

About the Possibility of Building of the System-Phenomenological Models of the World Economy

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Abstract—The historical and most widely known “Mir-2” and “Mir-3” models developed at the initiative of the club of Rome by J. Forrester and D. Meadows are analyzed. The model of M. Mesarovich and E. Pestel is briefly described. The analysis of such models of the world economy as the model of A. Onishi, V. Leontiev, the FUGI model, the LINK model of L. Klein, the “SARUM” and globus models is carried out. It is shown that the process of building models of the world economy rests on a problem of extreme complexity associated with a large number of interrelated subjects, a significant number of indicative indicators that require accounting, analysis and forecasting, low adequacy and accuracy of the models used, as well as the logical complexity of linking components, relationships and relationships into a single whole within a common model. In general, this work is aimed at finding new ways to model the description of national economies, the world economy and their development processes. It is proposed to create phenomenological models of urban, regional, national (industry) economies and the world economy as a whole based on the use of natural science methods that implement a system-phenomenological approach to describing multidimensional statistical data. Specific examples show the possibility of constructing phenomenological models in the form of equations of state for cities, regions, and countries that are structural elements of the general model of the world economy.

Keywords—phenomenological models of the world economy, interconnected economic space, system-dynamic models of the world's countries, linking components, connections and relations into a single whole within the framework of a common model, model description of hybrid economies, the world economy and their development processes, multidimensional statistical data.

I. INTRODUCTION

Since the appearance of the works of J. Forrester and D. Meadows, devoted to system dynamics and the study of long-term trends in global development [1, 2], proposed a number of models that characterize the world economy, as well as the processes and consequences of its development. The world economy is a set of national economies of all countries of the world that form an interconnected economic space of the

planet. Various spatial models of the world economy are known: two-, three-termed-, ten-termed and etc., which distinguish a different number of centers of the world economy.

There is a problem of linking spatial models of the world economy with system-dynamic models of countries and national economies. System dynamics models allow combining various spheres of human society functioning based on the use of simulation methods and tools. Development in this area follows the path of increasing complexity of the initial models, increasing the number of input and output variables, and representing national or industrial economies as a set of flows (monetary, material, commodity, human, etc.), which are described by a system of differential equations, agent-based or hybrid models. In turn, spatial models of the world economy are descriptive and expert in nature and develop along the way of increasing the centers of influence, complicating national, sectoral, spatial and hierarchical structures, using various development criteria in modeling, etc.

The process of building models of the world economy rests on a problem of extreme complexity associated with a large number of interrelated entities (more than 50 economic unions and more than 200 countries), a significant number (dozens and hundreds) of indicative socio-economic indicators that require accounting, analysis and forecasting, low adequacy and accuracy of the models used (econometric, neural network, simulation, economic equilibrium models, etc.), as well as the logical complexity of linking components, connections and relationships into a single whole within the framework of a common model [3].

Based on the above, the search for new ways to model the description of national economies, the world economy and their development processes is relevant.

II. RESULTS AND DISCUSSION

A. *Models of the World Economy*

The modern world is entering an era of political instability, local wars, economic crises and the struggle for resources, so strategic assessment and planning of the development of any country in the rapidly changing world of the XXI century becomes a vital fact. Protests, revolutions, external influences and changes of power in many countries indicate that the world is governed, and any country with a weak economy, unstable society and unpopular government can become the object of a large-scale political experiment.

Recently, such methods, measures and means of influencing states have been called predictive weapons. In this regard, the development of methods and tools for modeling and forecasting the development of countries and the world as a whole is an extremely urgent task of national security for any country. Therefore, researchers pay much attention to the development of a variety of models for the development of regions, countries, and the world economy (simulation, agent-based, object-oriented, system-dynamic and etc.).

