“Econometric analysis of the structure and sustainability of Ukraine socio-economic system in the context of the economic systems theory”

AUTHORS	Victoriia Dergachova https://orcid.org/0000-0003-0317-8675 Maryna Kravchenko https://orcid.org/0000-0001-5405-0159 Alexander Zgurovsky

ARTICLE INFO	Victoriia Dergachova, Maryna Kravchenko and Alexander Zgurovsky (2017). Econometric analysis of the structure and sustainability of Ukraine socio-economic system in the context of the economic systems theory. *Problems and Perspectives in Management*, *15*(4), 86-99. doi:10.21511/ppm.15(4).2017.08
DOI	http://dx.doi.org/10.21511/ppm.15(4).2017.08
RELEASED ON	Wednesday, 20 December 2017
RECEIVED ON	Sunday, 01 October 2017
ACCEPTED ON	Tuesday, 05 December 2017

LICENSE	This work is licensed under a Creative Commons Attribution 4.0 International License

JOURNAL	"Problems and Perspectives in Management"
ISSN PRINT	1727-7051
ISSN ONLINE	1810-5467
PUBLISHER	LLC “Consulting Publishing Company “Business Perspectives”
FOUNDER	LLC “Consulting Publishing Company “Business Perspectives”

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
37	4	3

© The author(s) 2026. This publication is an open access article.

BUSINESS PERSPECTIVES

LLC "CPC "Business Perspectives"
Hryhorii Skovoroda lane, 10, Sumy, 40022, Ukraine

www.businessperspectives.org

Victoriia Dergachova (Ukraine), **Maryna Kravchenko** (Ukraine), **Alexander Zgurovsky** (Ukraine)

ECONOMETRIC ANALYSIS OF THE STRUCTURE AND SUSTAINABILITY OF UKRAINE SOCIO-ECONOMIC SYSTEM IN THE CONTEXT OF THE ECONOMIC SYSTEMS THEORY

Abstract

The article is devoted to the development of a conceptually new systemic structural approach to the study of sustainability of economic systems. The problem of ensuring sustainability of economic entities remains unsolved, largely due to the lack of the necessary methodology. In the article, the approach is shaped by new economic systems theory, which implies the division of all economic systems into types depending on their spatiotemporal localization. Applied research of socio-economic system of Ukraine in its context is implemented by econometric modeling using data mining techniques and by calculating the economic sustainability index using the author's techniques. The indicators, announced by the State Statistics Service of Ukraine, as well as the ranking and indexing results, presented by leading international organizations, are used as the parameters. Alternative hypothesis about preconditioning of economic sustainability of the macro-level system by the structural balance of its four subsystems with different spatial and temporal localization is confirmed. The results of modeling have shown a number of interesting, previously not formalized, patterns of the country's development and have allowed to better understand the forming mechanism of its sustainability in different periods during 2000–2015. Both the methodology itself and the empirical results obtained on its basis open up a wide variety of perspectives of micro and macroeconomic analysis.

Keywords socio-economic system of Ukraine, economic sustainability, structural proportions, system economic theory

JEL Classification B59, C12, C82, O11

Received on: 1st of October, 2017
Accepted on: 5th of December, 2017

© Victoriia Dergachova, Maryna Kravchenko, Alexander Zgurovsky, 2017

Victoriia Dergachova, Doctor of Economics, Professor, Head of Management Chair, Management and Marketing Department, National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Ukraine.

Maryna Kravchenko, Ph.D. of Economics, Associate Professor, Management Chair, Management and Marketing Department, National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Ukraine.

Alexander Zgurovsky, Ph.D. of Economics, Associate Professor, International Economics Chair, Management and Marketing Department, National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Ukraine.

This is an Open Access article, distributed under the terms of the Creative Commons Attribution 4.0 International license, which permits unrestricted re-use, distribution, and reproduction in any medium, provided the original work is properly cited.

INTRODUCTION

The biggest challenges for business entities of macro, meso and micro levels are the speed of transformations of the environment and their ability to react to them, which actualizes the problems of economic sustainability and sustainable social and economic development. However, the problems remain unsolved either theoretically or methodologically, or in practice. It is partly due to the complexity of the integration of theoretical and empirical results, and due to fragmentariness of applied methodology. Modernization of economic methodology is possible through its integration with sciences, which study complex objects as dynamic systems. In this way, the system economic theory (SET) emerged and started claiming the role of a new modern paradigm of economic research. However, the provisions of the theory are unverified and require clarification.

The assumption that application of the provisions of SET will allow us to form a systematic understanding of the phenomenon of economic sustainability and will contribute to solving the applied problem of its ensuring has led to the choice of our research direction. In this article, a conceptually new systemic structural approach to the study of sustainability of economic systems, which is formed in the context of SET, is developed.

1. LITERATURE REVIEW

The problems of economic sustainability and sustainable social and economic development have become one of the most researchable among the domestic scientists (see, for example, Ishchenko, 2017; Frolov, 2016; Voitko, 2017). Understanding the decisive role of innovations in ensuring the effectiveness of economic mechanisms for the formation of sustainability, the economists recognize that one of the reasons for the gaps in the spectrum of scientific research is the lack of theoretical and methodological paradigm that would enable them to be included in the structure of economic systems on the general system-building principles (Yurynets, 2016). The necessity of such inclusion was emphasized by the classics of modern theory of innovations such as Drucker, Kondratiev, Lvov.

The necessity of updating the theoretical and methodological paradigm of economic research was emphasized by Coase, Kleiner (2007, 2009), Kornai (1998, 2016), Libman (2007), and others.

