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A METHODOLOGICAL APPROACH TO THE ASSESSMENT OF THE COMPONENTS OF THE INTERNATIONAL COMPETITIVENESS OF THE ELECTRIC POWER INDUSTRY IN CONDITIONS OF UNCERTAINTY

МЕТОДИЧНИЙ ПІДХІД ДО ОЦІНЮВАННЯ СКЛАДОВИХ МІЖНАРОДНОЇ КОНКУРЕНТОСПРОМОЖНОСТІ ЕЛЕКТРОЕНЕРГЕТИКИ В УМОВАХ НЕВИЗНАЧЕНОСТІ

The article is devoted to the development of a methodological approach for assessing the components of international competitiveness of the electric power industry under conditions of uncertainty. The article uses such general scientific research methods as critical, systemic and structural analysis and synthesis, decomposition, abstraction, and deduction. Research results: the essence of the international competitiveness of the electric power industry is defined, its components are structured, and a methodological approach to their assessment is developed, which takes into account the conditions of uncertainty of the factors of the international competitive environment. The practical significance of the research results is that, based on the developed methodological approach, it is possible to determine how the uncertainty of the factors of the international competitive environment affects the components of the international competitiveness of the electric power industry, and the establishment of this formal relationship will allow economic entities in the electric power industry to better predict their activities under conditions of uncertainty and identify ways to minimize it.

Keywords: components of international competitiveness, uncertainty of factors of the international competitive environment, information theory, probability theory, information entropy, proprietary information, power energy industry.

Стаття присвячена розробці методичного підходу до оцінювання складових міжнародної конкурентоспроможності електроенергетики в умовах невизначеності. Актуальність його розроблення полягає в тому, що міжнародна конкурентоспроможність як абстрактна економічна категорія є однією з найбільш складних в економічній науці. Міжнародна конкурентоспроможність є комплексною характеристикою об'єктів ринкової економіки різного рівня, а отже потребує декомпозиції на складові. У цьому контексті актуальним є дослідження мезорівневої конкуренції в межах галузі, яка є пріоритетною для розвитку національної. Пріоритетність електроенергетики як галузі обумовлена тим, що стабільне забезпечення домогосподарств та підприємств електроенергією як критично важливого ресурсу є необхідною умовою для їх безперерйного функціонування. Без електроенергії не будуть функціонувати прилади, технічне обладнання необхідні для запуску виробничих та бізнес-процесів. Важливість дослідження складових міжнародної конкурентоспроможності електроенергетики України пов'язана з її інтеграцією в ENTSO-E, яка дозволяє експортувати електроенергію на європейський енергетичний ринок. Оцінювання цих складових є необхідним для того, щоб визначити негативні фактори її міжнародного конкурентного середовища (тобто ті, фактори середовища функціонування електроенергетики, які негативно впливають на її конкурентоспроможність на міжнародному ринку). Через повномасштабну російську агресію проти України значна частина цих факторів характеризується високим рівнем невизначеності, оскільки війна за своєю природою є джерелом стохастичних процесів, які й підвищують цей рівень невизначеності. Саме тому при розробці методичного підходу до оцінювання складових міжнародної конкурентоспроможності електроенергетики України в її поточних реаліях актуальним є врахування умов невизначеності факторів її міжнародного конкурентного середовища. Результати дослідження: визначено сутність міжнародної конкурентоспроможності електроенергетики, структуровано її складові та розроблено методичний підхід до їх оцінки, який враховує умови невизначеності факторів міжнародного конкурентного середовища. Практичне значення результатів дослідження полягає в тому, що на основі розробленого методичного підходу можна визначити, яким чином невизначеність факторів міжнародного конкурентного середовища впливає на складові міжнародної конкурентоспроможності електроенергетики, і встановлення цього формального взаємозв'язку дозволить суб'єктам господарювання в електроенергетиці краще прогнозувати свою діяльність в умовах невизначеності та визначати шляхи її мінімізації.

