IMPACT OF ECONOMETRIC MODELING AND PERSPECTIVES OF ECONOMIC SECURITY OF THE CROSS-INDUSTRY COMPLEX

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Article history: Received 13 February 2023, Received in revised form 6 March 2023, Accepted 7 March 2023, Available online 9 March 2023.

This work has been published free of charge as a support of the publisher to the Ukrainian authors facing difficulties caused by the Russian war.

Highlight
Econometric modeling and forecasting of the economic security of an interdisciplinary complex describe the connections between economic variables and objects.

Abstract
The paper presents a forecast of the economic security of the inter-industry complex through the construction of a simulation model. The authors considered the possibility of using an econometric model in predicting the level of economic security of the inter-industry complex. The goal was to form a definition of the "inter-industry complex", as well as to study the issues of conceptual and fundamental methods of econometric modeling and forecasting the development of regional industry markets in dynamics. A range of issues related to the main components of economic security in the inter-industry complex has been allocated for scientific work in order to analyze the impact of the components of economic security on the integral indicator. The paper uses a methodology for predicting the structural and spatial-temporal dynamics of interbranch complexes, which

includes new and refined methods of modeling and forecasting. As a result, the authors proposed the definition of "inter-industry complex", "economic security in the inter-industry complex", as well as the general provisions of the methodology for econometric modeling and forecasting the level of economic security of the inter-industry complex. The paper presents a full-scale simulation model that allows you to set, evaluate and make a decision using large nonlinear data. This kind of system contains dynamic and retarded data, which makes it possible to apply econometric modeling in automatic calculation.

Keywords
economic security; intersectoral complex; econometric model; forecasting.

Introduction

Industry is considered one of the main structures of the economic complex of all developed and developing modern states. It includes, as a rule, many enterprises, industries of various industries that provide the extraction and processing of natural resources, the production of various products both for the needs of the industry itself and for other areas of human activity. In the analysis of the state of industry, special attention should be paid to the study of the functioning of intersectoral complexes, which are presented in works [1–3] in a certain way interconnected, interacting, and also complementing each other's activities with industrial sectors and industries [4,5]. An intersectoral complex is a special structure for the integration and interaction of one or more industries. Such a structure can be built in one industry segment and allocated in accordance with the division of labor. So, within the segment, machine-building, fuel and energy and other inter-industry complexes can be distinguished [6]. At present, the former types of organizational structures of economic entities are not effective enough, as a result of which there is a need to create new, modern types of organizational structures. An example of these types are network structures, which are now becoming a feature of the new economy. The network approach is considered in [7–10]. As a result, complex interactive relationships develop that connect the resources and activities of one party with the resources and activities of the other. It should be noted that in addition to the above reasons, the transition from the industry level to the network level is due to the principles of the fourth industrial revolution, which consider the network organization of production as a network, that is, when the boundaries between enterprises and even industries (types of economic activity) are erased, and the production process itself is considered like a network. Against this background, the topic of economic security of both the national economy and industries, as well as individual enterprises, is becoming increasingly relevant. It should be noted that the security of business structures is the basis for maintaining stable competitive positions, a prerequisite for the effective functioning and stable development of business entities. Based on the conducted research, it was established that the main negative factors in ensuring the proper level of economic security of enterprises are the following: lack of effective functioning of the market environment; incomplete formation of the institutional base of economic policy; imbalance of state regulatory policy; imperfection of budget policy; abuse of a monopoly price position; an increase in the number of criminal offenses, so-called "raiding", corruption and discriminatory actions regarding the specifics of the work of regional enterprises; the imperfection of the judicial system, the corruption of authorities and the absence of state institutions that would effectively protect the rights of the owner; low level of competitiveness of enterprises and their innovative activity; unsatisfactory indicators of the financial condition and efficiency of the functioning of enterprises and their use of resource provision, etc. As a result of the analysis, we note that the economic security of enterprises should be understood as the state of protection of its resources and intellectual potential from existing and potential threats of the external and internal environment of its functioning, which is characterized by high financial indicators of activity and the perspective of economic development in the future. Continuing the logic of our research, we should pay attention to the fact that network value chain analysis provides insight into the structure of the production process to identify areas where efficiency can be improved, thereby enhancing the efficiency of industrial complexes and strengthening their economic security.

