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A FORECASTING MODEL FOR ASSESSING THE INFLUENCE OF THE COMPONENTS OF TECHNOLOGICAL GROWTH ON ECONOMIC SECURITY

Olha ILYASH [1*], Ruslan LUPAK [2], Maryna KRAVCHENKO [3],
Olena TROFYMENKO [4], Natalia DULIABA [5], Iryna DZHADAN [6]

[1, 3, 4] *Faculty of Management and Marketing, National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Kyiv, Ukraine*
[1, 4, 6] *Department of Economics and Entrepreneurship, International University of Finance, Kyiv, Ukraine*
[2] *Department of Economics, Lviv University of Trade and Economics, Lviv, Ukraine*
[5] *Department of Management and International Entrepreneurship, Lviv Polytechnic National University, Lviv, Ukraine*

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Abstract. The system of indicators for assessing the impact of the components of technological growth on economic security is generalised. This task is carried out by selecting a system of indicators (40 indicators), which, on the one hand, are consistent with one another and with key indicators used in analysing the state of economic security, and which are identified by the components of technological development, on the other hand. The standardisation of the values of initial data i.e. indicators, the determination of the degree of their deviations from the reference parameters and further integral assessment helped to find a generalised indicator of the state of development and the influence of technological growth on the parameters of the system of economic security. The purpose of the study is to test tools for forecasting modelling of the results of assessing the impact of technological growth on economic security. In accordance with the purpose, the level of relationships between the indicators of technological growth and the level of economic security is assessed. High, average and low levels of their relationship is revealed. The obtained results made it possible to forecast the rates of technological growth, perform exponential smoothing of the forecast estimates of the impact of the components of technological growth on economic security and employ damping measurement of the forecast level of the dependence of technological growth and economic security. Taking into account trends in technological growth, the system of indicators of the forecasting model for assessing economic security is expanded. The accuracy of the forecast is determined by the limits of the analysed period of the dynamics of the indicators – from 2013 to 2019, considering the impact of changes in the methodology for calculating individual input data according to statistical sources for the period under study. The use of forecasting models to assess the impact of technological development on Ukraine's economic security will help identify political, economic, social and technological factors that will stimulate investment, strengthen economic openness, increase the volume and share of domestic high-tech exports, and thus, strengthen economic security.

Keywords: technological growth, economic security, forecasting, assessment, innovative development, national economy.

JEL Classification: O11, O30, Q50, Q01.

Introduction

Growing globalization challenges, digitalization of the economy, total informatization of relations and the constant development of scientific and technological progress intensify the transformational processes of socio-economic development (Soni et al., 2021). This, in turn, exacerbates the competition for resources between participants in socio-economic exchange and requires modernization of the established approaches to the effective functioning of industrial complexes on the basis of the implementation of mechanisms for innovative development, which will create conditions for dynamic competitiveness of the national economy. Furthermore, ensuring technological development of the economy today is increasingly associated with the level of economic security. The relevance of such statements is confirmed by the pace of interstate

*Corresponding author. E-mail: *oliai@meta.ua*

hybrid confrontation. It is worth mentioning the economy of Ukraine, which has long been under the influence of hybrid threats, and the reduction of the confrontation should be linked to technological growth. The country has already begun certain institutional reforms, in particular, the Strategy of Economic Security of Ukraine for the period up to 2025 envisages: strengthening industrial development through the expansion of domestic and foreign markets for the sale of domestic products, increasing their competitiveness; restoring the potential of high-tech economic activities and its consistent increase; providing financial and institutional conditions for the creation of technological ecosystems, accelerated development of Industry 4.0 and its integration into technological chains; introducing structural changes in the economy by stimulating the development of a circular economy and digitalization. Such trends are justified in the framework of accelerating the achievement of the Global Sustainable Development Goals by 2030 (8th, 9th and 12th goals out of 17).

The European Commission (2021) has already presented an updated Industrial Strategy, which provides organisational and regulatory measures to stimulate innovative development of European industry in the context of the post-crisis recovery from the COVID-19 pandemic. At the same time, Ukraine has not yet approved a Strategy for Technological Development of Industry, which should meet the current growing needs for economic security and take into account the global challenges associated with the formation of Industry 4.0. The absence of such a strategy is a threatening factor in ensuring the state's economic security, because according to the established research, the improvement to industrial production technologies is the driving force behind combating hybrid risks and threats. In such circumstances, the application of models that can be used to predict the expected consequences of hybrid aggravation and reduced economic security requires the development of methodological tools, which will help to define priority areas for reforming technological processes (Naudé & Nagler, 2017). Toffler argued, "technology is a great engine and a mighty accelerator of economic development, and knowledge is its fuel" (Toffler, 1970). According to Retter et al. (2020), technological progress shows the improvement in knowledge about production methods, which is one of the components ensuring economic security, and public institutions play a significant role in attracting investment in research and development in the field of technology and innovation. The study (Simanaviciene et al., 2015) singles out the country's industrial and scientific-technical potential among the indicators of economic security. Thus, stimulating the achievement of scientific and technological progress and ensuring its funding (in the form of R&D) has become the basis of social transformations and a major factor in economic development of the developed countries of the world (Zhen & Wang, 2021; Pala, 2019; Gordon, 2016; Aghion & Howitt, 2007). Such studies reflect the high dependence of economic security on technological trends (Heyets et al., 2021).

Rapid changes of global trends in innovative development and the challenges of Industry 4.0, the lack of strategic programming and a unified approach to taking into account and monitoring the indicators of technological growth in the system of economic security cause a research gap in this area.

