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CONVERGENCE TRENDS IN THE “ECONOMY – EDUCATION – DIGITALIZATION – NATIONAL SECURITY” CHAIN

Purpose. To identify the current level and trends of convergence to justify the directions of adjustment of approaches to the management of the national economy.

Methodology. The methodological basis of the study is economic and mathematical modelling using Barro-regression and variational analysis. Integral indicators for the characteristics of the components of the studied chain are defined as the arithmetic mean of partial indicators of economic development (24 indicators), educational development (28 indicators), digitalization (12 indicators) and national security (53 indicators), normalized by the method of natural normalization. To assess the pairwise, triple and complex convergent relationships in the studied chain, a multiplicative convolution of the corresponding integral indicators characterizing a pair, triple or four of the studied concepts, was performed. The sample consisted of 11 countries from Central and Eastern Europe (Croatia, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia, Ukraine). The research period includes 1999–2020.

Findings. The existence of dynamic convergent links in the “national security – digitalization”, “education – national security – digitalization” chains is confirmed, which indicates the need for further interstate integration of regulatory practices in the field of digitalization impact on the national security (including digital education effects). The links in the “economy – education”, “economy – national security”, “education – national security”, “economy – education – national security” chains have a fairly high static level of convergence, which indicates the need to level the differences in national practices of regulation of these directions. At the same time, current trends in the digitalization of education and the digitalization of the economy remain quite diversified, which determines the need to apply specific national government practices in this area.

Originality. Methodological principles of integrated assessment of convergent relationships in the “economy – education – national security – digitalization” chain differ from the existing ones by using integrated indicators of characteristics of single, pair, triple and complex relationships within the studied chain to determine the levels of their σ - and β -convergence. This allowed identifying the presence of the achieved level of convergence and dynamic convergent trends that arise in the process of economic and educational transformations in the context of overcoming security challenges in the national economy in the context of digitalization.

Practical value. The achieved significant level of convergence of the economy, education and digitalization of the studied countries has been revealed, as well as stable convergent links of integrated development of their economy, education and national security have been formed. The results obtained can be used as a scientific substantiation of adjustment of directions of state regulation of economy and education in the conditions of digitalization and in the context of overcoming security challenges.

Keywords: *economy, education, national security, digitalization, convergence, state regulation*

Introduction. Trends in global and national development indicate a significant convergence of strategic orientations of the countries. At the same time, the analysis of trends in the development of real indicators in the direction of increasing their complementarity is of scientific interest. Thus, the mutual strengthening of economic development and education is manifested through the emergence of new types and forms of entrepreneurship that require appropriate skills and competencies of specialists and justify supply and demand in the labour market and structural quantitative and qualitative transformations of the education system. In the context of digitalization, this relationship is mediated by the replacement of traditional technologies with digital ones, which require appropriate training and determine the structural transformations of the economic system. It is important that the social, ecological, energy and food security vectors of the national economy remain relevant in the digital age. It is digital technologies that expand the potential for their measurement and provision. At the same time, it should be noted that the central block, which is integrated with educational, digital and economic transformations in the context of overcoming without challenges, remains human development, which should pri-

marily focus on management decisions and strategic educational and economic programs. This testifies to the relevance of the integration of management strategies of the national economy, which has led to the need to assess the level of convergence in terms of the characteristics of economic development, education, digitalization and security levels of the national economy.

Literature review. Substantiated regularities of fundamental development of economy, education, ensuring the security of the national economy in the conditions of digitalization have proved the urgency of applying integrated approaches to the management of the national economy. It is proved that digitalization and global integration create certain information risks in the management of the national economy [1–3], which creates a significant impact on various areas of national security, among which the most relevant ones are social [4–6], economic, environmental and energy [7–9]. Thus, in the context of digitalization, approaches to the implementation of financial transactions and financial market development are changing [10–12]. In turn, this requires modification of approaches to organizational management [13–15]. It is important that digitalization is associated not only with economic but also with educational transformations, which requires the integration of management practices in the field of economics and education [16–18]. This indicates the relevance of re-

search to identify current trends in economic convergence and education in the context of digitalization and their role in ensuring national security.