The process of econometric modeling and forecasting of economic security includes several stages:

- At the first stage, it is necessary to set a meaningful goal and formulate research objectives. The purpose of the study is to assess the degree of influence of factors of the external and internal environment and the results of ensuring the economic security of the intersectoral complex.
- At the second stage, an econometric model is built. Therefore, in order to effectively ensure the economic security of the intersectoral complex, it is necessary to conduct a comprehensive analysis of the economic security of an enterprise based on an analysis of the total set of threats.

On Figure 1 shows the internal and external components of the cumulative assessment of economic security (ES) of intersectoral complexes (IC).

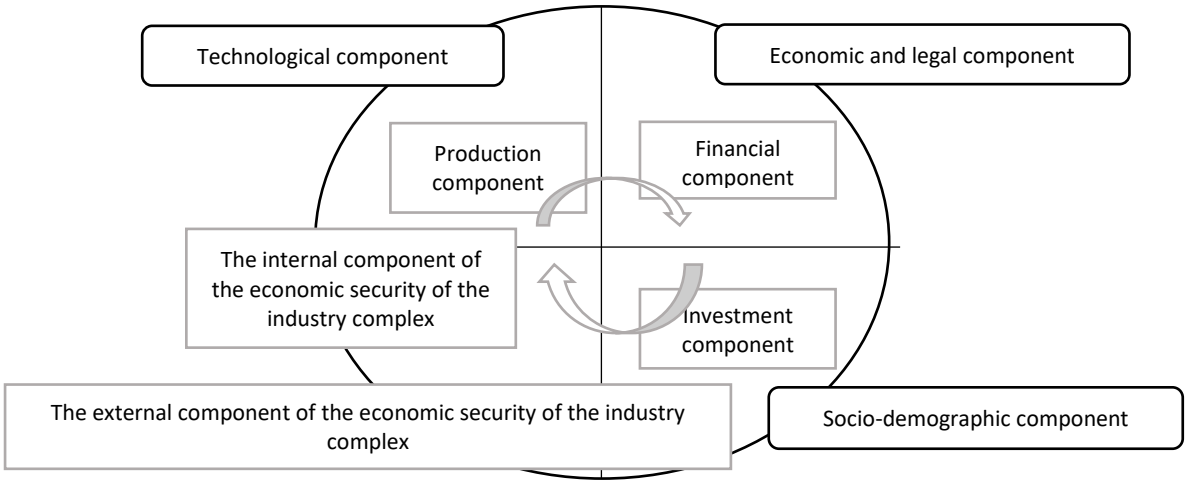

Figure 1. Aggregate Assessment of Economic Security of Intersectoral Complexes: Internal and External Components. *Source: Authors development.*

Methods

The level of economic security of enterprises is characterized by many indicators. The assessment of the state of economic security of enterprises is carried out through a system of criteria and indicators. The criterion of economic security of the enterprise is a measure of the state of the economic entity from the point of view of compliance of the actually achieved indicators of its activity with pre-established indicators that reflect the essence of economic security. In this case, the general task of forming an assessment of the economic security of the system is to develop such an assessment, with the help of which the threat of the destruction of the system is quantitatively detected during the operation of the system in order to take measures to prevent this in a timely manner. Such an estimate can be obtained using the parameters of the system motion trajectory in the form of a functional:

(1) $$J_S = J_S(t, s, u, \sigma, \varepsilon), s\hat{I}\,S, u\hat{I}\,U, s\,\hat{I}\,\mathring{a}, e\,\hat{I}\,X$$

where:
J_S - safety indicator
t - time
s – state
u - management
σ - the influence of the environment
ε - internal disturbance.