The above raises the issue of determining the analytical characteristics of technological growth that can provide the necessary level of economic security. This defines the purpose of our study, which is to test tools for forecast modelling of the results of assessing the impact of technological growth on economic security. In accordance with the purpose of the study, the following research objectives are set: (1) to generalise the system of indicators for assessing the impact of technological growth on economic security, (2) to perform exponential smoothing of the forecast estimates of the impact of technological growth on economic security; (3) to carry out damping measurement of the forecast level of the dependence of technological growth and economic security, (4) to interpret the forecast results of technological growth in terms of the indicators with high, medium and low correlations of the impact on economic security, (5) to expand the system of the indicators of the forecast model for assessing economic security taking into account trends in technological growth. As for the limitations of the study, the accuracy of the forecast is determined by the limits of the analysed period of the dynamics of the indicators – from 2013 to 2019, and it is influenced by changes in the methodology for calculating some input data according to statistical sources for this period.

1. Literature review

The works of many scientists are devoted to the problems of ensuring economic security and its individual functional areas, the definition of the driving forces behind innovative, industrial and technological development of the national economy and the causes of structural changes in the economy.

Morgenthau believed that the main tasks of strengthening the state's economic security are strengthening the competitiveness of national production, keeping trade preferences, ensuring the advantages of the national economy in world markets, as well as protecting the interests of the state in technological areas (Morgenthau, 1955). This indicates that even in the period of the industrial technological mode, technological growth of industry was of great importance for the state's economic security. A number of empirical studies, which regard the state's economic security as a set of factors that shape it, showed the significance of technology and innovation (Zhen & Wang, 2021; Pala, 2019; Castellacci & Archibugi, 2008). The feedback described in the work (Alvarez et al., 2016) proved that high innovative and technological development stimulates the productivity of social work. In turn, the introduction of innovations and the improvement to the technological level of the economy require an increase in its investment security, which is a component of economic security of the state (Kutsyk et al., 2020; Blakyta et al., 2018).

In addition, the importance of technological growth for increasing the level of economic security is confirmed by some research, in which it is stated "… investment is transformed into innovation and new competitive industries; thanks to technological investment, modernization is provided and a desired social effect is achieved" (Frolova at al., 2021; Ilyash et al., 2021a, 2021b; Chukhray et al., 2020; Rishnyak et al., 2020). The paper (Karpenko et al., 2021) is also devoted to the issue of ensuring investment development of the national infrastructure and to the compliance with the requirements for increasing the level of economic security. Such tendencies require proper forecast modelling, because the use of the obtained results makes it possible to qualitatively manage current processes of ensuring economic security (Official website of President of Ukraine, 2021).

It is necessary to emphasise the importance of conducting forecast modelling of economic security by basic components. For example, in the study (Dokiienko, 2021), modelling is performed taking into account mainly the level of financial security through the aspects of financial stability, solvency, and risk. We agree that this opens up the possibility to quickly analyse the financial sphere of economic security, as well as to identify promising trends in technological growth of the economy.

It is appropriate to take into consideration the industrial characteristics when modelling technological growth and its impact on the level of strengthening economic security. Khalatur et al. (2021), Liubokhynets et al. (2020) prove the need to use economic and mathematical tools to reliably substantiate forecast calculations; their priority is growing when studying the sectoral factor influence and when drawing the correct conclusions regarding the prospects of introducing technology to solve the problems of ensuring economic security.

There are many different scientific opinions on the nature and composition of the state's economic security, its importance, areas of its achievement and evaluation. The results of their research serve as a theoretical basis for defining the level of economic security and evaluating the impact of individual factors on it (Gontareva et al., 2021). In particular, the research of Boyko focuses on the main factors in ensuring economic security; the author singles out the main indicators of studying the state's economic security (Boyko, 2012). Another scholar in his study (Karpenko et al., 2021) proposes a conceptual basis for probability and statistical risk assessment of investment projects concerning the country's infrastructure development within a given interval of economic security. Andryeyeva et al. (2021) highlight the feasibility of logical and structural analysis, in which the forecast results are presented as a system of grouped factors of a positive (or negative) impact of technology on economic security.

It is worth noting that Ukraine has legally approved a methodological approach to defining the level of economic security. Such methodological recommendations are based on certain methods of selecting indicators of economic security taking into account the features of the state. Such a methodological approach includes a comprehensive systematic analysis of the indicators of the state's economic security with the identification of potential threats (Ministry of Economic Development and Trade, 2013). The empirical study of those indicators reveals the main threats to economic security. The threats are the inefficiency of the banking system; a significant decline in production; insufficient diversification of energy supply sources, a high level of material and energy consumption of production; the growth of the shadow economy; a considerable reduction in gross domestic product; a fall in investment and innovation activity and the scientific, technical and technological potential, a reduction in the number of research in strategically important areas of innovative development; the existence of numerous enterprises that run at a loss. Obviously, it is essential to ensure the technological level of production and increase innovation activity of the real sector of the economy. The aforementioned defines the basis of forecasting modelling and the objectivity of its results.

In spite of the existence of significant scientific achievements, another scientific problem needs to be tackled. It is necessary to develop theoretical and applied tools to ensure Ukraine's industrial and technological development in the system of economic security of the state. The need to address the outlined problems led to the choice of the research topic.

2. Research methods

Before forming a forecast model for assessing the impact of the components of technological growth on economic security, it is vital to establish a relationship between the given factors and the phenomenon (Liao et al., 2020). The study of the dependence of the level of the state's economic security on the components of technological growth should be carried out in the methodological sequence summarised in Figure 1.

Based on the assessment of the factor impact and the correlation between technological growth and economic security, we formed a system of indicators in terms of individual components of technological growth (Figure 2). The analysis of variance helped to select groups of indicators depending on the closeness of the correlations.

To establish the relationship between the identified components of technological growth and economic security, a method of regression analysis was chosen, as it studies the interdependence of factors with a fuzzy relationship.