The world economy consists of a historically established set of national economies of all world governments that are connected by world economic relations. Classical projects and models of global development (52 programs) are studied in the paper[4]. Another large group of models and projects consists of developments made by research departments of large international corporations, banks, and international organizations. First of all, these include, the models of the Japanese center for economic research, the annual reports of the World Bank, Chase Manhattan Bank and others. These developments are mainly devoted to the analysis of problems in the development of the world market economy and represent the interests of large businesses. The next group includes research carried out in recent years directly commissioned by the governments of the most developed countries. Here we should note the forecast developments of the state department and the Council on environmental quality of the United States, reports of the Organization for economic cooperation and development, the "SARUM" model, the FORCAST model complex, and others. Many global developments are becoming focused on the interests of the military-industrial complex. Finally, the fourth group of projects and models of global development is represented by developments carried out in various organizations under the auspices of the United Nations, such as UNESCO, UNIDO, UNCTAD and others. There are currently more than a dozen projects and models in this group. The reasons for the sharp increase in interest in forecasting development prospects are the need to study future alternatives for harmonious global economic development, significant improvement in computer technology capabilities, and the availability of financial resources during a period of intense economic growth.

The first, historical and most widely known models are "Mir-2" and "Mir-3"-were developed at the initiative of the club of Rome by American Professor J. Forrester (1971) [1]. The first global model is based on a simplified extrapolation of the five main factors of "global concern": population growth, industrialization, environmental pollution, food production, and natural resource extraction. The purpose of these studies using system dynamics methods is to trace the development of crisis trends in the interaction between society and its environment in the next century, based on the

assumption that the nature of socio – economic development remains largely unchanged.

In 1972, the Forrester model was detailed, at the same time an attempt was made to introduce extensive statistical data and verify the adequacy of the model. D. Meadows, the lead developer of the "Mir-3 model", which served as the basis for the report "Limits to growth" (USA, 1972), a decade after its publication, recognized that in the first global models, socio-political, cultural, and even scientific and technical factors were practically ignored. Subsequent global models were characterized by a much more objective approach to describing global processes.

In response to the criticism of the first models, the club of Rome proposed a new project – the search for a strategy for human survival based on the concept of "organic growth", which was created under the leadership of M. Mesarovich and E. Pestel (USA-Germany, 1974). In the model, the whole world was divided into 10 regions. The hierarchical system of models was based on the allocation of three levels: causal (including environmental and economic processes), organizational and the formation of social norms, values and goals of society. A system of submodels common to all regions was also developed, which included submodels of demography, economy, energy, oil crisis, and food problems.

This approach, which considers the world as a dynamic system of interacting regions at different stages of development, allowed us to take into account the specifics of the development of various countries, to trace the causes and dynamics of a number of crisis processes. In General, the main contribution of Mesarovich and Pestel is to develop a new class of models based on the theory of multilevel hierarchical systems, and to create a methodology for analyzing and evaluating alternative future scenarios.

Various modifications of such models are widely used by developers in many countries of the world in the analysis and forecasting of socio-economic development at different levels. An example is the Mesarovich-Pestel model-based study of the problems of urbanization in Mexico City as the world's largest megacity until 1990, the "China 2000" project, and the "FORCAST" model complex (USA).

The "World tension and a new perspective on development" model is dedicated to finding ways to reduce the income gap between developed and developing countries. According to the authors, the concentration and development of the most high-tech industries should be carried out in the most developed capitalist countries, and first of all, in Japan. The analysis of long-term strategies for the development of the Japanese economy in the context of global problems and structural crises of the world system is devoted to two more forecast developments of Japanese researchers: "the World economy and Japan in 1990" and the global macroeconomic model of A. Onishi, which has two forecast horizons: 1990 and 2000.

A. Onishi's macroeconomic model is intended for a comprehensive analysis of the world economy and global development alternatives for the third ten-year UN development program. Special attention is paid to the extraction and consumption of natural resources. The model consists of three interrelated submodels: a macroeconomic model designed to develop a system of scenarios for the development of the world economy; and a global input-output model designed to analyze various alternatives to global

industrial development; a forecast model focused on predicting the dynamics of production and consumption of natural resources. One of the latest modifications of the model includes about 10,000 equations describing world trade, taking into account the mechanisms of current price formation for 62 regions of the world [4].