The schematic diagram of the formation of the Jb safety indicator based on all information flows in the system is shown in Figure 2.

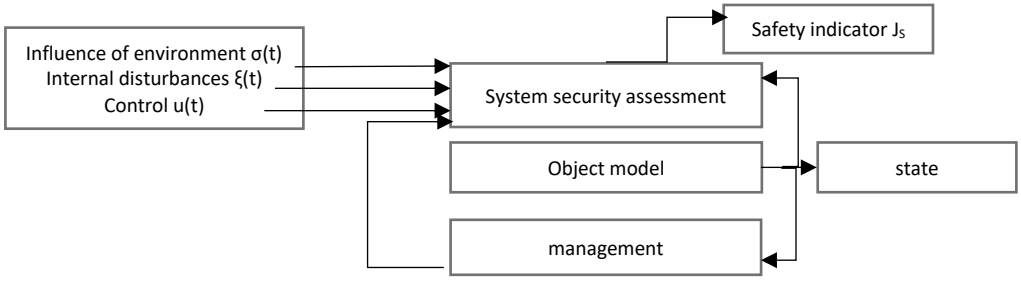

Figure 2. A typical logical scheme for forming an assessment of the economic security of an enterprise. *Source: Authors development.*

A comprehensive assessment of economic security can be represented as a function that includes the internal component of the ES IC: production, financial, investment, and the external component of the ES IC: technological, socio-demographic and economic and legal, which, in turn, are also divided into components indicators:

(2) $$C_{IN.C.} = \int (C_P, C_F, C_I)$$

where:
$C_{IN.C.}$- economic related industries; internal component security
C_P - production component of network associated industries
C_F - financial component of network related industries
C_I - investment component of network related industries.

At the same time:

(3) $$C_{EX.C.} = \int (C_{E\&L}, C_T, C_{S-D})$$

where:
$C_{EX.C.}$- external component of the security of network related industries
$C_{E\&L}$ - economic and legal component of network related industries
C_T - technological component of network related industries
C_{S-D} - socio-demographic component of network related industries.

It should be noted that the data for calculating the component can be expanded. Our choice stopped due to on the availability data on the indicators on the website of state statistics. In addition, these indicators can be tracked in dynamics, which will make it possible to calculate the level of economic security and analyze its dynamic change. It should also be clarified that indicators by type of network production can vary significantly due to the peculiarities of the functioning of production. That is why we propose to use normalized indicators to calculate the level of economic security. This econometric approach is considered in publications [11–14]. The next stage of econometric modeling is the selection of the necessary indicators for calculating the level of economic security of the intersectoral complex and the programming of the simulation model. Debugging a model involves assessing its adequacy and suitability, as shown by the values of the relevant criteria [15–17]. Examining the data of state statistics (Table 1), we can identify a number of indicators that tend to increase, decrease, and those that do not change in the period 2019–2022.

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The main factor determining the importance of an indicator is its weight. Before the introduction of one or another key risk indicator, its threshold values and limits are developed. Usually, the exponent *x* varies from some minimum value x_{min} (reflecting lack of quality) up to some maximum value x_{max} (extreme degree of manifestation, presence, severity and etc.). As a rule, the value is normalized in the range from 0 to 1.

To do this, the transformation function y = f (x) must have the following properties:

(4) $$y\,(x_{min}) = 0; y\,(x_{max}) = 1; dy/dx > 0$$

Any function with these properties can be used for normalization. For example, if then $x_{max} \to \infty$ you can choose a function:

(5) $$y(x) = 1 - \exp\,(1 - \frac{1}{x_{min}})$$

It is easy to see that, by choosing the appropriate function, one can consider various effects of estimation distortion. According to the methodology, since the indicators used to describe the state of economic security have different units of measurement, they were brought to a single scale using the standardization of values, which allows one to switch to a single dimensionless value. To assess economic security on the basis of the selected features, the entropy method for assessing the sustainability of economic security was adapted, which is considered in papers4 [18,19].