As a result, the closeness of the relationship between the factors is found and estimated, and then a certain dependence between the studied parameters is established. To measure the degree of the dependence between economic security and the components of technological growth, it is advisable to use the Pearson correlation coefficient (r) according to Eq. (1):

$$r = \frac{\left(N - \bar{N}\right) \times \left(Y - \bar{Y}\right)}{\sqrt{\left(N - \bar{N}\right)^2 \times \left(Y - \bar{Y}\right)^2}}\ , \tag{1}$$

where, $Y, \bar{Y}$ – the levels of economic security in the basic

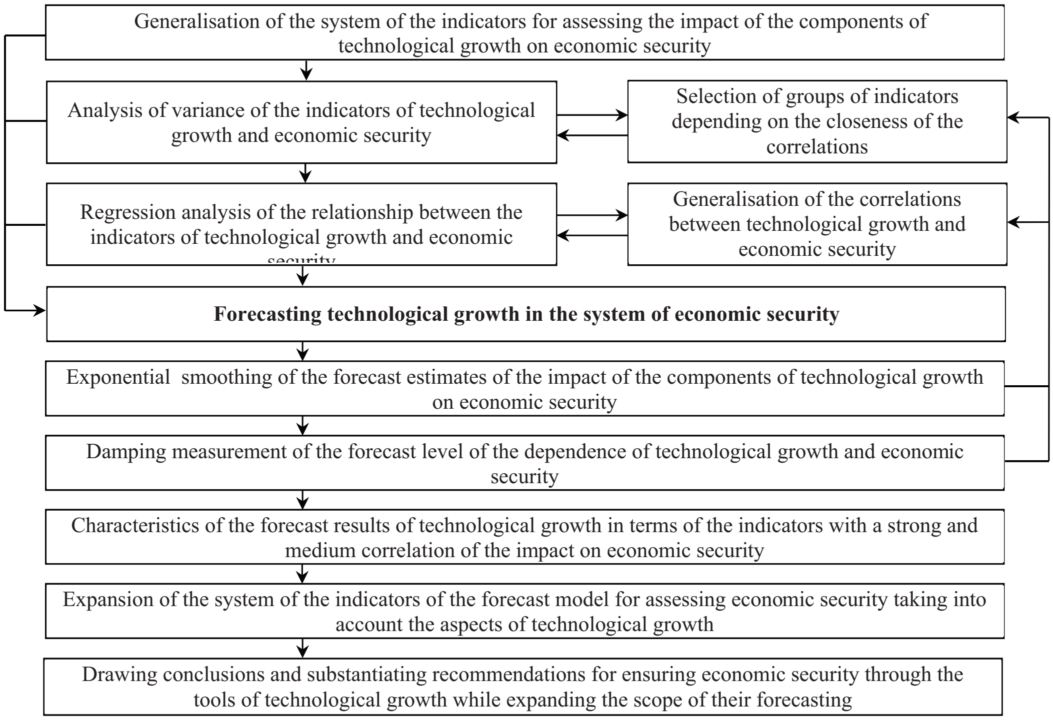

Figure 1. Methodological sequence of a forecast assessment of the impact of technological growth on economic security

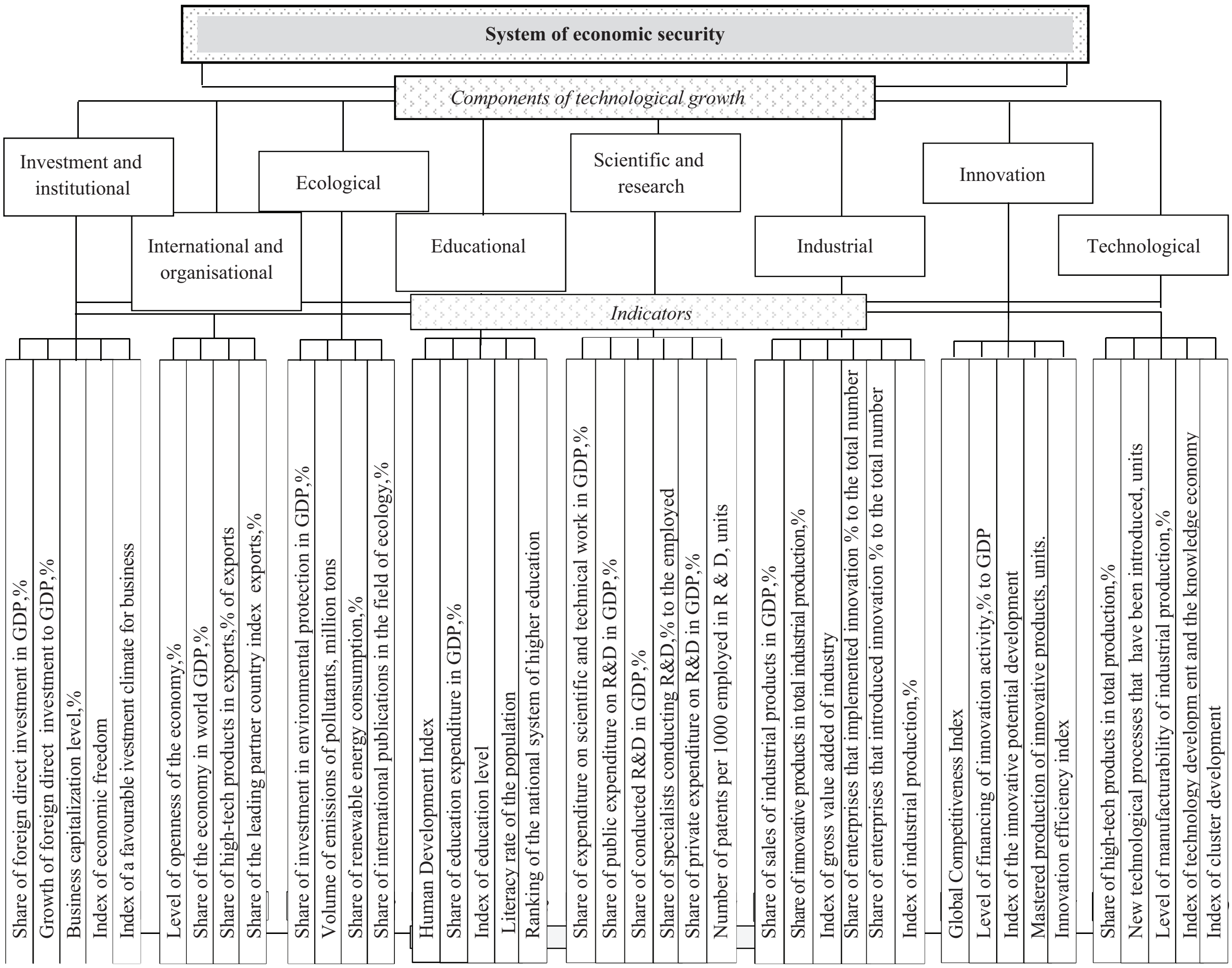

Figure 2. Indicators of assessing the impact of the components of technological growth on economic security

and average values, respectively; N, $\bar{N}$ – the indicators of technological growth in the basic and average values, respectively.