In 1977, the FUGI model developed in Japan was introduced. The model represented the world in 15 areas with the main goal of depicting future scenarios [5]. In the early 80's, the FUGI 4.0 model classified the world into 62 countries and regions. In 1981-1990, this model was used as a long-term forecast model for Forward planning studies in the division of International economic and social Affairs of the UN Secretariat in New York. During the 1980s, the UN Secretariat used the FUGI model for long-term economic research and the LINK 1 model in parallel. For short-term global economic forecasts, the model of the world economy developed by Professor V. Leontiev was also used at the same time [6]. Developed in the early 90's, the FUGI 7.0 model divided the world into 180/80 countries and regions. This model expanded the block of the model that takes into account the interaction of the environment and the model of energy production was presented in a new interpretation [7].

By the end of the 1980s, about ten global models and integrated forecasts of global development had been developed in various international organizations under the auspices of the United Nations [8, 9]. The most interesting of them are: the "Future of the world economy" model, models and forecasts of UNCTAD (United Nations Commission on trade and development) and the DIEM (UN Department of international economic and social Affairs).

The UN model "the Future of the world economy" was developed under the leadership of the Nobel prize winner V. Leontiev (1977). The purpose of the study is to analyze the impact of economic and political problems on the international development strategy formed by the UN in the future for three decades (1970–80, 1980–1990, 1990–2000). The model has a regional structure: it represents 15 regions of the world: eight developed country regions and seven developing country regions (three "resource rich" and four "other"). A description of each region is carried out in 45 sectors of economic activities. The integration of regions into a single model is carried out through a complex mechanism of relations, including export-import of goods and services, capital flows, aid transfers and interest payments abroad.

In General, the model of the V. Leontiev group represents a significant step forward in comparison with previously developed global models, primarily in the field of more objective, realistic consideration of the problems and features of the modern world, recognition of the determining role of socio-political factors of social development.

Within the framework of the UN economic Commission for Europe (ECE), an interconnected system of regional models was developed to forecast the economic development prospects of the ECE countries for the 80–90s. Various sub-models of individual regions were linked by means of matrix systems describing trade flows for different product groups. The following regions are identified in the UNECE model system: European market economies; European centrally planned economies; North American countries; and other economically developed countries; developing country. Statistical filling of models is carried out with the help of

specialized international agencies coordinated by the UNECE Secretariat in the following main areas: supply in the economy of individual countries, production development, employment, capital accumulation processes, labor productivity; final demand, profit distribution, consumption, investment and savings; energy use; international trade relations.

In the early 1980s, the United Nations Commission on trade and development (UNCTAD) also published two major projections: "Report on trade and development", "review and analysis of the main goals of the international development strategy for the third ten-Year UN development program". These developments were based not on traditional econometric models, but on carefully formed complex systems of parameters, the analysis of which allowed us to draw conclusions about the future prospects for trade, Finance, and economic growth in developing countries. The structure of the parametric system used by UNCTAD consisted of six sectors (regional modules) describing different groups of countries. Regions were connected through trade and financial flows.

One of the most comprehensive forecast developments is the report "Meeting the future", prepared in 1979 by a group led by J. Lezurn. The report was devoted to the search for ways to mitigate the progressive contradictions between developed capitalist countries and between them and the developing world in the context of escalating structural crises, raw materials, energy and environmental problems of our time. The methodological development of the project was based on the global "SARUM" model created by the Ministry of environment of Great Britain. The authors of the model focused on describing the economic processes of global development in the framework of neoclassical economic theory.