Purpose. The study involves testing the hypothesis of the convergent nature of economic development, education, digitalization and national security. The purpose of the study is to identify the current level and trends of convergence to justify the directions of adjustment of approaches to the management of the national economy.

Methods. To test the hypothesis, it is necessary to form integrated indicators of the characteristics of the studied concepts. The analysis of the scientific literature allowed determining the list of indicators that most fully characterize the economy, education, digitalization and national security, which should be used to form integrated indicators. The statistical base of The World Bank was used to select indicators [19]. Thus, 24 indicators were selected to assess the economy: agriculture, forestry, and fishing, value added (annual % growth); electricity production from coal sources (% of total); electricity production from hydroelectric sources (% of total); electricity production from natural gas sources (% of total); electricity production from nuclear sources (% of total); electricity production from oil sources (% of total); electricity production from renewable sources, excluding hydroelectric (% of total); employment in agriculture (% of total employment); employment in industry (% of total employment); employment in services (% of total employment); exports of goods and services (annual % growth); foreign direct investment, net (BoP, current US\$); GDP growth (annual %); gross capital formation (annual % growth); imports of goods and services (annual % growth); industry (including construction), value added (annual % growth); inflation, consumer prices (annual %); manufacturing, value added (annual % growth); new businesses registered (number); rural population growth (annual %); services, value added (annual % growth); self-employed, total (% of total employment); wage and salaried workers, total (% of total employment); urban population growth (annual %).

A list of 28 indicators has been formed to describe the field of education: government expenditure on pre-primary education as % of GDP (%); government expenditure on primary education, constant PPP\$ (millions); government expenditure on secondary and post-secondary non-tertiary vocational education as % of GDP (%); government expenditure on tertiary education as % of GDP (%); inbound mobility rate, both sexes (%); initial government funding per pre-primary student as the percentage of GDP per capita; initial government funding per secondary student as the percentage of GDP per capita; initial government funding per tertiary student as the percentage of GDP per capita; initial government funding per primary student as the percentage of GDP per capita; labour force with basic education (% of total labour force); labour force with advanced education (% of total labour force); labour force with intermediate education (% of total labour force); outbound mobility ratio, all regions, both sexes (%); the percentage of enrolment in post-secondary non-tertiary education in private institutions (%); the percentage of enrolment in pre-primary education in private institutions (%); the percentage of enrolment in primary education in private institutions (%); the percentage of enrolment in secondary education in private institutions (%); the percentage of enrolment in tertiary education in private institutions (%); the percentage of graduates from tertiary education graduating from Agriculture, Forestry, Fisheries and Veterinary programmes, both sexes (%); the percentage of graduates from tertiary education graduating from Arts and Humanities programmes, both sexes (%); the percentage of graduates from tertiary education graduating from Business, Administration and Law programmes, both sexes (%); the percentage of graduates from tertiary education graduating from Education programmes, both sexes (%); the percentage of graduates from tertiary education graduating

from Engineering, Manufacturing and Construction programmes, both sexes (%); the percentage of graduates from tertiary education graduating from Health and Welfare programmes, both sexes (%); the percentage of graduates from tertiary education graduating from Information and Communication Technologies programmes, both sexes (%); the percentage of graduates from tertiary education graduating from Natural Sciences, Mathematics and Statistics programmes, both sexes (%); the percentage of graduates from tertiary education graduating from Services programmes, both sexes (%); the percentage of graduates from tertiary education graduating from Social Sciences, Journalism and Information programmes, both sexes (%).