The method makes it possible to decompose the total entropy into components - the entropy of interaction, configuration, local, structural, etc., which makes it possible to develop solutions for their minimization.

Table 1. Initial data for building an econometric model for predicting the economic security of an intersectoral complex.
Source: Compiled by the authors based on state statistics [20].

Index	**2019**	**2020**	**2021**	**2022**
Initial data for calculating the production component				
Labor productivity index	100.7	97.8	99.8	99.88
Index of change in capital-labor ratio	105.2	104	103.8	105.03
Index of change in capital productivity	96.7	97	93.3	97.37
The coefficient of renewal of fixed assets	4.8	4.6	4.3	4.82
Initial data for calculating the investment component				
Share of investment in fixed assets in gross domestic product	20.5	19.6	20.8	20.15
Increase in the number of high-performance jobs	4.5	-9.1	-4.8	1.52
Innovative activity of organizations (share of organizations that carried out technological, organizational, marketing innovations, in the total number of organizations)	9.9	9.3	8.4	9.95
Share of internal spending on research and development in GDP and GRP	1.07	1.1	1.1	1.08
Initial data for calculating the financial component				
Profitability of organizations (excluding small businesses)	7	7.3	8.1	6.92
Return on assets	4.5	2.5	3.7	3.97
Dynamics of accounts payable of organizations (excluding small businesses)	33 174	38 925	42 280	33 573
Dynamics of receivables of organizations (excluding small businesses)	31 014	35 736	37 053	31 581
Initial data for calculating the technological component				
Production index for high-tech manufacturing economic activities	92.3	103	98.7	94.8
The share of internal costs for research and development in priority areas of development of science, technology and technology, in the total volume of internal costs for research and development	67.9	68.6	71	67.62
Number of advanced manufacturing technologies developed	1 409	1 398	1 534	1 384.5
Number of new technologies (technical achievements), software tools acquired by organizations	28 705	24 361	64 914	21 222
Initial data for calculating the economic and legal component				
Indices of physical volume of gross domestic product	100.7	97.5	99.8	101.5
Volume of loans provided to legal entities	203.84	182.68	188.94	209.43
Number of economic offenses	11.5	11.9	13.2	10
Index of output of goods and services by basic types economic activity	102	97.6	100.5	101.4
Initial data for calculating the socio-demographic component				
Working-age population	75.43	76.59	76.64	76.69
Employment rate	65.3	65.3	65.7	65.7
Unemployment rate	5.2	5.6	5.5	5.5
Average monthly salary	32.6	33.93	36.7	39.09

Results and Discussion

Entropy processes constitute an unshakable system-forming property of the vital activity of systems at any level of organization. Over the last year of a full-scale war, there has been a negative downward trend in investment. The deterioration of the economic situation had a negative impact on the volume of foreign direct investment attracted during the period of martial law. A large number of regional enterprises during the crisis were left

without the support of foreign investors, as well as completely / partially destroyed and forced to move their assets to safer territories. At the same time, over the past year, the leading regions of the country also show almost zero dynamics in the development of industry. The fall in prices for the products of basic industries has destabilized industrial safety in general.