A number of major banks, in particular the World Bank, pay considerable attention to the development of global models and alternatives for socio-economic development. The main tool for developing forecasts of the World Bank is the "SIMLINK" model, created to study the impact of changes in world oil prices and trade dynamics in the OECD countries, capital flows of various types of "aid" to developing countries. Later, the model was upgraded to take into account the peculiarities of national economic development and various aspects of international trade and monetary and financial relations. In the modern version of the model, exports from developing countries are correlated with the level of economic activity of developed countries using individual sub-models of commodity exchange. The economic growth of developing countries is linked to the level of investment and exports. The model describes imports and GDP growth in developing countries. The "SIMLINK" model was used in another major forecast study – the report to the US President "global problems 2000".

The global models of the World Bank are closely related to other model developments carried out in a number of international and private economic organizations: the Wharton Association for econometric research, the Basler research group ("the BAK" model), the research center in West Berlin (the "Globus" model), the International energy Agency (IEA), and others.

Summing up the review of global models and projects of global development, it should be noted that when making

scientific forecasts and comprehensive assessments of the development of the world and individual countries, usually well-known and numerous teams of researchers are involved. Among them are the Forrester model, the Mesarovich – Pestel model, the PricewaterhouseCoopers Forecast “The world in 2050”, the long – term model of energy development and the state of the EU environment-VLEEM, the forecast of J. F. Coates “2025: scenarios for the development of the United States and the world community under the influence of science and technology, the forecast of new technologies of the University of Washington”, forecasts of global climate and environmental changes, etc. Time usually shows low reliability of such forecasts and estimates, but they are of great importance for the development of integrated assessment and forecasting methodology in the study of global and regional processes.

The main directions and trends of research in the field of modeling and forecasting of development of countries and the world in General associated with the accumulation and development of more extensive databases of indicators of countries, using new methods of visualization and evaluation of data, using mathematical methods of data analysis, the creation of national information-analytical systems, storage, presentation and analysis of data, development of mathematical and simulation modeling, development of theory and methods of system dynamics.

One of the new ideas in this area is related to phenomenological approaches to the analysis and description of statistical data. This idea is related to the possibility of creating a set of models in the form of phenomenological descriptions based on extensive statistical information about the state and development of countries and the world economy. Government programs to create and develop technologies for analysis, modeling, and forecasting based on statistical data for key areas of public policy exist in the United States (2012), Japan (2013), Australia (2013), the United Kingdom (2011), and so on.

B. Hypotheses and Methods Used in Creating Models

The object model, which represents the structural aspects of the world economy system, consists of various models that are grouped according to a hierarchical principle: cities and districts are grouped into national regions, regions into countries, and countries into the world economy.

To solve these problems, it is proposed to create phenomenological models of urban, regional, national (industry) economies and the world economy as a whole based on the use of natural science methods that implement a system-phenomenological approach to describing multidimensional statistical data. In this case, statistical data sets are presented in a single structured form, and the form of their representation (in the form of objects – indicative indicators – time of statistical observations) is common for various hierarchical levels: world economy – national economies – regional (sectoral) economies of countries – urban economies. It is assumed that for each hierarchical level it is possible to use a common generic phenomenological model, which in class object is configured for the required list of indicative indicators and state variables, uses its own set of laws characterizing the state of objects and processes of their changes, and is based on temporal statistical data, which characterize these objects in several specific aspects (demographic, economic, social, etc.) in statics and dynamics. Particular phenomenological models

are combined into object models at a higher level of the hierarchy and identified by the corresponding phenomenological models that characterize this class of objects. In each case, linking components, relationships, and relationships into a single whole within a more General model (for example, in the cities – regions – countries – world economy line) is based on logical, balance-based, or other methods for establishing relationships between objects and their attributes. Thus, object-oriented modeling technology is used when building models.

When creating such a model, we assume that the position of each socio-economic object is determined by a set of values of its indicators, which are formed at a certain point in time. To describe the position of an object relative to all other objects of the same class, we will use the natural science concept of state space—an abstract space formed for socio – economic objects by several state variables. As state variables z_1, z_2, \dots, z_n we will take indicators selected for econometric analysis that are considered important among experts, characterize the studied objects in a certain aspect, are variable, and the significance of which can be justified by statistical methods. For each hierarchical level, all other indicative indicators (which could be significantly more than state variables) will be linked to state variables using event-based estimation methods [10, 11].