The Pearson correlation coefficient can take a value in the range from –1 to 1; a positive value reflects the growth of Y due to the growth of I_n, and a negative value means a decrease of Y due to the growth of I_n. It should be added that if the coefficient is close to zero, it means that there is no relationship between the categories. Interpretation of the correlation coefficient is based on the level of the strength of the relationship: weak positive relationship (r ≥ 0.1 ≤ 0.3), medium positive relationship (r ≥ 0.3 ≤ 0.5), strong positive relationship (r ≥ 0.5 ≤ 1.0), weak negative relationship (r ≥ –0.1 ≤ –0.3), medium negative relationship (r ≥ –0.3 ≤ –0.5), strong negative relationship (r ≥ –0.5 ≤ –1.0) (Cohen, 1988; Trofymenko et al., 2021).

To qualitatively substantiate the model of linear correlation regression of the impact of the components of technological growth on economic security, it is also obligatory to calculate the coefficient of determination (Eq. (2)).

$$R^2 = \frac{\sum_{j=1}^{n}\left(\widehat{Y_j} - \hat{Y}\right)^2}{\sum_{j=1}^{n}\left(Y_j - \bar{Y}\right)^2} = 1 - \frac{\sum_{j=1}^{n} U_j^2}{\sum_{j=1}^{n}\left(Y_j - \bar{Y}\right)^2}, \quad (2)$$

where, $\sum_{j=1}^{n}\left(\widehat{Y_j} - \hat{Y}\right)^2$ – the sum of the squares of deviations of the values of the assessment indicators; $\sum_{j=1}^{n}\left(Y_j - \bar{Y}\right)^2$ – the residual sum of the squares of deviations of the assessment indicators.

The value of the coefficient ranges from 0 to 1, and the closer the value is to 1, the more accurate the forecast of the model is, and if the coefficient is negative, the modelling should be assessed as erroneous.

The defined relationship between the studied indicators of technological growth and economic security makes it possible to forecast technological growth in the system of economic security. Exponential smoothing of the forecast estimates of the impact of the technological growth components on economic security and damping measurement of the forecast level of the dependence of the studied phenomena determine the indicators with a medium and strong correlation of the impact on economic security and characterise the forecast results of technological growth. This, in general, helps to expand the set of the indicators of the forecast model for assessing economic security, taking into account the aspects of technological growth.

To forecast technological growth in the system of economic security, it is appropriate to use the Holt method, thanks to which the values of the indicators are exponentially smoothed. Priority to this method is given because with the use of a small range of initial data of numerous indicators of technological growth it is possible to provide a long-term forecast of strengthening economic security.

Based on the existing scientific assumptions (Vasiliev & Lilka, 2010), an algorithm for smoothing the values of the forecast trend is determined (Eq. (3)).

$$\begin{cases} D_t = xV + (1-x)(D_{t-1} - B_{t-1}) \\ B_t = y(G_1 - G_{t-1}) + (1-y)B_{t-1}, \\ A_{t+q} = G_1 + qT1 \end{cases} \quad (3)$$

where D_t – the value of the forecast indicator in t period; B_t – trends in the forecast indicator in t period; A_t – time series of the values of the forecast indicator in t period; A_{t+q} –forecast values of the indicator in $t + q$ periods.

In the given system of model calculations, Equation (1) characterises a smoothed series of general values of the forecast indicators, Equation (2) estimates the forecast tendencies, and Equation (3) is used to draw conclusions regarding the expected forecast changes. According to the method of continuous Holt smoothing, after identifying a pair of indicators that best reflect the accuracy of the model in the set under study, the system of equations becomes the basis for making a forecast.

The proposed method of assessing technological growth as a factor influencing economic security makes it possible to comprehensively present the system of strategic project planning, which helps to reliably determine ways of fulfilling forecast expectations. The results of the analysis are employed to draw conclusions regarding the impact of the indicators of technological growth on economic security and justify the forecast of its development. Finally, recommendations concerning ensuring economic security through the acceleration of technological growth of the national economy are formulated.

3. Research results

The growing dependence of national competitiveness on the development of industry and modern innovation opportunities shapes the policy on the development of industrial technologies of the country and defines the direction of the policy on ensuring national economic security. In addition, it is vital to ensure timely monitoring of economic indicators of technological development, which are calculated by national agencies of Ukraine using the method of assessing the competitiveness index of regions and the regional index of human development. For instance, when speaking about the existing methodology for calculating the indicators of industrial technology development, it is worth mentioning that in 2007, the methodology for assessing the impact of innovative projects and science and technology parks was abolished, and in 2013, the methodology for carrying out a comprehensive assessment of the indicators of economic security was approved. Nevertheless, the existing methods of assessing the effectiveness of industrial policy in the field of technological development are insufficient to identify external and internal threats to economic security. Using the program R, a correlation-regression analysis of the closeness of the relationship of the factor features of technological development was conducted. Table 1 shows the calculated correlation coefficients and coefficients of determination of the components.

The calculation of the linear correlation coefficient of the indicators of technological development and the level of economic security resulted in singling out four groups of indicators depending on the closeness of the relationship. To illustrate, such indicators as the level of investment (I_3); openness of the economy (I_6); export of high-tech products in total exports (I_8) and the index of industrial products (I_{30}) show a strong correlation.