The development of digitalization was assessed using 12 indicators: automated teller machines (ATMs) (per 100 000 adults); computer, communications and other services (% of commercial service exports); computer, communications and other services (% of commercial service imports); international trade in digitally-deliverable services, annual growth, %; high-technology exports (% of manufactured exports); fixed broadband subscriptions; fixed telephone subscriptions; mobile-cellular subscriptions per 100 inhabitants; ICT goods imports (% total goods imports); ICT goods exports (% of total goods exports); individuals using the Internet (% of population); international bandwidth; in Mbit/s.

National security was assessed using 53 indicators that characterize its economic, social and informational components: GDP per capita (constant prices as of 2010, US \$); inflation, consumer prices (annual %); central government debt (% of GDP); net government lending/borrowing (% of GDP); corruption control (units); patent applications; research and development costs (% of GDP); researchers in research and development (ppm); trademark applications; net inflow of foreign direct investment (current prices, US \$); net outflow of foreign direct investment (current prices, US \$); government efficiency; regulatory quality (units); exports of goods and services (% of GDP); imports of goods and services (% of GDP); level of energy intensity of primary energy (MJ/\$ GDP, 2011); energy consumption (kg of oil equivalent per capita); renewable energy consumption (% of total final energy consumption); ease of doing business; Gini Index; share of income of 10% of the richest part of the population (units); income share of 10% of the poorest part of the population (units); share of labour force (% of population); unemployment rate (% of labour force); share of vulnerable employment (% of employment); productivity per person (in US \$ per PKS); size of the shadow economy (units); Human Development Index; age dependency ratio (% of working age population); population aged 65 and over; birth rate (per thousand people); mortality rate (per thousand people); population growth (annual %); public spending on education (% of GDP); health expenditure per capita (current prices, US \$); beds in hospitals (per 1000 people); number of armed forces (% of total labour force); intentional homicides (per 100 000 people); political stability and absence of violence/terrorism (units); share of the ICT sector in GDP (%); share of ICT workers in total employment (%); exports of ICT goods (%); imports of ICT goods (%); export of ICT services (%); e-commerce sales (billion euros); fixed broadband connection (pers.); fixed telephone communication (pers.); mobile broadband (pers.); secure Internet servers; E-Government Development Index; people who use the Internet (% of the population); Electronic participation index; Press Freedom Index.

Determination of integrated indicators carried out according to the formula

$$I = \frac{\sum_{j=1}^n \tilde{f}_j}{N}, \quad (1)$$

where I is the integral indicator; \tilde{f}_j is the normalized value of the i^{th} indicator (by the method of natural normalization); N is the total number of input indicators.

The pairwise, triple and complex convergent relationships in the “economy – education – national security – digitalization” chain should also be assessed. Integral indicators of pairwise characteristics will be determined by multiplicative convolution of pairs, triplets and four of the corresponding integral indicators. The sample consisted of 11 countries from Central and Eastern Europe (Croatia, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia, Ukraine).

Convergence is evaluated in two ways. The first indicator – the level of σ -convergence (sigma-convergence) will be estimated as the level of variation of the studied feature in terms of the sample of countries. The indicator will select the coefficient of variation, which reflects the static and dynamic average level of deviations and is calculated by the formula

$$CV_t = \frac{\left(\frac{1}{n} \sum_{i=1}^n (y_{it} - \bar{y}_t)^2 \right)^{1/2}}{\bar{y}_t}, \quad (2)$$

where \bar{y}_t is the average level of the integrated indicator in the period t ; y_{it} is the level of the integrated indicator in the i^{th} country, $i = \overline{1, n}$ in the period t .

On the other hand, it is of scientific interest to assess the rate of reduction of gaps between the levels of the studied integrated indicators. To this end, the presence of β -convergence (beta-convergence) should be analysed. To do this, we build the following econometric model

$$\ln \left(\frac{y_{i,t+1}}{y_{i,t}} \right) = \alpha + \beta \ln(y_{i,t}) + \varepsilon_{i,t}, \quad (3)$$

where $y_{i,t}$ is the level of the integrated indicator in the i^{th} country ($i = \overline{1, n}$) in the base period ($t = \overline{1, T-1}$); $y_{i,t+1}$ is the

level of the integrated indicator in the i^{th} country ($i = \overline{1, n}$) in the reporting period ($t = \overline{2, T}$); α is the coefficient that characterizes the basic level of the integrated indicator in the absence of changes in its dynamics; β is the coefficient showing the presence of β -convergence (provided $\beta < 0$); $\varepsilon_{i,t}$ is a standard error.