The main hypotheses adopted for modeling processes and justifying criteria for assessing the socio-economic situation and development of countries, regions, cities and others are as follows.

Let's assume that for m socio-economic objects (countries, regions, cities, etc.) there are statistical data for a certain list of indicative indicators, from which attribute indicators are selected z_1, z_2, \dots, z_n and which we will consider as state variables. Let's form a multidimensional state space in the form of a cartesian reference system with respect to these variables.

The main idea of the study is to study the possibility of creating models that differ in the description of geometric objects of points (states) and lines (processes) in the state spaces of socio-economic objects based on available statistical information. The simulation is based on the hypothesis of the existence of various complex measures of similarity of object states $W = W(z_1, z_2, \dots, z_n)$. This value is considered as a function of several variables. Various simple systems for measuring W values are proposed for relative comparison of the position of objects in a multidimensional state space. Among the many models obtained, the most qualitative phenomenological models are selected according to the adequacy criteria and statistical criteria, which are accepted for further analytical work.

The construction of models is based on the use of the principle of corresponding states, according to which the positions of objects can be described by a single equation of state, if you build an effective scale for comparing states with each other and use some of the given variables [10]. The equation of state is usually represented as: $F(z_1/z_{10}, z_2/z_{20}, \dots, z_n/z_{n0}) = 0$, where z_{k0} – indicator values for the reference state (for the corresponding object class).

In this approach, modeling objects are states of socio-economic objects that can be characterized by a general equation of state that is valid for the entire observed state space. The equation of states is created with respect to a particular selected state.

To construct an equation of state for a group of objects (countries, regions of countries, cities), a reference object or reference state is selected, and all other states are associated with the selected point in the state space. The validity of the principle is checked on a case-by-case basis based on available data.

The principle of corresponding states allows you to build a scale for relative comparison of the position of objects among themselves, in the form of an index $\theta = W/W_0$ that is linked to a certain class of objects. After creating a measuring econometric or sociometric scale, the equation of States is searched for as a regression relationship $\theta = f(z_1/z_{1_0}, z_2/z_{2_0}, \dots, z_n/z_{n_0})$. The procedure for constructing such scales is thoroughly worked out in thermodynamics. The paper uses the appropriate logic for constructing scales to compare the States of socio-economic objects. The essence of the method is to select both a reference state and a certain reference process in the state space [12]. This is due to the fact that when modeling the dynamics of objects, it is necessary to be able to compare both the States of objects and the processes performed by these objects over time.

Let's assume that a relationship can be established between the value W , as a measure of similarity of object states $z_1/z_{1_0}, z_2/z_{2_0}, \dots, z_n/z_{n_0}$ can be established link based on regression dependencies obtained from statistical data. and the given values of indicators based on regression dependencies obtained from statistical data. From the above, it is important to choose indexes θ for characterizing the states of objects or processes of state change, as well as to develop systems for measuring these values. The measure of similarity of states W will be represented as dependencies relative to the values of quantities z_1, z_2, \dots, z_n . Various values can be used as such a measure: geometric measures, as models and metrics of the state space; probabilistic measures, as statistical characteristics of groups of analyzed objects; empirical measures in the form of comparisons of relative changes in the states of objects in relation to the states of the reference object or control groups of objects [10, 11].

Thus, the tools used include econometric tools for comparing (measuring) States and processes in multidimensional spaces of socio-economic variables, methods for constructing and selecting empirical measures for complex characterization of object States and metrics for describing state spaces, methods for creating measurement scales and accepted measurement systems, methods and techniques for constructing state equations for homogeneous groups of objects that take into account the features of their collective behavior, methods for obtaining empirical dependencies and determining the values of phenomenological quantities and etc. [10, 11].

