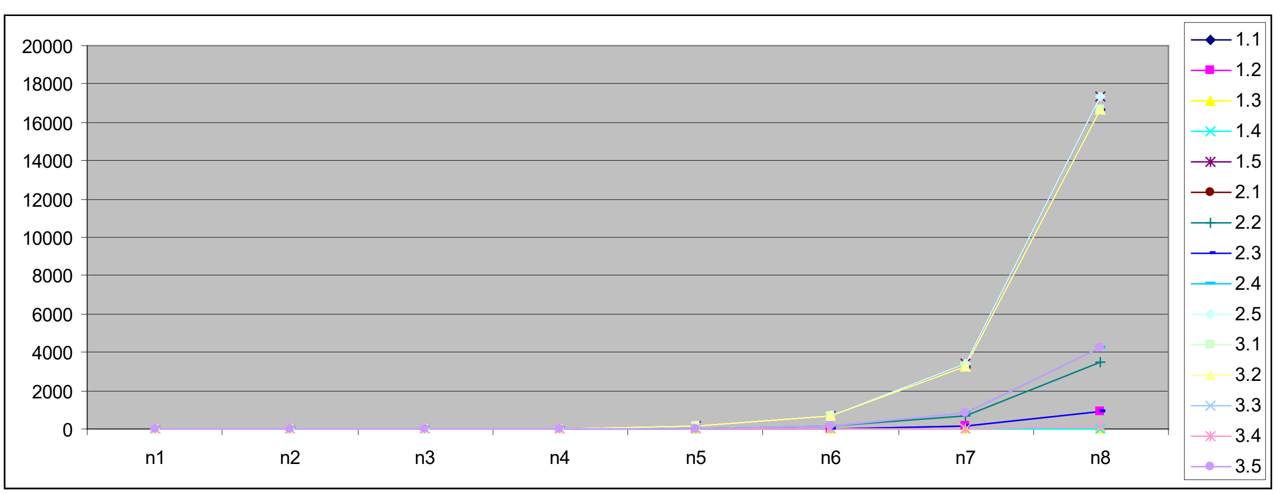

FIGURE 2 Impulse process – graph of changes in pulse values in vertices 1.1-3.5 when perturbations +1 are made to vertex K3.1

TABLE 3 The equation of multiple regression of the country's economic growth

Indicator	Value of indicator
The equation of multiple regression	Y = -2127.6227 + 6739.8189X1 + 46.9406X2 – 30.1849X3
Index of multiple correlation	0,9997
Coefficient of determination	0,999
F-statistics of the Fisher distribution	F > Fkp, the equation is significant
Goldfeld-Quandt test	F < Fkp = 18.5, then the hypothesis of the absence of heteroscedasticity is accepted
Durbin Watson criterion	0.82 < 3.08 and 1.75 < 3.08 > 4 – 1.75, then autocorrelation of the residuals is present

	Multiple regression output							
year	2013	2014	2015	2016	2017	2018	2019	2020
GDP per capita, USD	183310	131805	90615	93270	112154	130832	153781	155582
Population in urban agglomerations over 1 million (% of the total population)	4,5	4,6	4,6	4,6	4,6	4,7	4,7	4,7
Military expenditures per capita, USD	4024,1	2901,5	2110,9	2181,2	2633,7	3086,5	3648,2	3713,0
Internal state expenditures on health care per capita, PCS, USD	1107,2	1137,7	1190,4	1273,6	1357,4	1438,4	1575,1	1575,1

tions of the country (Zaporizhzhia, Mariupol, Kryvyi Rih and other industrial cities). Also, the economy faced a COVID-19 epidemic between 2019 and 2021, making domestic health care spending crucial in those years. Significant impact on economic growth in the 2013-2020 period was caused by military spending to address the needs of the large-scale military conflict in Donbass.

The significance of the factors was confirmed by constructing a multiple regression of the dependence of GDP per capita on % of population in urban agglomerations, public spending on health care per capita, military expenditures per capita. The parameters of the multiple regression are presented in Table 3.

As a result of the calculations the equation of multiple regression Y = -2127.6227 + 6739.8189X1 + 46.9406X2-30.1849X3 was obtained. There is a possible economic interpretation of the model parameters: a 1% increase in the population of urban agglomerations leads to an increase in GDP per capita by an average of $6,739.8; a $1 increase in military spending provides an average $46.9 increase in GDP per capita; an increase in health care spending provides an average $30.18 increase in GDP per capita. It is found that in the situation studied, 99.94% of all variability in GDP per capita is due to changing factors.