A medium correlation was typical of the share of renewable energy consumption (I_{12}); the level of expenditure on education (I_{15}); the share of specialists carrying out scientific and technical work (I_{22}); the volume of gross value added of industry (I_{27}); the index of global competitiveness (I_{31}), the development of technology and the knowledge economy (I_{39}) and the state of cluster development (I_{40}).

A weak correlation was found with the index of economic freedom (I_4); the size of Ukraine's economy (I_7); the share of the leading partner country in total exports of goods (I_9), the human development index (I_{14}); patent performance (I_{24}); the level of funding for innovation (I_{32}); the innovation potential (I_{33}); the number of mastered production of innovative products (I_{34}); the introduction of new technological processes (I_{37}).

At the same time, such indicators as the growth of foreign direct investment to GDP (I_2), the integral index of a favourable investment climate for the business environment (I_5), capital investment in environmental protection (I_{10}), emissions of pollutants and carbon dioxide into the atmosphere by stationary sources (I_{11}), the share of publications involving international cooperation in the field of ecology and the environment (I_{13}), the index of the education level (I_{16}) and the literacy rate of the country's population (expected duration of education) (I_{17}) do not show an established relationship.

As there are a large number of variables for representing the results of calculating the pairwise correlation of variables, it was decided to choose a special method of displaying correlations. This method is a correlation map using the corrplot function of the programming language R. The closeness of the relationship between the indicators of technological development and economic security was identified as an integral assessment. The identification was based on the relationship between 8 components of technological development, such as ecological, educational, scientific, investment, international, industrial, innovation and technological.

Thus, the formation of the correlation map is based on a dependent component of economic security (Y), and an independent component that includes 11 indicators of technological development with high and medium values of the correlation coefficient for the period 2013–2019, which serve as the information base of the study (Figure 3).

Table 1. Indicators of a correlation and variance assessment of technological growth and economic security

Components of technological growth	Indicators	Coefficient of correlation, r	Coefficient of determination, R^2	Components of technological growth	Indicators	Coefficient of correlation, r	Coefficient of determination, R^2
Investment and institutional	I_1	0.045	–0.200	Scientific and research	I_{19}	0.061	–0.127
	I_2	0.042	–0.150		I_{20}	0.009	–0.189
	I_3	0.693	0.632		I_{21}	0.072	–0.113
	I_4	0.111	–0.067		I_{22}	0.317	0.180
	I_5	0.020	–0.176		I_{23}	0.025	–0.170
International and organisational	I_6	0.799	0.760		I_{24}	0.051	–0.139
	I_7	0.177	0.014	Industrial	I_{25}	0.169	0.002
	I_8	0.820	0.785		I_{26}	0.011	–0.189
	I_9	0.110	–0.067		I_{27}	0.348	0.217
Ecological	I_{10}	0.058	–0.113		I_{28}	0.011	–0.187
	I_{11}	0.006	–0.194		I_{29}	0.018	–0.178
	I_{12}	0.375	0.252		I_{30}	0.704	0.646
	I_{13}	0.082	–0.102	Innovation	I_{31}	0.320	0.185
Educational	I_{14}	0.162	–0.006		I_{32}	0.132	–0.041
	I_{15}	0.434	0.322		I_{33}	0.147	–0.023
	I_{16}	0.013	–0.185		I_{34}	0.147	–0.024
	I_{17}	0.270	0.125		I_{35}	0.025	–0.170
	I_{18}	0.274	0.113	Technological	I_{36}	0.011	–0.188
					I_{37}	0.185	0.022
					I_{38}	0.008	–0.190
					I_{39}	0.371	0.246
					I_{40}	0.415	0.297

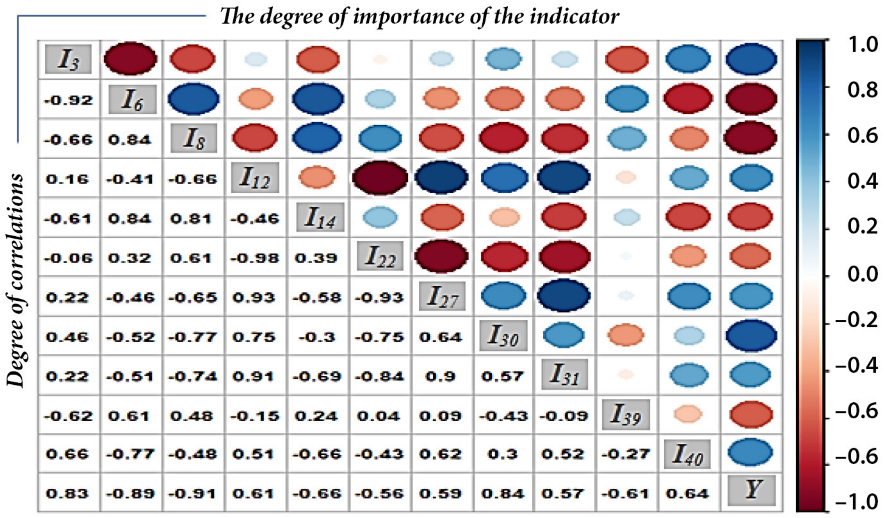

Figure 3. Matrix of correlation between the indicators of assessing the influence of the components of technological growth on economic security

$$Y = \begin{pmatrix} 1.039 \\ 0.954 \\ 0.933 \\ 1.018 \\ 1.018 \\ 1.039 \\ 1.039 \end{pmatrix}.$$

The argument in favour of the chosen method of displaying the correlation map is the relationship between a fall in the level of technological development (in terms of components) and a decline in the level of economic security in general.