The general method of obtaining equations of states and phenomenological relations for various classes of objects in each case includes the following steps:

- a database is compiled in the form of a single structured array of statistical data, for which information is collected, processed and analyzed from various international sources. The data array for each class of objects is represented by two-dimensional tables "objects-indicative indicators", and the set of tables is ordered by time with a certain step. Indicative indicators for uniformity are systematized and unified;
- for each hierarchical level (class) of objects (countries, regions, cities, etc.), a General list of indicative socio-economic indicators is formed, and a group of indicators is selected that act as state variables and characterize the class of objects in a certain aspect;
- based on the selected variables, a multidimensional state space is formed for each object class. Select a process that can act as a reference process in the state space. This process may correspond to a certain reference object whose indicators have changed over a certain period of time. In the reference process, reference points are set for building a linear scale of an index $\theta = W/W_0$ in order to compare the States of objects relative to each other. A measure of similarity of states W is determined in the form of some reasonable dependence, the States of objects are measured using the created index scale θ , and the values of this index for each object are found. Various options for constructing a measurement system for this value are studied and the most optimal measurement systems are selected;
- next, a set of empirical scales is created to measure the States of various classes of objects, their States are measured, and the regression method is used to find equations of state that characterize the collective behavior of objects in each specific case;
- state and phenomenological relations for state spaces are used to construct a system of phenomenological models for various classes of objects and their totality as a whole.

C. *Examples of the Construction of Phenomenological Models*

To measure the states of objects, we use values that allow us to evaluate the overall state of the object in relation to the selected reference states based on experimental data. This approach basically requires the creation of empirical measurement scales based on the use of various methods of scaling values. In general, the task is to establish a correspondence between the values of a certain conditional value, measured, for example, in percentages, degrees, points, points, etc., and the values of one or more input values. For this purpose are usually used devices, the computing algorithms, regression, etc. This approach is widely used in physics, chemistry, meteorology, geology, biology, psychology, sociology, as well as in the sciences related to system security, etc.

The most common form of obtaining empirical scales can be described as a two-point method (for example, creating scales in thermometry). In this case, two states are selected that can be reliably reproduced or observed, and two reference points are marked on the scale for these States. This method forms the base of the scale and sets the linear relationship between the values. Next, the entire scale interval

is divided into a randomly selected number of equal divisions (most often 5, 10, 12, 100). A change in one division is taken as the unit of measurement of the scale, which is called a percentage, fraction, degree, point, point, etc.

Among all the observed objects of the same class, a reference object is selected for which the condition of linearity of the scale for intermediate values of the measured value is most feasible. If necessary, an ideal class object can be formed for which the linearity condition of the scale is absolutely feasible. For complex measurement of object states, a certain value is selected, for example, x , which is a quantitative measure and is uniquely related to the measured complex index of the scale θ . A relationship is established between the values of these values. For non – stationary arrays of statistical temporal data, time can be used as the value x , for stationary arrays, it can be the length of the line connecting the reference points. In both cases, the value x can be set as a statistical or geometric probability of the position of a point in a multidimensional space. There are many other ways to establish a correspondence between the values x and θ , the use of which is determined by the specific application.

Let's create a measuring empirical scale θ based on the state variables that characterize the real economy sector of the Russian regions, which are taken as:

- the volume of goods produced in-house, works and services performed in-house;
- extraction of minerals z_1 ;
- manufacturing industries z_2 ;
- production and distribution of energy, gas and water z_3 ;
- agricultural product z_4 ;
- scope of work in construction z_5 ;
- volume of paid services to the population z_6 ;
- retail trade turnover z_7 .

Dimension of all the listed values – million rubles/thousand people (thousand rubles/person).

We will use the two-point method to build a linear scale. for this purpose, we will select a reference object and several reference States of this object. As the first reference state of the measuring scale (reference point), we will take the state of the Belgorod region in 2005, and as the second reference state (reference point M'_0) – its state in 2018. Other reference points on the scale will be determined by the object States for several years of statistical observations in the period from 2005 to 2018. For this region, as the test showed, the condition of linearity of the scale for intermediate values of the measured value (data in the range of 2005÷2018) is fulfilled with high accuracy.