5 Conclusions

The assessment of the dynamic relationship between technological development, national security, human capital and economic growth yielded the following results:

1) Using the data of the World Bank dashboard, three groups of indicators (factors) of influence on the economic growth of the country were formed. The level of causality was determined on the basis of the Fechner coefficient and the most significant ones were selected (k = 0.5-1).

2) The influence of factors, calculated on the basis of impulse processes of the cognitive model, allowed to form the economic growth of the country as a weakly structured system and to determine the parameters of the multiple regression.

3) As a result of economic and mathematical calculations the equation of multiple regression and the possible economic interpretation of the model parameters were obtained. It was found that in the situation under study 99.94% of all the variability of GDP per capita (indicator of economic growth) is explained by changes in factors.

4) The results of the study confirm Ukraine's economic growth processes. The period 2013–2020 was a period of increasing production of metal products and the development of metallurgical industrial groups. The majority of metallurgical enterprises are located in the old industrial agglomerations of the country, which was reflected in the calculations of cognitive modeling, when the significant indicator of the population in urban agglomerations is more than 1 million people (% of the total population). It could be argued that military spending is strategically important to national security and economic growth and is the biggest impulse disturbance of the cognitive model. Also, in 2019–2021, the economy faced a COVID-19 epidemic, making domestic health care spending in those years crucial to both the general population and to sustaining the nation's economic growth.

References

[1] Solow, R. M. (1957). Technical change and the aggregate production function. *Rev. Econ. Stat*, pp. 312–320.

[2] Shittu, W. O., Yusuf, H. A., El Houssein, A. E. M., & Hassan, S. (2020). The impacts of foreign direct investment and globalisation on economic growth in West Africa: examining the role of political governance. *J. Econ. Stud.*, vol. 47(7), pp. 1733–1755.

[3] Wu, J., Abban, O. J., Boadi, A. D., Haris, M., Ocran, P., & Addo, A. A. (2021). Exploring the relationships among CO_2 emissions, urbanization, economic growth, economic structure, energy consumption, and trade along the BRI based on income classification. *Energy Ecol. Environ*, vol. 6(3), pp. 213–231.

[4] Radmehr, R., Henneberrya, S. R., & Shayanmehrab, S. (2021). Renewable Energy Consumption, CO_2 Emissions, and Economic Growth Nexus: A Simultaneity Spatial Modeling Analysis of EU Countries. *Structural Change and Economic Dynamics*, vol. 57, pp. 13–27.

[5] Rehman, E., & Rehman, S. (2022). Modeling the nexus between carbon emissions, urbanization, population growth, energy consumption, and economic development in Asia: Evidence from grey relational analysis. *Energy Reports*, vol. 8, pp. 5430–5442.

[6] Hölzl, W., & Janger, J. (2014). Distance to the frontier and the perception of innovation barriers across European countries. *Research Policy*, vol. 43(4), pp. 707–725.

[7] Das, G., & Drine, I. (2020). Distance from the technology frontier: How could Africa catch-up via socio-institutional factors and human capital? *Technological Forecasting and Social Change*, vol. 150, pp. 119–755.

[8] Edquist, H., & Henrekson, M. (2017). Do R&D and ICT affect total factor productivity growth differently? *Telecommunications Policy*, vol. 41(2), pp. 106–119.

[9] Pietrucha, J., & Żelazny, R. (2019). TFP spillover effects via trade and FDI channels Economic Research-Ekonomska Istraživanja, vol. 33, pp. 1–17.

[10] Kim, Y. E., & Loayza, N. V. (2019). Productivity growth: Patterns and determinants across the world. *Economía*, vol. 42(84), pp. 36–93.

[11] Osadcha, O. O. (2016). Metodyka kilkisnoho otsiniuvannia yakosti oblikovo-analitychnoi informatsii [Methods of quantitative assessment of the quality of accounting and analytical information]. *Collection of Scientific Papers of the Ternopil National Economic university*, vol. 24, no. 2, pp. 155–161. (in Ukrainian)

[12] Shapurov, O. O. (2021). Formuvannia sukupnoho potentsialu zabezpechennia innovatsiinoho staloho rozvytku promyslovoho pidpryiemstva na osnovi kohnityvnoho modeliuvannia slabostrukturovanoi systemy [Formation of the overall potential for ensuring innovative sustainable development of an industrial enterprise based on cognitive modeling of a weakly structured system]. *Black Sea Economic Studies*, vol. 52, no. 2, pp. 154–163. (in Ukrainian)

Received on: 2th of July, 2022
Accepted on: 17th of August, 2022
Published on: 31th of August, 2022