Ключові слова: складові міжнародної конкурентоспроможності, невизначеність факторів міжнародного конкурентного середовища, теорія інформації, теорія ймовірності, інформаційна ентропія, власна інформація, електроенергетика.

Problem statement. Increasing the international competitiveness of the electricity sector as a priority industry of the national economy is one of strategic goals. The realization of this goal will allow business entities in the electricity sector to conduct their foreign economic activities more efficiently. The growth of the electricity sector's export earnings will help improve the country's foreign trade balance and have a positive impact on its economic growth. Also, the internationally competitive electricity sector becomes attractive to foreign investors for investing foreign capital. This improves the balance of foreign direct investment, which, together with the improvement of the foreign trade balance, increases the balance of payments surplus, thus increasing the international reserves, which are critically important in the context of ongoing full-scale war.

In addition, the level of international competitiveness of the electricity sector can be increased by implementing the concept of sustainable development (which is currently the dominant paradigm of economic development) of this industry (economic, social and environmental dimensions of its development), as the revenues from electricity exports are an investment resource for implementing projects of electricity production from sustainable sources, as well as for updating outdated fixed assets to more technologically advanced.

In order to increase the level of international competitiveness, it is necessary to first assess it. This assessment is integral, since the level of international competitiveness is an index dimensionless value that includes a number of components that need to be identified, classified, characterized and evaluated. The problem of assessing the components of the international competitiveness of Ukraine's electricity sector is that the environment of its functioning due to the ongoing full-scale war is characterized by uncertainty and dynamics. Therefore, in order to assess the components of international competitiveness, it is necessary to develop a methodological approach that would take into account the impact of uncertainty in the factors of the electricity sector environment. Given that the object of the study is the international competitiveness, the problem of taking into account the uncertainty of the factors of its international competitive environment.

Analysis of recent research and publications.

A number of domestic and foreign scholars have studied the components of international competitiveness of market participants. Thus, V. O. Denis and O. O. Denis [1, p. 63–64] found that such scientists as Y. B. Ivanov, P. A. Orlov and O. Y. Ivanova [2, p. 23] consider in their work such approaches to structuring international competitiveness at the enterprise level (micro level) as comparative, resource and systemic, as well as comparative-resource. V. O. Zenis and O. O. Zenis [1, p. 65] in their work concluded that it is advisable to use the comparative-resource approach to structuring international competitiveness and within it identified such components as price, commodity, service and resource: entrepreneurial, managerial, information. From [1, p. 66] it can be concluded that, according to the comparative-resource approach, the international competitiveness of an enterprise has two components: comparative (comparative competitive advantages) and resource. The work [1, p. 67–68] also presents the views of representatives of the systemic approach to structuring

international competitiveness: V. A. Pavlova [3, p. 115], who assesses the level of international competitiveness as a system of competitive advantages at the product level (nano-level) according to the criteria of price, quality and safety; I. V. Bagrova and O. G. Nefedova [4, p. 14], who present international competitiveness as a system of competitiveness and competitive potential in the areas of economic activity at the enterprise level (production, financial, innovation and investment).

The components of international competitiveness at the meso-level were considered by scientists N. K. Kolomiets and O. A. Yermakova [5, p. 56], distinguishing among them competitive advantages and competitive potential by components of social development of the region: territorial (natural resources), socio-legal, socio-economic. At the macro level, the components of international competitiveness were studied by M. Porter [6]: factors of production, demand, industry and competitive environments. The importance of taking into account the innovative component of international competitiveness at all levels of the economy is emphasized by A. Antonenko [7, p. 19–21].

At the micro level, A. D. Chykurkova [8, p. 10-11; 15; 18] proposed a comprehensive and differentiated approach to assessing the components of enterprise competitiveness, that is, a combination of different assessment methods and their differentiation at different stages. At the meso-level, I. Z. Dolzhansky proposes to focus on M. Porter's model of the five forces of competition to assess the components of competitiveness [9].