Table 2. Calculation of the level of economic security of intersectoral complexes in 2019–2022. *Source: Calculated by the authors.*

Index	**2019**	**2020**	**2021**	**2022**
ES IC of the production component	0.718	0.717	0.714	0.718
Labor productivity index	0.955	0.938	0.960	0.949
Index of change in capital-labor ratio	1	1	1	1
Index of change in capital productivity	0.915	0.93	0.894	0.923
The coefficient of renewal of fixed assets	-	-	-	-
ES IC of the investment component	0.408	0.499	0.437	0.372
Share of investment in fixed assets in GDP	1	1	1	1
Growth in the number of highly productive jobs Innovative activity of organizations (share of organizations that carried out technological, organizational, marketing innovations in the total number of organizations)	0.177	-	-	0.023
Share of internal spending on research and development	0.454	0.641	0.516	0.465
in GDP and GRP	-	0.355	0.23	-
ES IC of the financial component	0.503	0.511	0.495	0.508
Profitability of organizations (excluding small businesses)	0.087	0.132	0.114	0.1
Return on assets	-	-	-	-
Dynamics of accounts payable of organizations (excluding small businesses)	1	1	1	1
Dynamics of receivables of organizations (excluding small businesses)	0.925	0.912	0.865	0.933
ES IC of the technological component	0.508	0.472	0.592	0.48
Production index for high-tech manufacturing economic activities Share of domestic spending on research and development in priority areas of science and technology development	1	1	1	1
and technology, in total domestic research and development spending	0.732	0.661	0.715	0.709
Number of advanced production technologies developed Number of new technologies (technical advances); software tools acquired by organizations	-	-	-	-
Production index for high-tech manufacturing economic activities Share of domestic spending on research and development in priority areas of science and technology development	0.3	0.226	0.652	0.212
ES IC of the economic and legal component	0.484	0.501	0.497	0.479
Indices of physical volume of GDP	0.464	0.501	0.493	0.459
Volume of loans provided to legal entities Number of economic offenses	1	1	1	1
Index of output of goods and services by basic types of economic activity	-	-	-	-
Indices of physical volume of GDP	0.471	0.502	0.497	0.458
ES IC of the socio-demographic component	0.561	0.56	0.571	0.579
Working-age population	1	1	1	1
Employment rate	0.856	0.841	0.846	0.846
Unemployment rate	-	-	-	-
Average monthly salary, thousand rubles	0.39	0.339	0.439	0.472
Internal component of EB MK	0.543	0.576	0.548	0.533
External component of EB MK	0.511	0.511	0.552	0.506
EB MK level	0.53	0.543	0.551	0.523

The country's lag in the innovation sphere is primarily due to the martial law and the continuation of active hostilities in a large area of Ukraine. There is a deterioration in the state of external economic security. The decrease in foreign trade turnover is caused by the deterioration of logistics routes, their blockade by the aggressor and the presence of numerous barriers. The rise in inflation in 2022 was the result of a jump in the hryvnia exchange rate due to changes in the country's GDP and a decrease in the production capacities of enterprises of various levels. The decline in the solvency of Ukrainian organizations led to an increase in overdue accounts payable. These processes had a significant impact on the level of the country's financial security. The unfavorable economic situation also affected the standard of living of the population. There was a decrease in real incomes and, as a result, consumer demand decreased. There was a threat of a decrease

in the income of the population and, as a result, the percentage of the average income tends to approach the subsistence level, which leads to impoverishment of the population.

The calculation of entropy indicators shows that throughout the analyzed and forecast period, the entropy indicator characterizes a fairly large influence of production, financial, personnel, investment and environmental factors on the state of economic security of intersectoral complexes. The parameters of the regression equations were calculated by the least squares method using the Statistica program using the data given in Table. 2.

Standard deviations of initial samples data compared to the values of the data themselves are insignificant, that is, the scatter of points small in the samples. Deviations the maximum and minimum values of the samples from the respective medians and the average is also small. Values the coefficient of variation of the samples makes it possible to judge their homogeneity. Accepted points regression equations allow you to apply it for the forecast.

As a result of the calculations, the regression equations of the model were obtained, presented in Table. 3.