The calculated coefficients are employed when building linear regression models of the indicators with high and medium levels of the dependence:

$$\begin{cases} Y = 27{,}7600 + 1.2800 \times I_3 \\ Y = 58{,}2605 - 0.7021 \times \mathrm{I}_6 \\ Y = 63{,}8348 - 2.3437 \times \mathrm{I}_8 \\ Y = 21{,}0350 + 0.2713 \times \mathrm{I}_{30} \end{cases} \text{high correlation;}$$

$$\begin{cases} Y = 42{,}4814 + 1.3319 \times \mathrm{I}_{12} \\ Y = 67{,}9290 - 3.3330 \times \mathrm{I}_{15} \\ Y = 53{,}5240 - 9.4820 \times \mathrm{I}_{22} \\ Y = 36{,}4496 + 0.5093 \times \mathrm{I}_{27} \\ Y = 46{,}3175 + 0.04220 \times \mathrm{I}_{31} \\ Y = 67{,}5966 - 0.5772 \times \mathrm{I}_{39} \\ Y = 26{,}4725 + 0.6171 \times \mathrm{I}_{40} \end{cases} \text{medium correlation.}$$

Making a forecast of the indicators of the impact of technological growth on economic security will help to formulate the public policy measures for technological development of the national economy and avoid increasing risks of a decline in the level of economic security (Trofymenko et al., 2021) and it is the next stage of the study.

The level of technological development in terms of the indicators with high and medium correlations relative to the level of economic security was forecast using the Holt function and programming language R. The forecast of the level of development is provided for a period of 3 years at $\alpha = 0.8$, $\beta^* = 0.2$ and $\varphi = 0.9$. The results of the forecast are presented in Tables 2–3 and Figures 4–5.

A comparative analysis of the dynamics of the calculated Holt's forecast models in exports of high-tech products (6,758) and openness of the economy (16,615) shows a slight increase. Although by 2022, the indicators of investment (13,412) and the index of industrial development (97,379) will continue to decline, which testifies to the need to develop an effective investment mechanism for technological development.

Similarly, there is a downward trend in the indicators with a medium correlation such as the share of specialists carrying out scientific and technical work (0.4104533) and the state of cluster development (34.92714), while the indicator of education expenditure and ecological indicators show a tendency to a gradual rise (Table 3).

It is obvious that the forecast value for renewable energy consumption in the next three years will be 5.143742, for total industrial value added – 26.03699, for the global competitiveness index – 66.47696, and for the index of the technology development and the knowledge economy – 38.83011. The level of expenditure on education will remain unchanged (5.786700) (Figure 5).

The correlation analysis and the definition of the indicators with high and medium correlations between the level of technological development and the level of economic security make it possible to recommend the Ministry of Finance to expand the system of the indicators

Table 2. Results of forecasting technological growth by the indicators of economic security for the period up to 2022 (the indicators with a high correlation)

Years	Indicators							
	Level of business capitalization, I_3		Level of openness of the economy, I_6		Share of high-tech products in exports, I_8		Index of industrial products, I_{30}	
	Methods							
	Holt	Damping	Holt	Damping	Holt	Damping	Holt	Damping
2020	13.353	14.733	16.964	14.751	6.843	6.561	97.065	98.955
2021	11.481	14.038	19.812	15.732	7.182	6.664	94.645	98.125
2022	9.610	13.412	22.661	16.615	7.520	6.758	92.226	97.379
Smoothing parameters								
A	0.800		0.800		0.800		0.800	
β^*	0.200		0.200		0.200		0.200	
φ	0,000	0.900	0,000	0.900	0,000	0.900	0.000	0.900

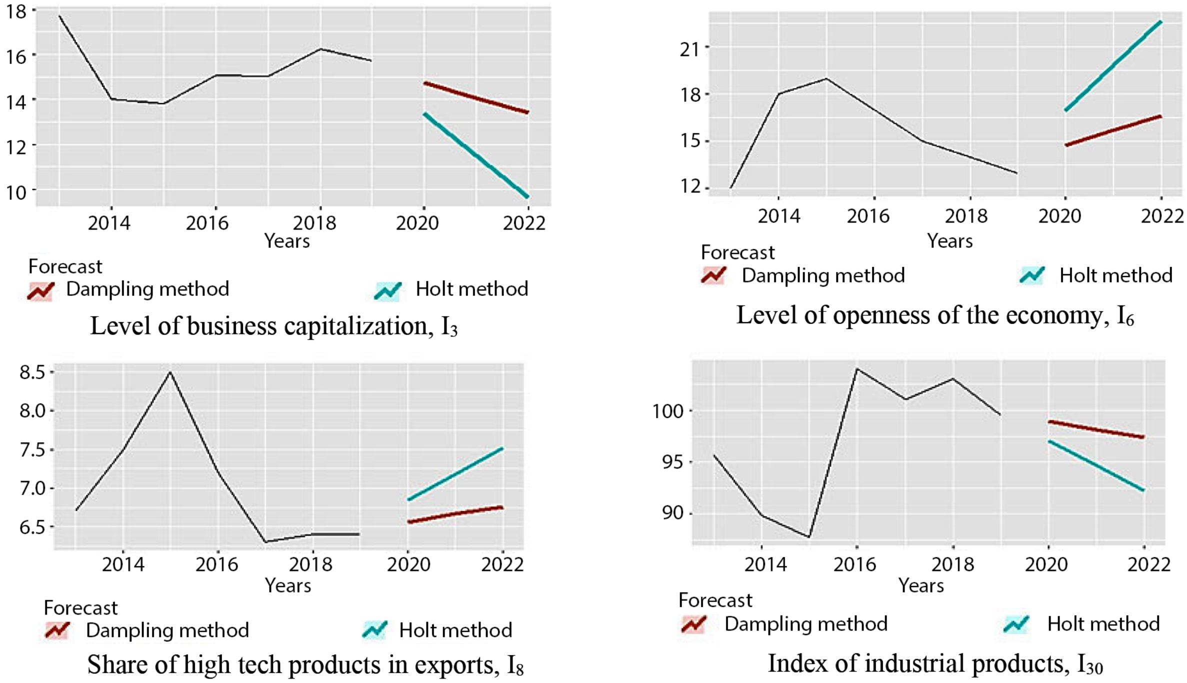

Figure 4. Forecast models of technological growth by the indicators of economic security with a strong correlation for the period up to 2022