The most detailed methodology for a multi-stage assessment of the components of competitiveness of enterprises in the industry based on the formation of integral indices and cluster analysis was proposed by V. Prokhorova and V. Protsenko [10, p. 7]. This methodology is adapted to machine-building enterprises, however, since it is based on the methods of integral and cluster analysis of competitiveness components, which are universal for open economic systems of different levels, it can be applied to business entities in the electricity sector in terms of their competitiveness in the international market. The methodology proposed in this paper is flexible and can be improved to take into account the conditions of uncertainty that affect its activities in the international market.

At the same time, an analysis of recent research and publications on the issue raised in this article has revealed a number of unresolved issues within the research topic. Firstly, the components of international competitiveness are the most studied at the level of goods, enterprises, countries and their regions. According to the analyzed works, the components of international competitiveness at the industry level can be determined on the basis of the analysis of components at other levels of the economy, since an industry is related to a particular country, consists of enterprises that produce products and are concentrated in certain regions closer to either production factors or consumers, depending on the specifics of the industry. And yet, in the context of the problem under analysis, this specificity remains insufficiently covered in relation to the electricity sector. It is this specificity of the industry that determines the list of components of its international competitiveness, and its understanding is the basis for determining their importance.

Secondly, the issue of choosing the optimal approach to assessing the components of international competitiveness for the specifics of a particular industry remains unresolved. This is especially true for the electricity sector, since its competitiveness at the nanoscale relates to a specific homogeneous product – electricity, services for its supply and maintenance of the supply infrastructure. In addition, the specifics of the international electricity market need to be disclosed: its segmentation and institutional regulation.

Thirdly, the issue of comparing scientific approaches to structuring the components of international competitiveness at the industry level and methodological approaches to assessing these components is not fully disclosed. Fourthly, the issue of taking into account the uncertainty of the factors of the international competitive environment of the electric power industry and the impact of this uncertainty on the components of its international competitiveness when developing a methodological approach to their assessment is problematic.

Formulating the purposes of the article. The purpose of the research is to develop theoretical and methodological foundations for assessing the components of international competitiveness of the electric power industry under conditions of uncertainty.

To achieve this goal, the following sequence of tasks has been defined:

1) to define the essence of the international competitiveness of the electric power industry and structure its components;

2) to define the essence and classify the factors of the international competitive environment of the electric power industry under conditions of uncertainty;

3) to develop a methodological approach to assessing the components of the international competitiveness of the electric power industry, taking into account the uncertainty of the factors of its international competitive environment.

Methodology consists of a critical analysis of scientific literature, decomposition and system-structural analysis of the components of the international competitiveness of the electric power industry under conditions of uncertainty, as well as factor analysis, provisions of the theories of probability and information to develop a methodological approach to assessing the components of the international competitiveness of the electric power industry under conditions of uncertainty of the factors of the international competitive environment.

Presentation of the main research material. An analysis of recent studies and publications has shown that international competitiveness is a complex abstract concept. Lexically, this concept refers to the ability (actual ability and potential ability) of market participants to compete in the international market, which are classified by the types of their production and economic activities within a particular industry.

Based on Art. 260 of the Economic Code of Ukraine [11], we propose that an industry in a market economy should be understood as a set of market entities within one or similar types of production and economic activities, as a result of which they sell manufactured goods, perform work and provide services in the market. When entering the international market, manufactured products cross the state border.

The definition of the industry implies that the electricity sector is a set of business entities operating in the same

area related to the production, distribution, supply and sale of electricity. In other words, their activities relate to one product – electricity – as well as related services, works and maintenance. In addition, by its physical properties, electricity is a specific commodity that cannot be evaluated by the consumer in terms of its appearance: electricity is supplied in the form of electric current under a certain voltage. It is these specific properties of electricity as a commodity that make it difficult to define the essence and components of the international competitiveness of the electricity sector.

Based on the decomposition of the concepts of “international competitiveness of a market entity”, “industry”, and “electricity”, it is possible to reveal the essence of international competitiveness of the electricity sector as the ability of market entities in this sector (engaged in similar economic and production activities) to compete for a higher share (competitive position) in the international electricity market due to the presence of competitive advantages (which form competitiveness) and potential competitive opportunities (which form competitive).