Table 3. Regression models of economic security components of sectoral complexes. *Source: Calculated by the authors.*

Model parameters	**Production component of ES IC**	**Investment component of ES IC**	**Financial component of ES IC**
Regression Equation	$ES\ IC_P = -0.0002x+0.717$	$ES\ IC_I = -0.017x+0.4713$	$ES\ IC_F = -0.0001x+0.5044$
Average	0.716506	0.428876	0.504188
Standard error	0.001012	0.026869	0.003595
Median	0.717215	0.422135	0.505528
Standard deviation	0.002025	0.053738	0.007189
Sample variance	$4.1*10^{-6}$	0.002888	$5.17*10^{-5}$
Excess	2.672686	0.469564	-0.06333
Asymmetry	-1.63986	0.664946	-0.87658
Interval	0.00446	0.127023	0.016416
Minimum	0.713568	0.372106	0.494641
Maximum	0.718028	0.499129	0.511057
Sum	2.866026	1.715504	2.016753
Check	4	4	4
Largest (1)	0.718028	0.499129	0.511057
Smallest (1)	0.713568	0.372106	0.494641
Reliability level (95%)	0.003222	0.085509	0.01144
Model parameters	**Technological component of ES IC**	**Economic and legal component of ES IC**	**Socio-demographic component of ES IC**
Regression Equation	$ES\ IC_T = -0.0037x+0.5037$	$ES\ IC_{E\&L} = -0.0016x+0.4943$	$ES\ IC_{S\text{-}D} =0.0065x+0.5518$
Average	0.512992	0.490248	0.568022
Standard error	0.027377	0.005215	0.004528
Median	0.494153	0.490477	0.566356
Standard deviation	0.054755	0.01043	0.009057
Sample variance	0.002998	0.000109	$8.2*10^{-5}$
Excess	2.289132	-4.6903	-2.27709
Asymmetry	1.56335	-0.0545	0.628249
Interval	0.119943	0.021483	0.019367
Minimum	0.471858	0.479278	0.560004
Maximum	0.591802	0.500761	0.579371
Sum	2.051967	1.960993	2.272086
Check	4	4	4
Largest (1)	0.591802	0.500761	0.579371
Smallest (1)	0.471858	0.479278	0.560004
Reliability level (95%)	0.087127	0.016596	0.014411

Impact

In order to determine the influence and usefulness of the published scientific work, it is worth reminding that the inter-industry complex is an integration structure that unites economically interconnected branches of the production and (or) non-production spheres and characterizes the interaction of different industries and their elements, different stages of production and distribution of the product. In order to correctly interpret the received data and calculations, we first want to note that as a result of the analysis of economic data of inter-industry balances for 36 leading countries of the world, gross value added (GVA) is a significant indicator. Thus, in 2019 (calculated once every five years), the economies of the following countries had the largest specific weight of industrial GVA: China - 36.7%, Korea - 33.7%, Czech Republic - 30.8%, Russia - 27.2% and Mexico – 26.3%. According to this indicator - 22.6%, Ukraine took 33rd place among 36 countries of the world. The total amount of VAT of industry in 2019 increased from 9116851.4 million dollars. in 2014 to 13330371.0 million dollars. in 2019 or by 146.2%. From 2014 to 2019, the following countries had the highest growth rates of industrial GVA: Korea – 203.4%, China – 200.3%, Estonia – 156.2%, Sweden – 154.7% and Russia – 153, 0% According to this indicator - 97.6%, Ukraine took the 35th place among 36 countries and had a decrease.

Considering the purpose of this research, we will substantiate or refute the hypothesis regarding the feasibility of maintaining and improving the econometric modeling of economic security cross-industry complex of Ukraine. Probability predicting the economic security of intersectoral complexes is significant advantage in modern economy. Based on this model, using regression equations, predictive calculations of the economic security of intersectoral complexes for the period up to 2030 were carried out (Figure 3).The proposed method using econometric models makes it possible to evaluate the results of the development of economic security of intersectoral complexes and respond to negative performance indicators. In addition, it is necessary to carry out strategic planning; it should include an active industrial policy in various sectors of the economy.