Table 3. Results of forecasting technological growth by the indicators of economic security with a medium correlation for the period up to 2022

Years	Indicators					
	Share of renewable energy consumption, I_{12}		Share of education expenditure in GDP, I_{15}		Share of specialists conducting R&D, I_{22}	
	Methods					
	Holt	Damping	Holt	Damping	Holt	Damping
2020	4.978	4.958	5.860	5.748	0.433	0.459
2021	5.104	5.056	5.970	5.769	0.384	0.433
2022	5.231	5.144	6.080	5.787	0.336	0.410
Smoothing parameters						
A	0.800		0.800		0.800	
β^*	0.200		0.200		0.200	
Φ	0.000	0.900	0.000	0.900	0.000	0.900

End of Table 3

	Index of gross value added of industry, I_{27}		Index of global competitiveness, I_{31}		Index of the development of technology and the knowledge economy, I_{39}		Index of cluster development, I_{40}	
	Holt	Damping	Holt	Damping	Holt	Damping	Holt	Damping
2020	25.554	25.252	61.990	60.749	38.828	36.617	34.443	35.951
2021	26.264	25.665	66.414	63.764	41.884	37.782	32.649	35.412
2022	26.973	26.037	70.837	66.477	44.941	38.830	30.856	34.927
A	0.800		0.800		0.800		0.800	
β^*	0.200		0.200		0.200		0.200	
Φ	0.000	0.900	0.000	0.900	0.000	0.900	0.000	0.900

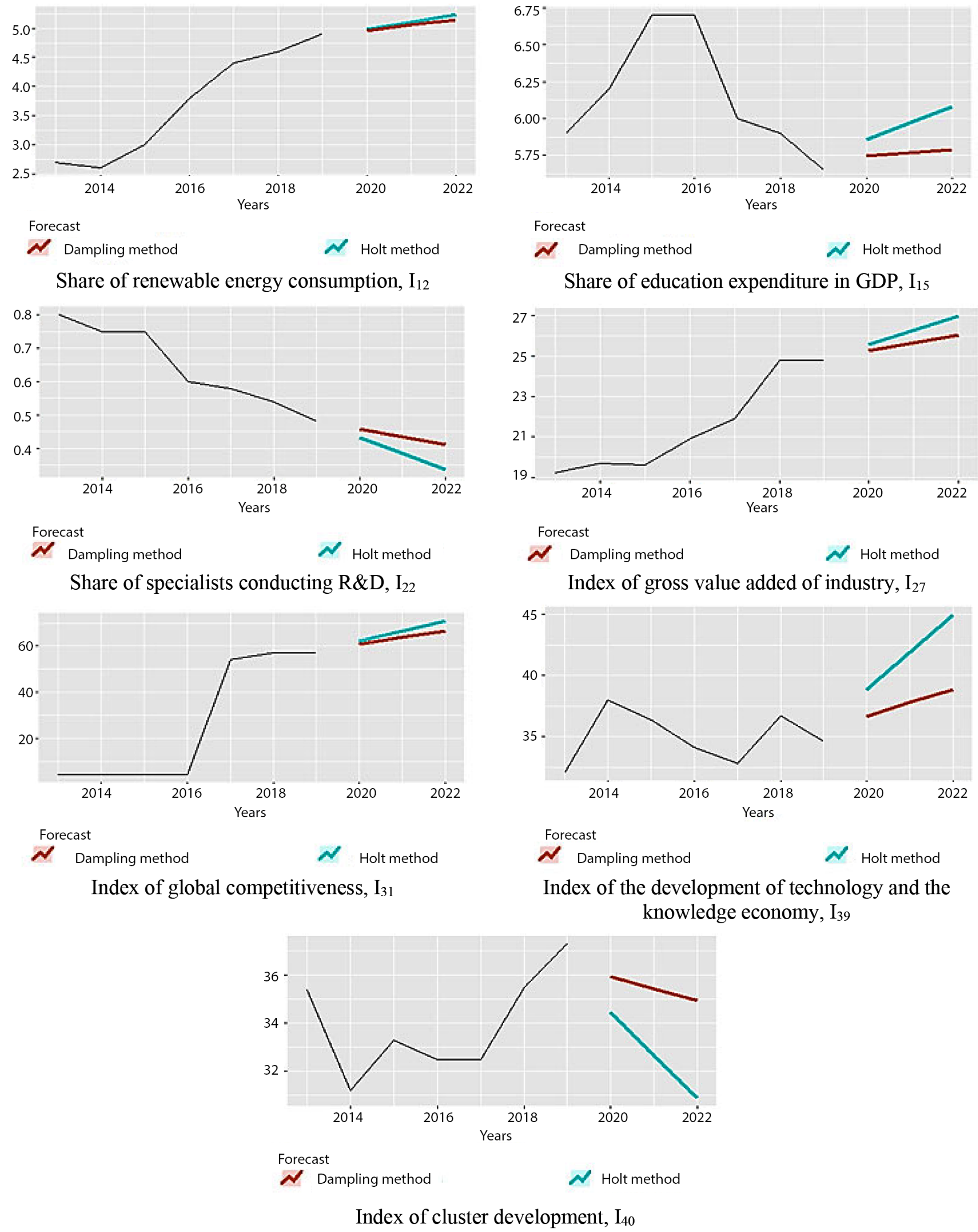

Figure 5. Forecast models of technological growth by the indicators of economic security with a medium correlation for the period up to 2022

Table 4. Expanding the system of the indicators of the forecast model for assessing the indicators of technological growth and economic security of high and medium levels of correlation

Indicators of technological growth						
Level of investment development of the economy	Share of export of high-tech products in total exports	Share of renewable energy consumption in the energy balance of the state	Level of expenditure on educational development	Global competitiveness index	Level of technological development of the economy	Index of cluster scaling
High correlation		*Medium correlation*				
Investment and innovation	Foreign economic	Energy	Social	Macroeconomic	Investment and innovation	
Components of economic security						

for assessing the level of economic security. In particular, add the following components (1) the level of investment development of the economy (investment and innovation security); (2) the share of export of high-tech products in total exports (foreign economic security); (3) the share of renewable energy consumption in the energy balance of the state (energy security); (4) the level of expenditure on educational development (social security); (5) the global competitiveness index (macroeconomic security); (6) the level of technological development of the economy (investment and innovation security), the index of cluster scaling (investment and innovation security) (Table 4).