From this definition, it follows that international competitiveness at both the micro (enterprise) and meso (industry) levels has three universal components: competitive position (which is a comparative characteristic of the level of competitiveness of market entities), competitive advantages (which form this level, are its determinants) and competitive potential (which, based on a scientific study [12], we propose to interpret as a set of opportunities and resources of industry entities to create new and more efficient. Let us consider in more detail each of these components and their peculiarities for the electricity sector in the activities of its entities in the international market.

The first component, competitive position, is a resultant characteristic. The higher the competitiveness, the higher the competitive position of the business entity, i.e. its place in the ranking of competitors, which can be formed by their market shares. This rating can be formed not only by electricity companies at the micro level, but also by countries that compete in this industry on the international market. This requires segmenting a specific international electricity market (e.g., the European energy market within ENTSO-E) and determining the total market share of electricity business entities for each country in that segment. For the international electricity market, the segment in which competition takes place is the electricity supplier segment, since in the electricity generation and distribution segment, this industry is characterized by the existence of natural monopolies due to the pronounced economies of scale. That is why we propose to understand the competitive position of a country's electricity sector in the international market as the total market share of electricity suppliers (exporters) from that country to other countries. In this definition, market share means the share of all transactions for the sale of electricity to the international market, since when electricity is supplied directly to the consumer in the power grid, he receives its “mix”. In other words, electricity in the country's power grid is a mixture of electricity obtained from different sources of electricity and supplied from different countries.

The second component, competitive advantages, is formative. It is the competitive advantages that determine

the actual ability of the industry's business entities to compete in the international market. Competitive advantages are those economic characteristics of the industry's enterprises and their products that are better than those of competitors. For the electricity sector, its competitive advantages in the international market include the following parameters:

1) lower prices than competitors (by reducing costs or dumping, but anti-dumping regulations should be taken into account);

2) compliance with certain technical parameters of electricity and its infrastructure, which form the quality system: for example, a stable voltage level, frequency of electrical fluctuations, absence of harmonics and voltage deformation;

3) quality of maintenance of the electricity supply infrastructure.

The third component, competitive potential, is a supporting one. Competitive potential is a set of resource capabilities of an electricity business entity to increase its competitive advantages in the international market. We propose to understand resource support as a set of necessary resources that ensure the availability of competitive advantages. These resources include the following types: financial, investment, innovation, material and technical, natural and geographical, raw materials, production, management, human resources, intellectual, information, time, institutional, etc. It is important to keep in mind that in order to increase the competitive advantages of the country's electricity sector in the international market, it is necessary to optimize the use and distribution of competitive potential. If the competitive potential is used and distributed suboptimally, this will lead to a loss of competitive advantage in the international market in the long run.

Thus, when determining the essence and components of the international competitiveness of the electric power industry, we combined the systemic, comparative and resource approaches proposed by scientists Y. B. Ivanov, P. A. Orlov and O. Y. Ivanova [2, p. 23]. As already noted in the analysis of recent studies and publications, V. O. Zenis and O. O. Zenis [1, p. 63–64] emphasized the need to combine two of the three approaches mentioned above, the

comparative and resource approaches at the micro level. However, we conclude that at the meso-level it is advisable to combine all three approaches. We propose to call the approach formed by applying these three approaches systemic and structural, since it takes into account the following:

1) the electric power industry is a complex and open economic system;

2) the country's electric power industry as a multifactor system has a resultant (dependent) variable, and that is why the first component of its international competitiveness is its competitive position in the international market, which describes this resultant variable;

3) the competitive position is formed due to the existence of a system of comparative competitive advantages (which led to the use of the comparative approach as part of the systemic-structural approach, since international competitiveness is a comparative and relative, not an absolute characteristic);

4) competitive advantages can be structured by certain parameters: price, production costs, as well as the quality of electricity, electricity supply services, and maintenance of electricity infrastructure;

5) competitive advantages, in turn, are ensured by optimizing the use and distribution of competitive potential (this demonstrates the systemic interdependence of the electricity sector components);

6) the competitive potential of the industry is inextricably linked to the system of its resource provision (unity of system and resource approaches);

7) the electricity market is segmented, which requires a structural approach.