The main requirement when choosing a forecasting method is its sufficient simplicity, combined with acceptable efficiency and reliability. The scientific literature on socio-economic forecasting, including sectoral forecasting, offers several hundred methods for developing forecasts.

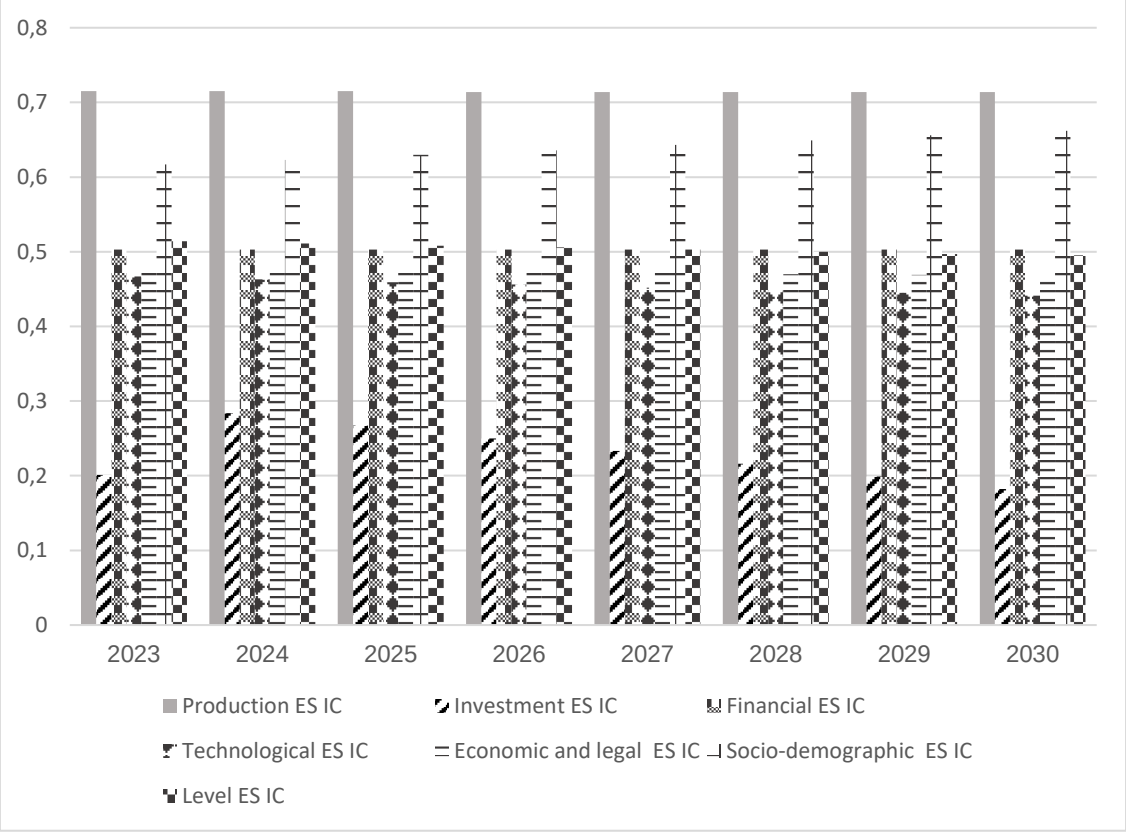

Figure 3. Econometric modeling of economic security of intersectoral complexes. *Source: Authors development.*

In this situation, it is impossible to give unambiguous advice on choosing the optimal forecasting method - one should be guided by the specific goals for which the forecast is carried out, consider the hierarchical level of forecasting, the characteristics of the available data on the socio-economic system, and much more. Quite often, the choice of a forecasting method is determined not by the appropriateness of its application, but by the information available to the researcher.