System economic theory started becoming an independent economic paradigm in the works of Kornai. According to him, the angle of consideration of economic systems should be changed from the traditional endogenous to exogenous (Kornai, 1998). A similar approach was developed in the work of Pryor (2008).

In present form, the theory is formed largely in the works of the group of researchers from Central Economics and Mathematics Institute of the Russian Academy of Sciences (CEMI RAS) led by Kleiner. In various sources, the theory was called "the resource theory of the systematic organization of the economy" (Kleiner, 2011(a)), "the new theory of economic systems"(Kleiner, 2009), "the neosystem theory" (Kleiner, 2013), "system theory of economic equilibrium" (Rybachuk, 2014), "system economic theory" (Kleiner, 2011(b)), and we will follow the last name.

In theory, based on the assumptions that the system is part of the environment relatively stable in space and time, fundamental characteristics of all economic systems, regardless of their level, the presence of boundaries in space and time (the observer's perspective) is recognized. Space and time are considered to be the main forms of existence of economic systems and the measurement of economic phenomena, including sustainability (Kleiner, 2007–2015; Rybachuk, 2014).

The theory has a high explanatory force, assimilates the fundamental provisions of other basic economic theories, and gives an opportunity to develop their methodological shortcomings, including the inclusion of innovations in system structure. In support of the possibility of designing such a general system economic theory, it is expedient to recall the words of Samuelson who noted that the presence of analogy in the main provisions of different theories means that there should be a more general theory that unites the private and unifies them relative to common properties (Samuelson, 1960). Actually, this happens in the context of SET, which was the basis of our study of the economic sustainability of systems of micro and macro levels (Kravchenko, 2015).

2. THEORETICAL FRAMEWORK AND HYPOTHESIS

The main theoretical and methodological provisions for the formation of economic sustainability were summarized as follows (Kravchenko, 2015):

1. The complete group consists of four types of economic systems with different spatiotemporal localization: a) the systems of the project type which are localized both in space and time; b) the systems of process type which are localized in time, but not in space; c) the sys-

Table 1. Distribution of the elements of country's socio-economic system by the subsystems and their systemic features

Temporal localization	Spatial localization	
	Defined	**Undefined**
Undefined	The subsystem of the subject-object type (So) Population As the subject and object of economic activity, which includes both economically active and inactive categories	The subsystem of the environment type (En) State As the form of organization; which is determined by the state social and economic arrangement and by the set of formal institutes and regulations
Defined	The subsystem of the project type (Pj) Business As a set of different organizational and legal forms of economic entrepreneurial activity, which is realized in order to profit	The subsystem of the Process type (Pc) Economy As a sphere of economic processes realization of production, consumption, distribution, exchange, including the results of their realization

Note: the proposed location of the systems corresponds to the structure of their relationships in tetrad: systems having one common systemic feature interact directly with each other; systems whose features are opposite do not interact directly.

tems of subject-object type which are localized in space, but not in time; d) the systems of the environment type which are not localized neither in space nor in time. A set of elements or subsystems of a certain type is considered as the economic system of this type (Kleiner, 2009).

2. None of the economic systems of one particular type is capable of sustainable autonomous functioning in the spatiotemporal continuum. To ensure their normal functioning, systems formulate the symbiotic pairs, which lock into tetrad (from the Greek τετράδα – group of four) (Kleiner, 2009).

3. The tetrad is a minimal economic system capable of an autonomous functioning for a certain period, since its subsystems, having formed structure with unchanged nature of interconnections provide:

- realizing of the full cycle of economic functions – production, consumption, distribution; exchange;
- mutual supporting of subsystems within the tetrad by the resources;
- ensuring the sustainability of the system through maintaining a balance of variability and stability both in space and time;
- mutual substituting between elements of one type and a partial substituting between elements of neighboring types.

In order for the system to be equally stable in space and time, such properties should be expressed equally, which is possible in the case of a structural balance of subsystems among themselves.

4. Such tetrad can be allocated to each economic system at any level with sustainable structure in the long run. Table 1 shows the distribution of the elements of the subsystems of the macro level.

5. In the short run, during the lifecycles of time-limited subsystems (process and project), the basis of sustainability is the lack of subsystems dysfunctions and the inevitability of relation between them. In order to ensure the stable functioning of the tetrad in the long run, it is necessary to update Processes and Projects to replace those with a complete lifecycle.

6. Interaction of the systems as components of higher-level systems occurs on the same principles as inside the tetrad, resulting in a logical matrix structure, where the number of counteragents of each system is duplicated in each direction, but their set remains unchanged.

The postulates of the theory and the derived methodological provisions have allowed formulating the hypothesis that the economic sustainability of the macro-level system is structurally balanced by its higher-defined subsystems. If so, then assessing the level of economic sustainability can be based on the measurement of structural equilibrium. This hypothesis was the basis of applied research. Previously, a similar hypothesis was put forward

and confirmed at the micro level. If it is confirmed at the macro level, this will also ensure the verification of the fundamental provisions of the SET.

3. METHODS

Of the three main methodological techniques, through which the verification of theoretical positions in economic research is carried out: verbal modeling, mathematical economics and econometrics, we have chosen the last one. It has been proved that econometrics based on the use of inductive statistics methods have far more advantages than others (Kim, 2006; Adams, 2012).

In our case, the econometric approach should be based on the intelligent processing of a large array of diverse data on the functioning of systems to identify non-obvious patterns of their functioning. The most commonly used term to name such data processing is data mining (Cios, 2007; Zaki, 2014). Knowledge here is usually understood to mean mathematical relationships between the parameters of the functioning of economic systems.