In this case, when analyzing data, a value θ measured in degrees of this value is taken as a complex index. The measurement scale was formed by establishing a linear relationship between the index θ and specific indicators of the development $z_1 \div z_7$. The values θ of the value in the time interval 2005–2018 depended linearly on time: 2005 – 0 G, 2006 – 10 G and others until 2018 – 130 G. Thus, the scale

in the time interval 2005–2015 was divided into 100 equal divisions. The change in one division was taken as the unit of measurement of the scale (1 G), and each year corresponded to 10 G.

Data processing allowed us to establish a functional relationship for building the scale (fig. 1):

$$\theta = -27.754 + \Theta$$

$$\Theta = 0.101z_1 + 0.128z_2 + 0.490z_3 - 0.254z_4 - 0.0212z_5 + 0.417z_6 + 0.470z_7 \quad (1)$$

The maximum error of the scale does not exceed 0.57 G the average 0.38 G. Reference points for two years (2008, 2009) were excluded.

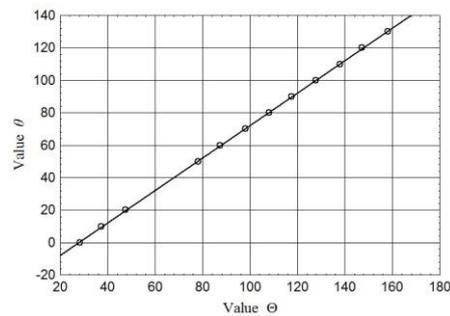


Fig. 1. Compare of empirical scales of values θ and Θ when assessing of the similarity of the states of the Russian regions

By analogy with thermodynamics the value Θ obtained by adding the constant $a_0 = 27.754$ to the value θ (see formula(1)), we call the absolute index and denote it by the letter Θ . Dependence (1) was used to measure the states of Russian regions on a scale Θ that acts as a measure of similarity of states and is related via the constant a_0 to an empirical value θ in the form $\Theta = \theta + 27.754$. At the same time $\theta_0 = -27.754$ receive $\Theta = 0$ this state is called absolute zero, and the values of the state $z_k = 0$ variables correspond to it. Using of the absolute index Θ for measurements is determined by its positive values, as opposed to the value θ

We establish the relationship between the absolute value Θ and the function of the measure of relative changes for the state space of the form:

$$T = \frac{z_1 z_2 \dots z_n}{z_{1_0} z_{2_0} \dots z_{n_0}} \quad (2)$$

Processing all data for 80 regions of Russia over 14 years allowed us to get the following:

$$\ln T = -25.550 + 6.434 \ln \Theta \quad (3)$$

The correlation coefficient of dependence (3) was 0.91, the results of data processing are shown in figure 2.

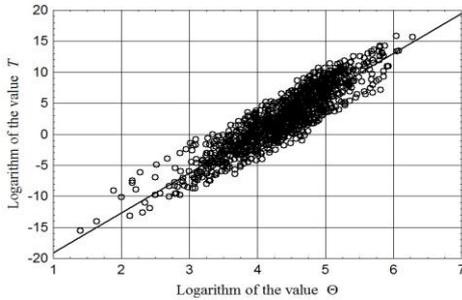


Fig. 2. Compare of empirical scales of values θ and Θ when assessing of the similarity of the states of the Russian regions Equation of the relationship between the values T and Θ to assess the similarity of the states of the Russian regions (the entire object class was processed, time range 2005–2018 years)

As can be seen from the figure, the time dependence of equation (3) in the range of 2005–2018 is weak, despite the fact that the change in state variables over time is very significant. This indicates that by introducing corrective corrections for each instance of the class, state equations that characterize the collective behavior of objects can be obtained with high accuracy.