Forecasting methods are enriched and improved at an accelerated pace. Two factors play a special role in this. The first is the economic crises of the last quarter of the 20th century. They forced economists and managers to look for new adequate management methods. The second factor is related to the rapid spread of information technologies and computer equipment. These tools have made outlook analysis and forecasting publicly available. They made it possible to automate, simplify and speed up the execution of a huge number of planning and control functions.

The main requirements for this information base are:

- probability of quantitative characteristics of indicators;
- sufficiency and completeness of the provided information;
- the systematic nature of the provided information, which implies the possibility of interlinking the indicators of different information blocks and levels;
- comparability, i.e., consistency of quantitative characteristics of various indicators with each other.

The use of econometric modeling and forecasting of the economic security of the inter-industry complex can be justified by the following reasons:

- firstly, the mechanism of regulation of production, consumption, exchange and distribution in the economy is characterized by a complex of centralized and autonomous decisions, the consequences of which can only be described as stochastic processes. Econometric analysis is intended for modeling such processes. Only on its basis it is possible to establish which economic indicators have dependencies, what is the analytical nature of relations and relationships between economic phenomena and what are their numerical values;
- secondly, the use of scientifically based complex econometric models allows for meaningful analysis and forecasting of economic development. Econometric methods make it possible, in addition to the main variants of forecasts, to model many subsequent variants, in which, as a result of expected changes in economic policy, certain externally specified (exogenous) variables change. This use of econometric models allows to determine the consequences of a number of predictive options for development and at the same time ensures consistency and connection of the studied indicators;
- thirdly, econometric modeling and forecasting is a fairly effective tool for controlling the proportions of economic development. Complex econometric models reflect the structural and dynamic changes that are occurring as a whole. This allows you to check compliance with the main proportions of the most important indicators during the specified period and provides information for making decisions about the most appropriate measures of economic policy.

Conclusions

The use of econometric modeling and forecasting of the economic security of an interdisciplinary complex makes it possible to single out and formally describe the most important, most essential connections between economic variables and objects, as well as to obtain new knowledge about the object in an inductive way. In such modeling and forecasting, in a simplified form, under many assumptions, the main dependencies between economic indicators are established. Thus, econometric modeling and forecasting of the economic security of an interdisciplinary complex is not only a powerful tool for obtaining new knowledge in the economy, but also a very important component in justifying the adoption of practical management decisions. To improve the financial condition and ensure financial stability, it is necessary to apply econometric modeling and forecasting of the economic security of the inter-industry complex. The process of developing management decisions to ensure a sufficient level of economic security of the interdisciplinary complex must be scientifically based. This involves the use of econometric modeling and forecasting. In the circumstances that have developed in most branches of Ukraine at the moment, there is practically no potential for development due to the war and aggression of the Russian Federation. Leading enterprises are developing development programs that provide for the expansion of production capacities, renewal of production equipment, development of the scientific base, improvement of the consumer properties of the products produced, as well as those produced

in future periods after the implementation of all works related to the return to the pre-war period. It should be recognized that this is the only possible way out of the crisis and transition to the development of industries. In this case, the approach proposed by the authors regarding the implementation of econometric modeling as a strategic lever for planning the development of the inter-industry complex is clearly followed. However, the implementation of these programs is complicated due to the lack of adequate funding at the moment, since most enterprises, if they do implement technological innovations, do so mainly at the expense of their own funds, which currently slows down the time for their implementation. Without pretending to be exhaustive of the systematic assessment of the economic security of enterprises, it should be concluded that the necessary conditions for the formation of an effective system of economic security of the inter-industry complex of Ukraine are as follows: increasing the level of security of entrepreneurship due to the strengthening of the responsibility of the state (legal, judicial, institutional, etc.) to economic entities activities; the effectiveness of the business support policy; implementation of adaptive security management systems; ensuring the internal balance of the main economic parameters of regional enterprises; strategic focus on long-term and rational development.

Conflict of interest

There are no conflicts to declare.

Acknowledgements

The article will be funded at the author's expense.

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