3.1. Data

A specific set of parameters for simulation of elements of socio-economic subsystems of Ukraine, was determined based on the composition of macroeconomic indicators obtained from:

- statistical information published by the State Statistics Service of Ukraine (SSSU) (SSSU, 2016);
- data of ranking and indexing published by international organizations – The World Bank (WB) (World Bank, 2016), Central Intelligence Agency (CIA) (CIA, 2016), Organization for Economic Cooperation and Development (OECD) (OECD, 2016), World Economic Forum (WEF) (WEF, 2016), United Nations Development Program (UNDP) (UNDP, 2016), European Business Association (EBA) (EBA, 2016), The Institute of Management Development (IMD) (IMD, 2016), Transparency International (TI) (TI, 2016), Yale Center for Environmental Law and Policy (YCELP) (YCELP, 2016), Social Progress Imperative (SPI) (SPI, 2016), The Heritage Foundation (HF) (Heritage, 2016), Bertelsmann Foundation (BF) (Bertelsmann, 2016).

For simulation of each of the subsystems ten parameters were selected. All parameters are widely used for macroeconomic analysis, we have only made their selection and grouping by subsystems, (Table 2). The observation period was determined on the basis of data availability and covered the time interval of 2000–2015.

3.2. Techniques of data analysis

A methodology similar to one, previously approbated at the micro level, at the microeconomic level was used, but somewhat corrected (Kravchenko, 2016(a); 2016(b)). It provides an index evaluation of the functioning of each of the subsystems, calculation of the level of their mutual balances and on their basis with the use of analytical geometry methods – computing the index of economic sustainability of the system. To verify the validity of the methodology and to confirm the hypothesis, the degree of correlation of the obtained index of sustainability with the value of GDP of Ukraine in dollar terms, as indicator that are traditionally used in the economic practice for the sustainability analysis, was determined.

An index evaluation of the functioning of each of the subsystems was determined on the basis of the normed values of the parameters by the formula of arithmetic mean:

$$I_{So} = \frac{1}{10}\sum_{n=1}^{10} So_n^{norm}, \quad (1)$$

$$I_{En} = \frac{1}{10}\sum_{n=1}^{10} E_n^{norm}, \quad (2)$$

$$I_{Pc} = \frac{1}{10}\sum_{n=1}^{10} \Pi_n^{norm}, \quad (3)$$

$$I_{Pj} = \frac{1}{10}\sum_{n=1}^{10} P_n^{norm}, \quad (4)$$

where So_n^{norm}, E_n^{norm}, Π_n^{norm}, P_n^{norm} – normalized values of the n-th parameter of functioning of the subsystem.

Table 2. Characteristics of functioning parameters of the subsystems of socio-economic system of Ukraine

Subsystem type	Index (parameter)	Organization that defines the index	Code	Desired dynamics
Subject-object (So)	Gini index	WB	So_1	Decreasing
	Human development index	UNDP	So_2	Increasing
	Social progress index	SPI	So_3	Increasing
	Unemployment rate	SSSU	So_4	Increasing
	Economically active population rate	SSSU	So_5	Increasing
	Labor force index	WB	So_6	Increasing
	Education index	UNDP	So_7	Increasing
	Global gender gap index	WEF	So_8	Increasing
	*Demographic load*index	SSSU	So_9	Decreasing
	Load per vacancy ratio	SSSU	So_{10}	Decreasing
Environment (En)	Index of economic freedom	HF	E_1	Increasing
	Voice and accountability	WB	E_2	Increasing
	Political stability and absence of violence	WB	E_3	Increasing
	Government effectiveness	WB	E_4	Increasing
	Regulatory quality	WB	E_5	Increasing
	Rule of law	WB	E_6	Increasing
	Control of corruption	WB	E_7	Increasing
	Corruption perceptions index	TI	E_8	Increasing
	Environmental performance index	YCELP	E_9	Increasing
	Bertelsmann transformation index	BF	E_{10}	Increasing
Process (Pc)	Global competitiveness index	WEF	Π_1	Increasing
	Exports of goods and services index	SSSU	Π_2	Increasing
	Industrial production index	SSSU	Π_3	Increasing
	Global enabling trade index	WEF	Π_4	Increasing
	Capital assets depreciation rate	SSSU	Π_5	Decreasing
	Knowledge economy index	WB	Π_6	Increasing
	External debt stocks	WB	Π_7	Decreasing
	Inflation rate	SSSU	Π_8	Decreasing
	GDP per capita index, PPP	CIA, WB	Π_9	Increasing
	GDP growth, current USD	CIA, WB	Π_{10}	Increasing

Table 2 (cont). Characteristics of functioning parameters of the subsystems of socio-economic system of Ukraine

Subsystem type	Index (parameter)	Organization that defines the index	Code	Desired dynamics
Project (Pj)	Investment attractiveness index	EBA	P_1	Increasing
	Doing business index	WB	P_2	Increasing
	Business confidence index	OECD	P_3	Increasing
	Foreign direct investment equity index	SSSU	P_4	Increasing
	Number of business entities index	SSSU	P_5	Increasing
	Business extent of disclosure index	WB	P_6	Increasing
	New businesses density	WB	P_7	Increasing
	Level of enterprises profitability	SSSU	P_8	Increasing
	Number of employed in enterprises index	SSSU	P_9	Increasing
	Share of innovative enterprises	SSSU	P_{10}	Increasing

To evaluate the mutual balance (bal) of the subsystems, we introduce a set of indicators: *D = {a = bal(So-En), bal(En-Pc), bal(Pc-Pj), bal(Pj-So)}.*

The values of the indicators are determined on the basis of the modification of the method proposed by Rybachuk (2014). It involves evaluating the balance using the techniques of analytical geometry by displaying the proportions of subsystems in two-dimensional space in Cartesian coordinates, as shown in Figure 1.