As a second example of building a phenomenological model in a certain aspect of country development, we will consider the processes of land use in countries of the world in accordance with the data [13]. Let's create an empirical scale based on the state variables that characterize these processes:

- natural land area z_1 , km²;
- area of mosaic (managed) land z_2 , km²;
- area of cultivated land z_3 , km²;
- marginal land area z_4 , km².

Choose a reference object and several reference States of this object. As the first reference state of the empirical scale (reference point M_0), we will take the state of Austria in 1995, and as the second reference state (reference point M'_0) – its state in 2015. Other reference points on the scale will be determined by the object States for different years of statistical observations in the period from 1995 to 2015.

In this case, when analyzing data, a complex index θ measured in degrees of this value is taken as an empirical measure. The measurement scale was formed by establishing a linear relationship between the index θ and the variables $z_1 \div z_4$. The values of the value θ in the time interval 1995–2015 depended linearly on time: 1995 – 0 G, 2000 – 25 G and so on until 2015 – 100 G. Thus, the scale in the time interval 1995–2015 was divided into 100 equal divisions. The change in one division was taken as the unit of measurement of the scale (1 G), and each year corresponded to 5 G.

Data processing allowed us to establish a phenomenological relationship for constructing the scale:

$$\theta = -7680.52 + \Theta;$$

$$\Theta = 0.090 z_1 - 0.002 z_2 + 0.080 z_3 + 0.470 z_4 \quad (4)$$

As well as, the index Θ obtained by adding the constant $a_0 = 7680.52$ to the value of the value θ is called the absolute index and will be denoted by a letter Θ . Dependence (4) is used to measure the state of countries in the world according to accepted land use indicators on a scale of absolute value Θ , which is positive.

Let's establish the relationship between the absolute index and the function of the measure of relative changes of the form (2). processing all data for 250 countries of the world over 20 years allowed us to obtain the following equation:

$$\ln T = -35.391 + 3.944 \ln \Theta \quad (5)$$

The correlation coefficient of dependence (5) was 0.99 the results of data processing are shown in figure 3.

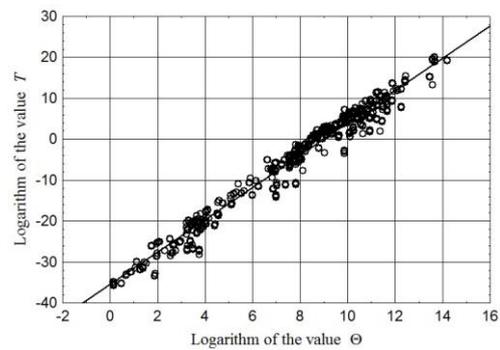


Fig. 3. Equation of the relationship between the values T and Θ for assessing the similarity of the states of the world's countries in terms of land use (the entire class of objects was processed, the time range 1995–2015)

As can be seen from the figure, the time dependence of equation (5) in the range of 1995–2015 is poorly expressed, so for each country the corresponding equations of States can be obtained in the form of phenomenological relations with very high accuracy.

A number of other examples of constructing phenomenological relations to describe the collective behavior of objects: cities, regions, and countries are given in the works of the authors [10–12, 14].

By analogy with the logical approach adopted in thermodynamics, equations of States of the form (3) and (5) allow us to establish a relationship between the values of state variables and the values of the absolute indices of the state space of objects. It is known that such relations are the basis for applying the theory and mathematical apparatus used in creating system-phenomenological descriptions of objects.

III. CONCLUSION

Thus, the examples show the possibility of constructing phenomenological models for cities, regions, and countries that are structural elements of the general model of the world economy. Linking these components into a single whole, taking into account existing connections and relationships, will allow us to develop an object model of the world economy. This scientific direction in modeling belongs to the relevant sections of econophysics and sociophysics and allows us to formulate a fundamentally new approach to describing

and predicting the development of territorial entities. The proposed approach will make it possible to develop algorithms for processing, analyzing and describing statistical data and create methods and information and analytical support for open collective access, allowing experts and analysts to develop phenomenological models of countries, regions and the world economy as a whole.

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