Results. The results of estimating the level of σ -convergence for the identified four integral indicators are presented in Fig. 1. Importantly, a level of variation of less than 0.3 indicates homogeneity of the sample, which should be considered as a significant level of convergence. From the data of Fig. 1 it can be stated that in the studied European countries the levels of economic development, education and national security are homogeneous at the beginning of the study period (values of the coefficient of variation do not exceed 0.2), and their low volatility during the analysed period does not indicate a divergent trend. At the same time, the values of the integrated indicator of digitalization characteristic are the most variable – as of the beginning of the period the coefficient of variation reaches the level of 0.37–0.39, but by the end of the research period it decreases to less than 0.15. Thus, the generalizing parameters allowed us to determine that European countries have reached a stage of relatively homogeneous economic development, education and overcoming without pitfalls in the context of digitalization.

Therefore, the results presented in Table 1, confirm the conclusion that there is no further convergence of economic development of the studied countries. In this case, given the above results, it is impossible to say about the divergent trend, as convergence has already been achieved at the beginning of the analysed period.

Similar results were found for the education sector. It should be noted that the results of the evaluation of β -convergence processes in relation to digitization did not allow obtaining statistically significant results. At the same time, the above parameters indicate a convergent trend rather than a divergent one. At the same time, the estimated level of β -convergence

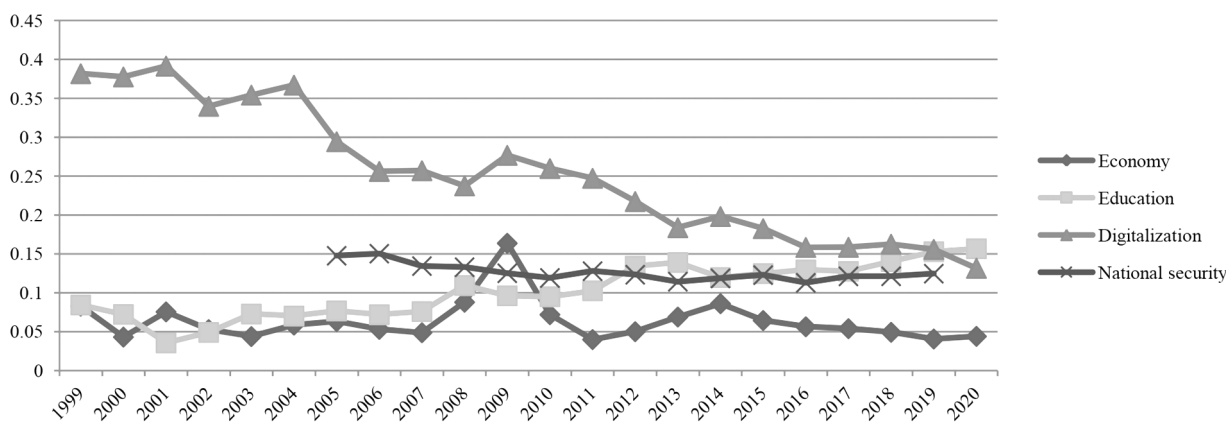


Fig. 1. Results of s -convergence assessment in European countries in terms of economy, education, digitalization and national security

Table 1

The results of the assessment of the processes of β -convergence of economic, education, national security and digitalization development in European countries during 1999–2020

Integral indicator of chain	Coefficient	St. error	t -value	p -value	Lowest 95 %	Highest 95 %	Sig
economy	0.550	0.060	9.19	0.000	0.432	0.667	***
education	0.112	0.025	4.54	0.000	0.064	0.160	***
digitalization	0.004	0.017	0.27	0.790	-0.029	0.038	
national security	-0.022	0.012	-1.84	0.066	-0.045	0.001	*

Note: *** $p < 0.01$ (statistical significance at the level of 99 %); * $p < 0.1$ (statistical significance at the level of 90 %)

showed a significant convergence of national security levels in the studied European countries.