The coordinates X_A, Y_B, X_C, Y_D of the points $A(X_A;\ 1)$, $B(1;\ Y_B)$, $C(X_c;\ 0)$, $D(0;\ Y_D)$ are calculated by the formules:

$$X_A = \frac{I_{So}}{I_{En} + I_{So}}, \tag{5}$$

$$Y_B = \frac{I_{Pc}}{I_{En} + I_{Pc}}, \tag{6}$$

$$X_C = \frac{I_{Pj}}{I_{Pc} + I_{Pj}}, \tag{7}$$

$$Y_D = \frac{I_{Pj}}{I_{Pj} + I_{So}}, \tag{8}$$

where $I_{So},\ I_{En},\ I_{Pc},\ I_{Pj} > 0$.

The coordinates of the P_{int} point are determined analytically from equation of a straight line passing through two points. The indicators of mutual balance of the subsystems a, b, c and d are defined as the lengths of the segments $[P_{\text{int}},\ A]$, $[P_{\text{int}},\ B]$, $[P_{\text{int}},\ C]$ and $[P_{\text{int}},\ D]$. Given that $X_B = Y_A = 1$ and $X_D = Y_C = 0$, the formula can be represented as:

$$a = \overline{|P_{\text{int}};\ A|} = \sqrt{(X_O - X_A)^2 + (Y_O - 1)^2}, \tag{9}$$

$$b = \overline{|P_{\text{int}};\ B|} = \sqrt{(X_O - 1)^2 + (Y_O - Y_B)^2}, \tag{10}$$

$$c = \overline{|P_{\text{int}};\ C|} = \sqrt{(X_O - X_C)^2 + Y_O{}^2}, \tag{11}$$

$$d = \overline{|P_{\text{int}};\ D|} = \sqrt{(X_O)^2 + (Y_O - Y_D)^2}. \tag{12}$$

When structure of the system is completely balanced, $X_A = Y_B = X_C = Y_D = 0.5$, points A, B, C, D and P_{int} have coordinates $A(0.5;\ 1)$, $B(1;\ 0.5)$, $C(0.5;\ 0)$, $D(0;\ 0.5)$, $P_{\text{int}}(0.5;\ 0.5)$, and the length of the segments $a = b = c = d = 0.5$ (see Figure 1).

The next task was to deduce a function that would allow to determine the index of economic sustain-

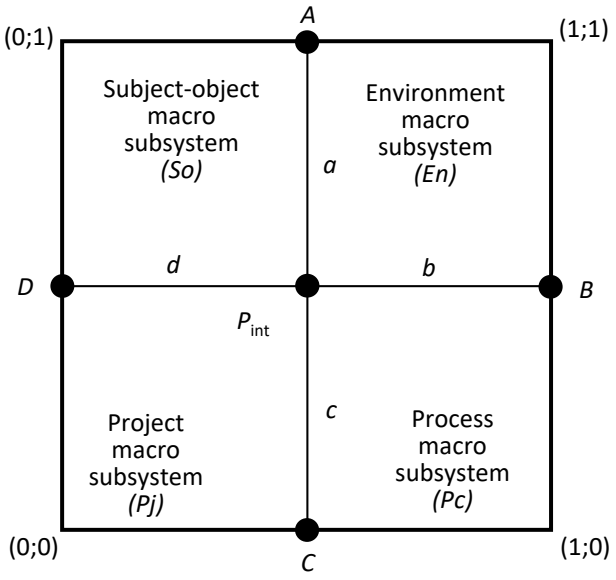


Figure 1. Graphical interpretation of the ideal configuration of a completely balanced system structure

ability of the system based on the values of the indicators a, b, c, d. After analyzing various types of functions, it is determined that the function of Euclidean metric in a four-dimensional parametric a, b, c, d space is satisfying all cona ditions. The values of a, b, c and d for each case can be considered as the coordinates of the system in this space. The point $N_{\text{int}}(a,\ b,\ c,\ d)$ is indicate the position of the system in terms of its balance. The point $N_0(0.5;\ 0.5;\ 0.5;\ 0.5)$ is indicate the ideal position and corresponds to interpretation on Figure 1. The distance between the points N_{int} and $N_0 r(a;\ b;\ c;\ d)$ by the hypothesis corresponds to the level of economic unsustainability of the system:

$$r(a,\ b,\ c,\ d) = \\ = \sqrt{(a-0.5)^2 + (b-0.5)^2 + (c-0.5)^2 + (d-0.5)^2}. \quad (13)$$

To determine the level of economic sustainability of the system, it is expedient to use the opposite value – the difference between the maximum distance, corresponding to the absolute unbalance, and $r(a,\ b,\ c,\ d)$. By graphical interpretation of the method, the maximum distance between the points N_{int} and N_0 is $\sqrt{2.1716} = 1.4736$.