The above components of the international competitiveness of the electric power industry according to the systemic and structural approach form its internal environment. Since the electric power industry is an open economic system, it is influenced by the factors of its external environment. We propose to call that part of the external environment of the electric power industry, the factors of which have an impact on the components of its international competitiveness, the international competitive environment. These factors can be classified according to many features (Table 1) [13–14].

Table 1

Classification of factors of the international competitive environment of the electric power industry

Classification Feature	Type of Factors	Examples of Factors
By the level of socio-economic environment	Megaenvironment	World energy prices, global market trends
	Macroenvironment	GDP dynamics, inflation rate, unemployment rate
	Mesoenvironment	Energy infrastructure stability
	Microenvironment	Level of depreciation of fixed assets, financial stability, intensity of competition, market concentration
By the sphere of social life	Economic	Financial, investment, technological
	Political-legal	Institutional, regulatory, geopolitical
	Social	Demographic, employment and welfare
	Cultural	Corporate culture, scientific development
	Ecological	Climatic, natural-resource
By the degree of controllability	Controlled	Financial, production, innovative
	Uncontrolled	Military-political, natural disasters
By the nature of the impact	Positive	Innovations, technological modernization
	Negative	Economic crisis and turbulence, depletion of fuel and energy resources, military actions, natural and man-made disasters

Source: developed by the author and based on [13–14]

The classification of factors of the international competitive environment of the electric power industry proposed in Table 1 demonstrates a significant variation of their characteristics. Table 1 gives only some examples of these factors, since it is impossible to form an exhaustive list of them in a real economic system. In addition, the international competitive environment is characterized by uncertainty of its factors (characteristics, circumstances, conditions of their influence). This uncertainty is due to the fact that the international competitive environment of an industry is by its nature external (exogenous) to its market participants, which is why they need to have structured information about this environment to make it certain. This implies that the categories of certainty and uncertainty are not properties of the system's external environment, but characteristics of the subjective perception of its state by economic entities based on available information about it.

From this definition it follows that the concept of "uncertainty" has common features with such a concept of information theory as "information entropy", since it is also a function of the state of the system object. This term was proposed by the scientist C. Shannon in 1948 [15–16]. According to C. Shannon, the information entropy (H) of a discrete random variable X with probable values $\{x_1, x_2, \dots, x_n\}$ and a probability mass function $P(X)$ is defined as follows:

$$H(X) = E[I(X)] = E[-\log(P(X))], \quad (1)$$

where E is the operator of mathematical expectation; I is the amount of information (intrinsic information, or surprise, as a measure of information content, according to C. Shannon) of a discrete random variable X .

Formula (1) can be presented explicitly:

$$-\sum_{i=1}^n P(x_i) \log_2 P(x_i), \quad (2)$$

where the base of the logarithm shows that information is measured in bits (a unit of information in the binary system).

Formula (2) implies the following consequences regarding the uncertainty of environmental factors in general (and by deduction, these consequences are also valid for the international competitive environment of the electricity industry in a particular case) [17]:

1) the lower the probability of occurrence of an elementary event $\omega \in \Omega$ (the space of elementary events), which determines the future state of the environmental factor (acquisition of its probable value x_n by a discrete random variable X), the higher the measure of information content (own information, surprise) $I(X)$ of the discrete random variable X that describes it;

2) information entropy as a measure of uncertainty is a mathematical expectation E of intrinsic information (surprise) as a measure of information content of a discrete random variable X (which is a quantitative expression of an environmental factor) with probable values $\{x_1, x_2, \dots, x_n\}$;

3) the greater the number of possible elementary events $\{\omega_1, \omega_2, \dots, \omega_n\} \in \omega$, as a result of the occurrence of one of which the discrete random variable X (which is a quantitative expression of the environmental factor) takes one of the probable values $\{x_1, x_2, \dots, x_n\}$, the higher the information entropy (as a measure of uncertainty) of this discrete random variable;

4) if the n possible elementary events $\{\omega_1, \omega_2, \dots, \omega_n\} \in \Omega$ are equally probable, the information entropy (as a

measure of uncertainty) of the discrete random variable X of the environmental factor will be higher than in the case when these elementary events are not equally probable.