At the next stage of the study, we move on to assess the pairwise convergent relationships in the “economy – education – national security – digitalization” chain.

Calculations of coefficients of variation for integrated indicators of the characteristics of pairwise relationships of the studied chain (Fig. 2) showed that during the analysed period there is a gradual increase in the homogeneity of the levels of the studied indicators. It is important that at the beginning of the analysed period, the relationships in the “economy – education”, “economy – digitalization” and “digitalization – national security” chains were more heterogeneous in terms of the studied countries, which are approaching the end of the analysed period. On the other hand, the other pairings were characterized by significant convergence throughout the study period.

At the same time, the results are presented in Table 2, point to the fact that the relationship between the “economy – education” chain, formed in European countries, has not yet reached a significant level of convergence, i. e. convergent processes are not complete. Thus, economic and educational transformations are quite differentiated for the national environment of different countries, and therefore their relationship cannot be considered stable and transitional from the stage of national development to globalization and international integration. A similar trend can be observed for the relationships found in the “economy – digitalization” chain – statistically significant results indicate a divergent trend, i. e. the digitalization of the economy causes the growth of differences in the development of European countries. Accordingly, it can be stated that there is a significant influence of national characteristics of the country on the development of the economy in the context of digitalization, which requires

the formation of national rather than global strategies for digitalization of the economy.

The following vector of evaluation of convergent relations did not allow obtaining statistically significant results for the chains of “education – digitalization”, as well as “education – national security”, which showed the absence of both convergent and divergent trends. The results showed that national strategies for ensuring the economic component of national security at the present stage of development remain diversified, and these differences are quite volatile, which demonstrates the need to take into account in their development and adjust more national characteristics than international experience.

The last block of paired relationships is characterized by the presence of stable β -convergence. This points to the fact that at the present stage of development, the impact of digitalization on national security has reached a global nature, and strategies to address digital security challenges in most countries are unified, given the specifics and speed of penetration of information technology. Thus, in this context, the management of the national economy should be focused on international recommendations and strategic documents.

At the next stage of the study, we move on to the analysis of the threefold relationships that emerge in the “economy – education – national security – digitalization” chain. Therefore, the results of estimating the s-convergence of the triple relationships of the studied chain are presented in Fig. 3. Analysing the data in the figure, we note that more complex relationships are characterized by a higher level of variation than those found in previous stages of the study. Thus, only the relationship in the “economy – education – national security” chain can be considered relatively stable in terms of European countries. On the other hand, for most of the studied blocks,