To maintain the dimensionality of the system unbalance and balance indicators in the range $[0;\ 1]$, the normalization of their numerical values is carried out. The normalized indicator of the system balance is used as an index of economic sustainability of the system (E):

$$E = f_{norm}(a,\ b,\ c,\ d) = \\ = \frac{r(a,\ b,\ c,\ d)_{\max} - r(a,\ b,\ c,\ d)}{r(a,\ b,\ c,\ d)_{\max}} = 1 - \\ - \sqrt{\frac{(a-0.5)^2 + (b-0.5)^2 + (c-0.5) + (d-0.5)^2}{2.1716}}. \quad (14)$$

After calculating the index, we consider it expedient to determine the degree of its coherence with the value of the GDP of Ukraine on the basis of a correlation analysis.

3.3. Analysis

The index estimations of the functioning of socio-economic subsystems have demonstrated different rates of growth (Figure 2).

The index estimation of the subject-object subsysu tem I_{So}, reflecting the characteristics of the population of Ukraine as a subject of economic relations, had the greatest growth rate – its value increased from 0.14 in 2000 to 0.61 in 2015, i.e., by 4.47 times.

Note: * here and below on the chart area the crisis periods of the general economic dynamic of Ukraine, determined based on GDP growth rate, are highlighted by grey color.

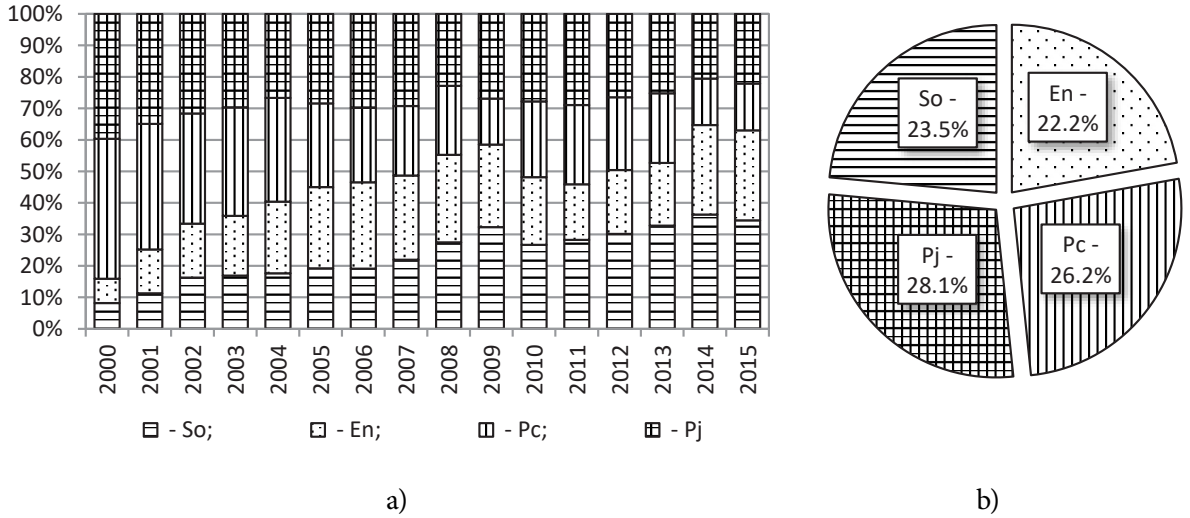
Figure 2. Graphical representation of the index estimations of the subsystems of socio-economic system of Ukraine for the period of 2000–2015 years*

The index estimation of the environment subsystem I_{En}, reflecting the characteristics and level of state regulation, had the second growth rate – its value increased from 0.13 in 2000 to 0.51 in 2015, i.e., by 3.93 times.

The index estimation of the Process subsystem I_{Pc}, reflecting the characteristics of the sphere of realization of economic processes, had the largest decline rate – its value decreased from 0.74 in 2000 to 0.26 in 2015, i.e., by 2.82 times.

And the index estimation of the project subsystem I_{Pj}, reflecting the characteristics of the business sector, had the second decline rate – its value decreased from 0.66 in 2000 to 0.39 in 2015, i.e., by 1.69 times.

Such tendencies caused various proportions of the subsystems in the structure of socio-economic system of the country in different periods as shown in Figure 3.



a) b)

Figure 3. Graphical representation of the subsystems proportions in general structure of the socio-economic system of the country: a) in dynamics by years; b) on average for the analyzed period

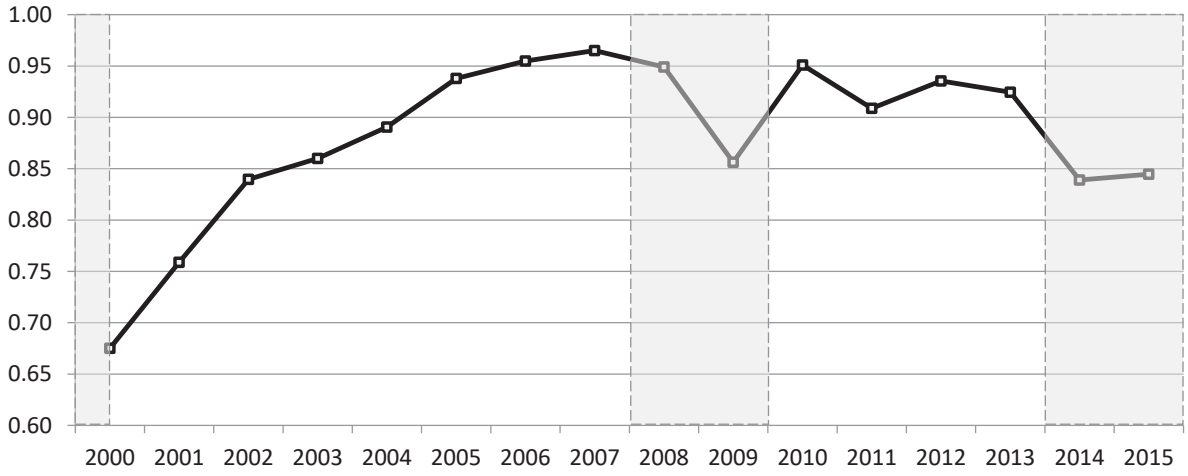


Figure 4. Graphical representation of the index of economic sustainability of the country's socio-economic system fo the period 2000–2015 years

In 37.5% of cases the subject-object subsystem was the most pronounced in the structure in 2008–2009 and in 2012–2015. The process and project subsystems became the next most pronounced ones: the dominance of each of them was observed in 31.3% of cases.