The proposed indicators, which complement the components of investment and innovation security, will serve as a basis for determining the level of investment, the dynamics of the knowledge economy, cluster development, the growth of patent performance, financial support of the innovation potential and so on. At the same time, the implementation of the technological process will create conditions for effective control over the innovation process in the country and form a new economic system, elements and prerequisites for innovation and development of the national economy.

The system of foreign economic security was expanded by adding such indicators as the total volume of export of high-tech products in the total volume of exports and the size of the Ukrainian economy. Hence, foreign economic security is now able to compensate for the impact of negative factors of reducing the level of security of sustainable economic development.

As for the development of the energy sector, it should be mentioned that a rapid increase in the share of renewable energy stimulated changes in the calculation of global energy security and provided a new impetus for technological development. A precondition for ensuring a high level of economic security is the level of competitiveness; that is why the global competitiveness index was included in the indicators of macroeconomic security. The estimation of the human development index and the level of education expenditure will make it possible to use the potential of human capital as a factor in strengthening the social security system. The proposed indicators will strengthen the system of monitoring of the level of national economic security, while timely analysis will prevent the growth of threats and risks.

Conclusions and discussions

The need to create conditions for ensuring and developing economic security when geopolitical and globalization challenges are exacerbating has led to the study of the impact of certain factors on economic security.

To characterise the state's economic security and determine its level, a large set of indicators of economic development is used. The choice of a set of such indicators is still controversial in both domestic and foreign studies. The necessity of studying the impact of technological development on economic security has determined the feasibility of organising the 40 most representative indicators into 8 groups. The investment and institutional component reflects the development of innovation and the effectiveness of investing in the country's economy, investment return. The international and organisational component shows how the organisation of the country's international economic activity influences its development and the country's economy as a whole. The ecological component characterises the level of the formation of ecological security in the country and the impact of technological growth on this process. The educational component indicates the level of education of the nation through the indicators of the state and quality of education and its coverage of the country's citizens. The scientific and research component reflects the degree of material and institutional support of the country's scientific development. The industrial component helps to determine the impact of industrial development, including innovation, on the country's economy. The innovation component shows the degree of ensuring the country's innovative development and the place of domestic innovative products in the world economy. The technological component determines the state of technological development of domestic industry.

The study employs a unified author's method of multidimensional statistical analysis. Based on the careful ranking of technological growth factors in terms of the closeness and direction of the influence, a forecast of the impact of technological growth on the country's economic security is provided. An in-depth study of the factors also made it possible to group them by growth criteria and identify both the positive aspects and severe shortcomings of industrial development of the national economy.

It is found that an empirical study of the indicators that in the current conditions of the development of the domestic and world economy largely reflect the impact of ensuring economic security becomes the basis for forecasting the impact of technological growth on the country's economic security. The tools of multidimensional statistical analysis, the harmonization of the indicators of industrial and technological development and economic security of Ukraine and the use of static data helped to determine the influence of the indicators-factors of technological growth on the state of Ukraine's economic security.

An integral assessment of technological growth of the national economy in the system of economic security of Ukraine is carried out. Both its positive aspects and severe shortcomings are identified. In 2017–2019, only upward dynamics prevailed, reaching the level of the integral index of 0.695 (the highest value for 2014–2019); the values of innovation, ecological and investment and institutional components were the most significant among the components. However, there was considerable instability of the state of technological growth of the national economy in the system of Ukraine's economic security. Moreover, the values of educational, scientific and research, international and organisational, industrial and technological components were low in 2019.

The strongest correlation is characteristic of the following indicators: the level of business capitalization, the level of openness of the economy, the share of high-tech products in exports, the index of industrial products. The medium correlation is found with the share of renewable energy consumption, the share of education expenditure in GDP, the share of specialists carrying out scientific and research work, the index of gross value added of industry, the index of global competitiveness, the index of the development of technology and the knowledge economy, the index of cluster development. The low level of correlation is typical of the index of economic freedom, the share of the economy in world GDP, the share of the leading partner country in exports, the human development index, the share of patents per 1,000 employees in R&D, the level of funding for innovation, the innovation potential index, the number of mastered production of innovative types of products, the introduction of new technological processes. Forecasting the impact of the indicators of marketing support of technological growth on Ukraine's economic security preceded the identification of a set of factors (such groups were identified: political, economic, social, technological factors). If these factors are influenced, it will be possible to attract investment, strengthen economic openness, increase the volume and share of domestic high-tech exports, ensure the growth of production and sales of competitive industrial products.

It is important to devote future research to the determination of the dependence of ensuring a high level of economic security in modern conditions on the development of the knowledge economy, the quantity and quality of research and development and the level of human capital. It should be noted that stimulating the growth of an educational and scientific level of society and the economy requires significant financial support.

The introduction of new technologies has different effects on the growth of economic security of countries with equal levels of development. Hence, those countries, which have a lower level of development, need more investment to strengthen their own economic security through increasing the technological level of industry.

In the future, it is necessary to continue finding the ways to promote the technological growth of industrial production for the development of sustainable social business, which is a vital part of the state's security development. The areas of further research will concern the determination of the technological level of the shadow industry and the study of its impact on economic security.

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Author contributions

MC and GGN settled the general pattern of the paper. Authors were altogether involved in development of the work, data collection, analysis and interpretation, drafting the article, writing the paper and approved its final version.

Disclosure statement

The authors declare that they do not have competing financial, professional, or personal interests from other parties.

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