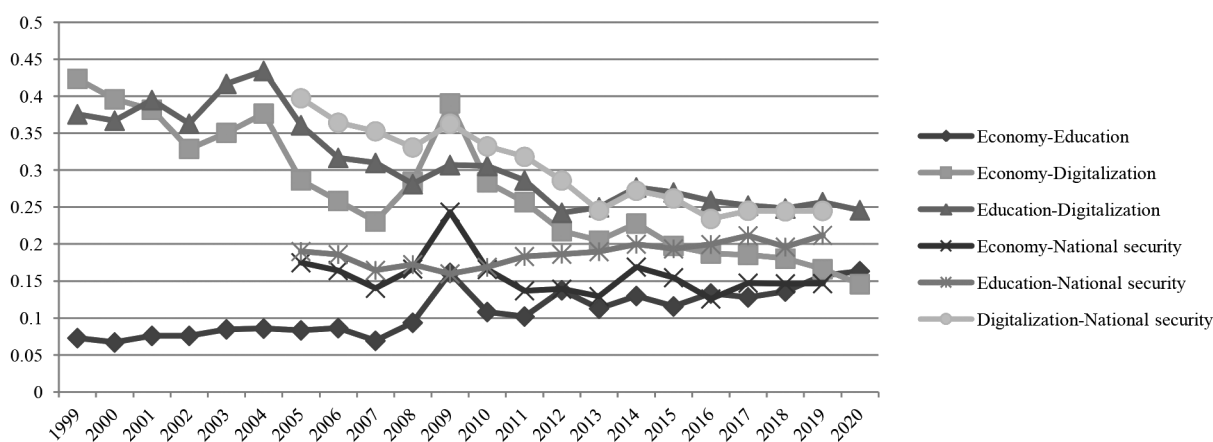


Fig. 2. The results of the assessment of s-convergence in European countries in terms of paired relationships in the “economy – education – national security – digitalization” chain

Table 2

The results of the assessment of the processes of b-convergence of in European countries in terms of paired relationships in the “economy – education – national security – digitalization” chain during 1999–2020

Integral indicator of chain	Coefficient	St. error	t-value	p-value	Lowest 95 %	Highest 95 %	Sig
“economy – education”	0.283	0.045	6.29	0.000	0.194	0.371	***
“economy – digitalization”	0.057	0.029	1.97	0.049	0.000	0.113	**
“education – digitalization”	0.021	0.016	1.31	0.190	-0.010	0.051	
“education – national security”	0.003	0.017	0.18	0.860	-0.031	0.037	
“economy – national security”	0.210	0.046	4.57	0.000	0.120	0.300	***
“national security – digitalization”	-0.044	0.018	-2.39	0.017	-0.079	-0.008	**

Note: *** $p < 0.01$ (statistical significance at the level of 99 %); ** $p < 0.05$ (statistical significance at the level of 95 %)

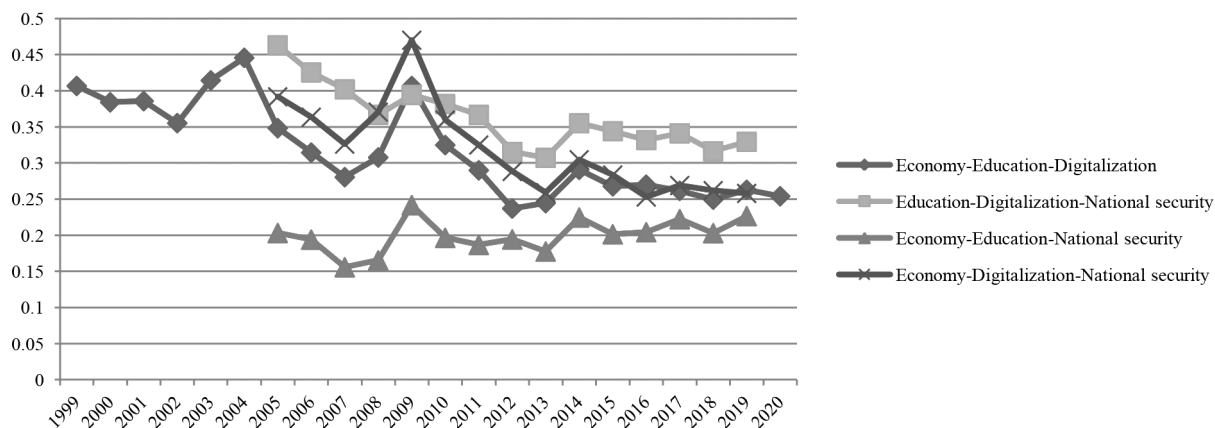


Fig. 3. The results of the assessment of σ -convergence in European countries in terms of the triple relationship in the “economy – education – national security – digitalization” chain

Table 3

The results of the assessment of the processes of b-convergence of in European countries in terms of tripled relationships in the “economy – education – national security – digitalization” chain during 2005–2020