The index estimations were used to calculate the index of economic sustainability of Ukrainian socio-economic system (Figure 4).

The value of the index of economic sustainability fluctuated in the range of 0.68-0.97, while for the period, it increased by 12.6%.

From the graphs shown in Figure 2 and Figure 4, it is clearly evident that during the crisis periods there was a sharp decrease in both the index of economic sustainability and the index estimates of all subsystems.

In order to verify the validity of the methodology and to test the hypothesis, a correlation analysis of the index E values with the values of the nominal GDP of Ukraine was conducted. It revealed the existence of a direct close linear correlation with the probability of an error-free forecast higher than 99.9% between values (Pearson correlation coefficient was 0.703).

We believe that the revealed correlations allow to confirm the proposed alternative hypothesis that the level of economic sustainability of the systems is determined by the level of their structural balance. In addition, we can conclude on the validity of the methodology used.

4. RESULTS

Our research did not reveal a strong direct dependence of the index of economic sustainability on the indicators traditionally used to reflect the dynamics of economic development of the country such as the level of innovation, investment and entrepreneurial activity, the volume of industrial production, exports, etc. Instead, a significant dependence on such indicators as the level of human development, education, as well as on indicators reflecting the influence of the state governance was revealed (Table 2). It is concluded that on the one hand, this is a reflection of the irrational deindustrialized structure of Ukrainian socio-economic system, on the other – is a evidence of the country's involvement in the process of transformation into the knowledge economy.

The applied methodology allowed to identify the following structural patterns of development of the country, which determine the mechanism of its sustainability formation during the period 2000–2005:

4.1. Increase in the share of the subject–object subsystem, which reflects the characteristics of the population of Ukraine as a participant in socio-economic relations.

Its share has increased more than fourfold, from 8.2% to 34.5%. In both crisis years, in 2008 and in 2014, this subsystem became the strongest, dominant in the structure of the socio-economic system, most of its indicators (6 out of 10), reflecting the level of human and social development, education, society's homogeneity, demographic load and gender gap, demonstrated the desired dynamics. The exception were the indicators reflecting the economic characteristics of the population – unemployment, level of economic activity, labor force index, load per vacancy ratio, which seems logical. The correlation between the index of economic sustainability E and ISo was also strong (Pearson correlation coefficient was 0.703). In our view, this, as well as the upward trend of ISo graph and an increase in the share of So subsystem in the overall structure of system, is a clear econometric confirmation of the strengthening of the role of the population in ensuring the sustainability of the socio-economic system. The revealed tendency shows that human capital determines the development of the socio-economic system of the country, causes growth, and does not allow catastrophic reduction of macroeconomic indicators in crisis periods.

Table 3. Distribution of the model parameters by their correlation degree with the index of economic sustainability of Ukrainian socio-economic system

Level and direction of correlation with index E	The range of the correlation coefficient	Distribution of the indexes (model parameters) by the subsystems			
		The subsystem of the subject-object type (So)	The subsystem of the environment type (En)	The subsystem of the process type (Pc)	The subsystems of the project type (Pj)
Strong direct correlation	(0.7; 0.9]	Human development index	Corruption perceptions index	–	–
		Education index	Control of corruption		
		Unemployment rate	Rule of law		
		Load per vacancy ratio	Bertelsmann transformation index		
Medium direct correlation	(0.5; 0.7]	Labor force index	Regulatory quality	–	–
		*Demographic load*index	Voice and accountability		
Weak direct correlation	(0.2; 0.5]	Economically active population rate	Index of economic freedom	GDP growth, current USD	New businesses density
				Inflation rate	
		Gini index	Political stability and absence of violence	Exports of goods and services index	Foreign direct investment equity index
				External debt stocks	
Very weak direct correlation	[0.0; 0.2]	Global gender gap index	Government effectiveness	GDP per capita index, PPP	Doing business index
					Level of enterprises profitability
					Business confidence index
					Number of employed in enterprises index
Very weak inverse correlation	[–0.2; 0.0)	–	–	Industrial production index	Number of business entities index
Weak inverse correlation	[–0.5; –0.2)	Social progress index	Environmental performance index	Capital assets depreciation rate	Business extent of disclosure index
				Knowledge economy index	Investment attractiveness index
Medium-inverse correlation	[–0.7; –0.5)	–	–	Global competitiveness index	Share of innovative enterprises
				Global enabling trade index	

4.2. Increase in the share of the environment subsystem, which reflects the characteristics and level of state regulation of the socio-economic system

Its share has increased more than three and a half times, from 7.7% to 28.6%. Despite the fact that the index estimation *IEn* was the highest in the period 2005–2008 and most of its indicators (8 out of 10) reached their maximum at that time, the share of the subsystem in the overall structure increased gradually throughout the period and reached its maximum in 2015. During the crisis periods, this subsystem had the second highest share in the overall structure of the socio-economic system. The correlation between the index *E* and *IEn* was strong (Pearson correlation coefficient was 0.85). In our view, the parabolic trend of *IEn* graph with the maximum of 2006, and an upward-increase in the share of En in the overall structure are econometric confirmations of the decline in the quality of state regulation of economic processes in the country, but enhancing its role in ensuring sustainability. In fact, the second trend is evidence of an decrease of the socio-economic system capacity for self-organization and self-sustainability. The development of the system is provided at the expense of political influence, which, however, is not enough efficient.