For a better understanding of the above implications, their theoretical explanation should be supplemented with a practical example related to the assessment of the components of the international competitiveness of the country's electricity sector in the face of uncertainty in the international competitive environment. For example, let us consider such a component of the international competitiveness of Ukraine's electricity sector as its competitive potential, which, in turn, also has certain components. Given the uncertain realities of the ongoing full-scale Russian aggression against Ukraine, it is relevant to consider the infrastructure potential as a component of the competitive potential of the Ukrainian electricity sector in the international market. Let us consider the impact of the sustainability of the heat and power infrastructure as an infrastructural factor of the international competitive environment of the Ukrainian electricity sector on its competitive potential in the face of uncertainty due to a full-scale war.

One of the discrete values that can describe the resilience of the thermal energy infrastructure during military operations is the degree of destruction of TPPs as a result of an air strike (missile, drone, bomb) on a scale from 0 to 10, determined by the method of expert assessments. Given that war is a random non-stationary process (i.e., a process whose law of distribution of random variables changes over time), the described discrete variable X is random, and therefore we can estimate its information entropy using formula (2) as a measure of the uncertainty of its corresponding factor. Then, a random event A (which is a subset of the space of elementary events Ω) will be an air strike with a certain type of weapon. The elementary events of this random event will be variants of possible consequences of an air strike $\{\omega_1, \omega_2, \dots, \omega_{10}\}$, as a result of which the percentage of TPP destruction (value X) can take the value $\{x_1, x_2, \dots, x_n\} = 1, 10$ with the corresponding probabilities, the sum of which is $\sum_{i=1}^n P(x_i) = 1$. However,

since the consequences of the described random event A depend on many parameters and circumstances (type and characteristics of the type of enemy air defense means, saturation of the air defense area, etc.), the uncertainty assessment of the random variable X given in the example requires the use of such a methodological approach as Monte Carlo simulation [18]. Thanks to its application, it is possible to establish the range of probabilities for each of the elementary events $\{\omega_1, \omega_2, \dots, \omega_{10}\}$ of a random event A , and hence the range of information entropy of this event. In the context of uncertainty due to military actions, this methodological approach is working, and therefore it is proposed to apply it to take into account the uncertainty of the factors of the international competitive environment of the electric power industry when predicting their impact on the components of its international competitiveness.

Conclusions. As a result of the study on the development of a methodological approach to assessing the components of the international competitiveness of the country's electric power industry in the context of uncertainty of the international competitive environment, the following conclusions have been drawn.

1. Based on the decomposition of the concept of international competitiveness of the electric power industry, it was determined that its level is a competitive position in the international market, formalized through the market share (the share of electricity exports from the country to the international electricity market in the total volume of electricity supply in this market). Based on the systemic-structural approach (a complex of systemic, comparative and resource approaches), the author establishes that, in addition to the competitive position, the components of international competitiveness are comparative competitive advantages and competitive potential.

2. Based on the systemic and structural analysis of the international competitive environment of the electric power industry, we propose to understand it as the result of interaction of subjects of international market competition in this industry and their internal environment with the

external environment of their functioning, the factors of which can be classified according to various criteria. The uncertainty of the factors of the international competitive environment described by a random variable can be measured through information entropy.

3. Based on a critical review of the scientific literature related to theories of competition, probability and information, as part of a methodological approach to assessing the components of the international competitiveness of the electric power industry under conditions of uncertainty, their system-structural analysis, factor analysis, and the Monte Carlo method are proposed.

Prospect for further research is to find ways to apply the Monte Carlo method in modeling and forecasting the components of the international competitiveness of the electric power industry in the face of uncertainty in the international competitive environment.

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