Integral indicator of chain	Coefficient	St. error	t-value	p-value	Lowest 95 %	Highest 95 %	Sig
“economy – education – digitalization”	0.048	0.024	2.01	0.045	0.001	0.095	**
“education – national security – digitalization”	-0.036	0.018	-2.00	0.046	-0.071	-0.001	**
“economy – education – national security”	0.132	0.036	3.64	0.000	0.061	0.203	***
“economy – national security – digitalization”	0.083	0.036	2.29	0.022	0.012	0.154	**

Note: *** $p < 0.01$ (statistical significance at the level of 99 %), ** $p < 0.05$ (statistical significance at the level of 95 %)

the detected trend of variation is downward, but the data are characterized by a certain volatility, which does not allow stating the achievement of convergence.

A deeper analysis of b-convergence in terms of the studied blocks showed that, in particular, the development of relationships in the “economy – education – digitalization” chain (Table 3) is not yet complete and has significant differences in terms of European countries that may grow over time, which indicates the need for continuous adjustment of national strat-

egies for economic and educational transformation in the context of digitalization.

At the same time, countries’ national strategies for meeting educational transformation without the challenges of digitalisation are gradually converging. The results confirmed that the convergence of economic and educational transformations, as well as the digitalization of the economy in the context of overcoming security challenges has not yet been achieved.

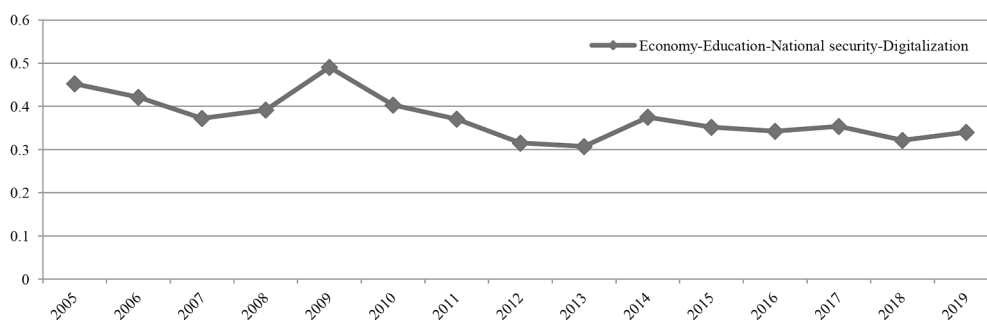


Fig. 4. Results of the assessment of s -convergence in European countries in the “economy – education – national security – digitalization” chain

Table 4

The results of the assessment of convergence (b-convergence) in the “economy – education – national security – digitalization” chain in European countries during 2005–2019

Integral indicator of chain	Coefficient	St. error	t-value	p-value	Lowest 95 %	Highest 95 %	Sig
“economy – education – digitalization – national security”	0.053	0.031	1.75	0.080	-0.006	0.113	*

Note: * $p < 0.1$ (statistical significance at 90 %)

The last block of research is devoted to the assessment of the convergent relationships of the “economy – education – national security – digitalization” chain will be conducted in a complex for an integrated indicator of the complex characteristics of the studied chain. Therefore, the results presented in Fig. 4, show that the analysed integrated indicator is quite variable in terms of the analysed countries. At the same time, during the period there are quite significant fluctuations, which do not allow one to definitively determine the prospects for further development of the relationships that characterize the studied chain.

An in-depth analysis of the convergent links in the “economy – education – national security – digitalization” chain (Table 4) showed that during 2005–2020 b-convergence was not achieved. Thus, it can be stated that at this stage the strategies to overcome the security challenges of national economies under the influence of economic and educational transformations in the context of digitalization should be individual in terms of countries, focused primarily on the national environment and achieving state goals.