4.3. Decrease in the share of the process subsystem, which reflects the characteristics of the sphere of implementation of the main economic processes

Its share has decreased almost threefold, from 44.5% to 14.9%. In both crisis years, in 2008 and in 2014, this subsystem became the weakest, peripheral in the overall structure, most of its indicators (in 2008 – 6 out of 10, in 2014 – all) reduced its value. This is generally logical and can be explained. The correlation of the index E with I_{Pc} was very weak and inverse (Pearson correlation coefficient was –0.15). We believe this is an indication that ensure the sustainability of socio-economic system of the country was carried out not because of, but in spite of economic development and the development itself had destructive character.

4.4. Decrease in the share of the project subsystem, which reflects the characteristics of the of business initiatives scopes

Its share decreased relatively less, from 39.6% to 22.1%. Despite the fact that the index estimation I_{Pj} was the highest in the period 2005–2007 and most of its indicators (7 out of 10) reached their maximum at that time, the share of the subsystem in the overall structure gradually decreased throughout the period and reached its minimum in 2015. During the crisis periods, this subsystem demonstrated second peripheral level in the overall structure. Its indicators that had a strong correlation with the index of economic sustainability were not found. The correlation between the index of economic sustainability E and I_{Pj} also was very weak (Pearson correlation coefficient was 0.22). The parabolic trend of IPj graph with the maximum in 2006, and a decrease in Pj share in the structure of the socio-economic system confirmed the decline in investment and entrepreneurial activity and weakening their impact on ensuring the sustainability of the country. It also testified irrational structure of the investment and business initiatives, including innovative projects.

4.5. The four tendencies outlined above – an increase in the shares of subject-object and environment subsystems and a decrease in the shares of the project and process subsystems – are also the reflections of the implementation processes of the a priori systemic properties of subsystems in the time interval of 2000–2015)

Kleiner (2013) notes that the development of subject-object and environment systems mainly is evolutionary (due to their unlocalization in time) and the development of process and project sys-

tems is a cyclic (due to their localization in time –auth.). The revealed patterns of an increase in the shares of So and En subsystems reflect the tendencies of their evolutionary development, and a decrease in the shares of the Pc and Pj subsystems reflect the tendencies of decay of industrial and economic systems formed by the previous industrial structure, the final exhaustion of their potentials, as a consequence – the completion of their lifecycles.

4.6. In crisis periods 2008–2009 and 2014–2015 the proportionally similar structure of socio-economic system was formed

Against the background of a sharp decrease in the share of the process subsystem, an increase in the share of the subject-object subsystem was observed, which resulted in the following relation: $I_{So} > I_{En} > I_{Pj} > I_{Pc}$. It should be noted that in pre-crisis periods the structure of the economic system was different. This allows to assume with a certain degree of probability that the mechanism of avoiding the crisis within the system is similar and structurally identical.

4.7. The total shares of two pairs of directly interacting subsystems – the subject-object and the project, on the one hand, and the environment and process, on the another, fluctuated in the range of 50 ± 10%

We believe that the revealed structural feature demonstrates the presence of a compensatory mechanism for maintaining spatial sustainability within the socio-economic system (in more detail, the formation mechanism for the spatiotemporal sustainability is described in Voitko (2017). At the same time, the total share of the subject-object and project subsystems gradually increased during the period from the lower to the upper limit, and the total share of the environment and process subsystems decreased.

CONCLUSION

The results of empirical testing of the methodology developed by us have shown that it meets all of the requirements for scientific methods: it is valid, comprehensive, diagnostic, reliable and representative.

The research carried out on its basis has made it possible to identify a number of interesting, previously not formalized and therefore scientifically significant systemic and structural patterns of the development of the national socio-economic system and to better understand the formation mechanism of its economic sustainability in different periods. It has been formally determined that this mechanism varies according to trends of socio-economic development of Ukraine, which may be clearly defined. They are: gradually increasing the impact on sustainability of non-economic components of socio-economic system (political, social and cultural), against reducing the impact of economic components (industrial and commercial); the presence of a compensatory mechanism for maintaining spatial sustainability of the system; its similar structure in crisis periods.

The research has not reveal a strong direct dependence of the level of economic sustainability of the country on the indicators traditionally used to characterize the dynamics of economic development, such as the level of innovation, investment and entrepreneurial activity, the volume of industrial production, exports, etc. Instead, the significant dependence on indicators such as human development, education, and indicators that reflect the state's regulation of social and economic processes has been revealed. On the one hand, this is a reflection of the irrational unbalanced structure of the socio-economic system of Ukraine with the pronounced dominance of socio-cultural and socio-political components and the peripheral of the industrial and economic ones. On the other hand, it is a clear indication that Ukraine is fully involved in the global process of transforming from an industrial-type economy to a

post-industrial and knowledge economy. The determined patterns, in our opinion, open a wide range of directions for further micro and macroeconomic analysis.

ACKNOWLEDGEMENT

This paper has been prepared within applied research project "Development of an online platform analysis and scenario planning of sustainability of Ukrainian regions of in the context of the quality and safety of human life" (number of state registration 0117U002476), supported by the state budget fund.

REFERENCES

1. Adams R., Jeanrenaud S., Bessant J. et al. (2012). Innovating for sustainability: a systematic review of the body of knowledge. *Harvard Business Review*. Retrieved from http://nbs.net/wp-content/uploads/NBS-Executive-Report-Innovation.pdf
2. Bertelsmann Foundation (2016). Retrieved from https://www.bertelsmann-stiftung.de
3. Bobkov, A. N. (2005). General theory of systems and the dialectic of the single and plural. *Philosophy and Society, 4,* 56-72.
4. Central Intelligence Agency (CIA) (2016). Retrieved from https://www.cia.gov/ru
5. Cios K., Pedrycz W., Swiniarski R. et al. (2007). *Data mining. A knowledge discovery approach.* New York, Springer.
6. European Business Association (EBA) (2016). Retrieved from http://www.eba.com.ua
7. Frolov, S., Savytska, O., & Ostapenko, L. (2016). Impact of social and economic development of the region on the international trade by the example of Ukraine. *Public and Municipal Finance, 5*(3), 7-15. Retrieved from https://businessperspectives.org
8. Harm, Ch. (2006). *Theory Building.* Institutional and Organizational Economics Academy. Retrieved from https://www.ioea.eu/presentations/lecturers/28.html
9. Ishchenko, A. (2017). Stimulation of effective ecological and economic interactions in the process of business environment creation. *Environmental Economics,* 8(2), 57-66. Retrieved from https://businessperspectives.org
10. Kim, E., Morse, A., Zingales, L. (2006). What has mattered to economics since 1970? *Journal of Economic Perspectives, 20*(4), 189-202.
11. Kleiner, G. B. (2007). The system paradigm in economic research: a new approach. *Civilization of knowledge: Russian realities: Proceedings of the Eighth Scientific Conference, April 20-21, Moscow.* Retrieved from http://kleiner.ru/wp-content/uploads/2014/12/Sistemnaya-paradigma-v-e%60konomicheskih-issledovaniyah.pdf
12. Kleiner, G. B. (2013). System economics as a platform for the development of modern economic theory. *Problems of economics, 6,* 4-28.
13. Kleiner, G. B. (2009). A new theory of economic systems and its application to economic policy studies. *Russian research center working paper series, 13,* 1-31.
14. Kleiner, G. B. (2011). Resource theory of the system organization of the economy. *Russian Journal of Management, 3*(9), 3-28.
15. Kleiner, G. B. (2011). The system resource of the economy. *Issues of Economics, 1,* 89-100.
16. Kleiner, G. B. (2015). The state – region – industry – enterprise: the framework of system sustainability of the Russian economy, Part 1. *The economy of the region, 2,* 50-58.
17. Kornai, J. (1998). The System Paradigm. *William Davidson Institute Working Papers,* 278 (April).
18. Kravchenko, M. O. (2015). Methodological framework of system analysis of the industrial enterprises economic sustainability. *Technological audit and production reserves, 1/3*(27), 84-89.
19. Kravchenko, M. O. (2016). Structural balance as a basis of the economic sustainability of an enterprise. *World Scientific News, 57,* 300-308.
20. Kravchenko, M. O. (2016). Formation mechanism of economic sustainability of the enterprise: systemic-structural approach. *Sciences of Europe, 6*(1), 45-51.
21. Libman, A. M. (2007). Modern economic theory: the main trends. *Problems of economics, 3,* 36-54.
22. Organization for Economic Cooperation and Development (OECD) (2016). Retrieved from http://www.oecd.org
23. Pryor, F. L. (2008). System as a causal force. *Journal of Economic Behavior & Organization, 67,* 545-550.
24. Rybachuk, M. A. (2014). Analysis and measurement of the proportions of the organization' system structure: the example of the University of Dubna. *Economic science of modern Russia, 3*(66), 130-146.
25. Samuelson, P. A. (1960). *Structure of a minimum equilibrium system.* Essays in economics

and econometrics. Chapel Hill, University of North Carolina press.

26. Social Progress Imperative (SPI) (2016). Retrieved from http://www.socialprogressimperative.org
27. State Statistics Service of Ukraine (2016). Retrieved from http://www.ukrstat.gov.ua
28. The Heritage Foundation (2016). Retrieved from http://www.heritage.org
29. The Institute of Management Development (IMD) (2016). Retrieved from https://www.imd.org
30. The World Bank (2016). Retrieved from http://www.worldbank.org
31. Transparency International (2016). Retrieved from https://www.transparency.org
32. United Nations Development Program (UNDP) (2016). Retrieved from http://www.undp.org
33. Voitko, S. V., & Kravchenko, M. O. (2017). The formation mechanism of economic sustainability of the machine-building enterprises (neo-system approach). *Marketing and Management of Innovations, 4,* 211-221.
34. World Economic Forum (WEF) (2016). Retrieved from https://www.weforum.org
35. Yale Center for Environmental Law and Policy (YCELP) (2016). Retrieved from http://envirocenter.yale.edu
36. Yurynets, Z. (2016). Forecasting model and assessment of the innovative and scientific-technical policy of Ukraine in the sphere of innovative economy formation. *Investment Management and Financial Innovations, 13*(2), 16-23. Retrieved from https://businessperspectives.org
37. Zaki, M., & Meira, W. (2014). *Data mining and analysis: fundamental concepts and algorithms.* New York, Cambridge University Press.