Conclusions. Summarizing the results, we can substantiate a number of conclusions about the specifics of national economies achieved to date in the context of prospects for convergence: 1) trends in national security, as well as the relationship in the “national security – digitalization”, “education – national security – digitization” chains are characterized by high levels of convergence, which indicates the need to integrate national strategies to ensure them both in the context of developing comprehensive national development programs and in terms of international integration and adherence to a single global vector of development in order to maintain the trend towards further convergence; 2) at the present stage, the level of economic development, education and digitalization, as well as the chain links “economy – education”, “economy – national security”, “education – national security”, “economy – education – national security” in the countries of Europe is quite close, which allows you to implement successful international management practices with minimal consideration of national characteristics, which can reduce their effectiveness in overcoming without pit challenges; 3) chain relationships in the systems of “economy – digitalization”, “education – digitalization”, “economy – education – digitalization”, “economy – national security – digitalization”, “economy – education – national security – digitalization” continue to form, which requires the most diversified strategies for managing the national economy.

Acknowledgements. This research was funded by the grants from the Ministry of Education and Science of Ukraine (reg. No. 0120U102001, reg. No.0121U109553).

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Конвергентні тренди в ланцюзі «економіка – освіта – цифровізація – національна безпека»

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Мета. Визначення поточного рівня й тенденцій конвергенції для обґрунтування напрямів коригування підходів до управління національною економікою.

Методика. Методологічною основою дослідження є економіко-математичне моделювання з використанням регресії Барро та варіаційного аналізу. Інтегральні показники для характеристик складових досліджуваного ланцюга визначаються як середнє арифметичне часткових показників економічного розвитку (24 показники), освітнього розвитку (28 показників), оцифрування (12 показників) та національної безпеки (53 показники), нормалізованих за методом природної нормалізації. Для оцінки попарних, потрійних і складних збіжних зв'язків у досліджуваному ланцюжку була виконана мультипліка-

тивна згортка відповідних інтегральних показників, що характеризують парну, потрійну чи чотири досліджуваних поняття. Вибірка складалася з 11 країн Центральної та Східної Європи (Хорватія, Чехія, Естонія, Угорщина, Латвія, Литва, Польща, Румунія, Словаччина, Словенія, Україна). Період дослідження включає 1999–2020 роки.

Результати. Підтверджено існування динамічних конвергентних зв'язків у ланцюгах «національна безпека – цифровізація», «освіта – національна безпека – цифровізація», що засвідчує необхідність подальшої міждержавної інтеграції регуляторних практик у галузі цифровізаційних викликів національної безпеки (включаючи цифровізацію освіти). Зв'язки в ланцюгах «економіка – освіта», «економіка – національна безпека», «освіта – національна безпека», «економіка – освіта – національна безпека» мають досить високий статичний рівень конвергенції, що вказує на необхідність нівелювання відмінностей у національних практиках регулювання даних напрямів. У той же час, сучасні тренди діджиталізації освіти й діджиталізації економіки залишаються досить диверсифікованими, що визначає необхідність застосування специфічних національних державних практик у цій сфері.

Наукова новизна. Методологічні принципи інтегрованої оцінки конвергентних відносин у ланцюжку

«економіка – освіта – національна безпека – цифровізація» відрізняються від існуючих використанням інтегральних показників характеристик одиночних, парних, потрійних і складних відносин у межах досліджуваного ланцюга для визначення рівнів їх σ - та β -конвергенції. Це дозволило виявити наявність досягнутого рівня конвергенції та динамічних конвергентних тенденцій, що виникають у процесі економічних і освітніх трансформацій у контексті подолання викликів безпеки в національній економіці в контексті цифровізації.

Практична значимість. Виявлено досягнутий значний рівень конвергенції економіки, освіти й цифровізації досліджуваних країн, а також сформовані стійкі конвергентні зв'язки комплексного розвитку їх економіки, освіти та національної безпеки. Отримані результати можуть бути використані як наукове обґрунтування коригування напрямів державного регулювання економіки та освіти в умовах цифровізації та в контексті подолання безпекових викликів.

Ключові слова: економіка, освіта, національна безпека, цифровізація, конвергенція, державне регулювання

The manuscript was submitted 11.04.21.