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QUANTITATIVE MEASUREMENT OF THE LEVEL OF ECONOMIC SECURITY OF THE REGIONAL SYSTEM BASED ON THE INSTRUMENT OF THE ORDER AND CHAOS

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In the article the possibility of using the instrument of order and chaos in quantitative measurements of the level of economic security of the regional system was investigated. It has been noted that the existence of conditions for non-linearity of regional development requires a detailed study of methods and approaches to the management of territorial development from a synergistic approach. In the article was proved that in order to measure the economic security of a regional system, threshold values should be introduced. The authors of the article found that on the basis of the proximity of the state of a particular subsystem to the boundary of its stability, that is to the point of bifurcation, it is possible to quantify the level of security of the system. The corridor for the development of the regional socioeconomic system was calculated and it was found that with the strengthening of state interference in the economic complex of the region there is an increase in the orderly system with simultaneous decrease of entropy, which leads to delaying the development of the RSES in the zone of «evolutionary impasse» and makes it impossible to transition to the concept of self-organization and new technological structure. It has been proved that the development of regional economies in time and structure of the national economy of Ukraine is a process strictly regulated by the state, which does not correspond to the main principle of the system – self-development and contradicts the laws of the development of a market economy.

Keywords: regional system, economic security of the region, socio-economic development, region, synergetic approach.

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Introduction

From the position of system approach, the region is a complex spatial socio-economic system; the development of the region is a dynamic, cyclically developing process; the region as a holistic complex socio-economic system is prone to self-development. Ability to self-development is one of the fundamental properties of the system. The transition of the economy to high-tech industries involves the development of new approaches to the management of sustainable development of territories on the basis of self-development of regional socio-economic systems.

Self-development of regional socio-economic systems is a modern paradigm of territorial development, according to which territories should strive for economic growth at the expense of its own resources. A balanced development is a prerequisite for the economic security of the region. Most researchers, under the term «economic security of

the region», believe it is stable, sustainable development, expanded reproduction and protection of national (regional) interests.

Both in foreign and in the national scientific literature considerable attention is paid to the study of economic growth and economic cycles. These problems were studied abroad at different times by K. Zhugliar, D. Kitschin, J. M. Clark, S. Kuznets, V. Leontiev, V. Rostow, A. Toffler, J. Forrester, E. Hansen, R. Harrod, P. Heine, J. Hicks and others. Substantial contribution to the development of methodological foundations of the theory of economic growth and long-wave economic dynamics was made by such Russian scientists as M. Kondrayev, E. Slutsky, M. Tugan-Baranovsky and others. Among the Ukrainian scientists who deal with the problems of nonlinearity of development can be called the following: V. Vitlinsky, V. Heyets, V. Vovk, T. Klebanova, K. Kononova, N. Maksyshko, A. Matviychuk, T. Merkulova, V. Solovyov, V. Stepanov,

O. Chernyak, I. Shkrabak et al. But the existence of conditions for the non-linearity of regional development requires a detailed study of the methods and approaches to the management of territorial development from a synergistic approach.

The purpose of the study is to determine the possibility of using instrument of order and chaos in quantitative measurements of the level of economic security of the regional system.

The main material

The region's economic security is prone to the impact of many external and internal factors that either hinder or contribute to security. Incorrect or untimely regulation of the factor of influence contributes to the change in the state of a regional system from a relatively controlled state into a new, unmanaged one, which is capable of posing a serious threat to economic security. Thus, any factor of influence, which is detected untimely, or it is not manageable, can become overgrown and threatened.

The problems of developing a methodology for security in Ukraine are mainly addressed by the National Institute for Strategic Studies. At the moment, the methodology for calculating the integral estimation of the level of economic security of Ukraine has been developed. This technique includes 9 components of the integral assessment: demographic, energy, food, social, innovation, foreign economic, financial, investment and macroeconomic. The scientists of this institute state that the economic security of the state is an important component of national security, but underline that this is a complicated system that has its own structure and internal logic that makes it necessary to improve the methodology of the integrated assessment of the level of economic security of the state in order to ensure an adequate response to destabilizing factors.

Professor Gumenyuk AM (National Institute of Strategic Studies) in their works notes that in the theoretical and methodological plan there is still no clear approach to creating a system for ensuring economic security of the country as a whole, and at the regional level, there are still more problems (the minimum informative set of indicators, their thresholds, methodological issues of monitoring and decision-making on preventing threats to economic security have not been solved, etc.) [1].

It is not necessary to identify the concept of «economic security of the region» and «socio-economic development». A set of indicators for evaluation The same assessment methodology can be similar in the study of these two phenomena, but there is one significant difference. The socio-economic development of the region is measured in comparison with other regions, as is correctly done through the ranking and averaging procedure. Economic security is measured by similar methods, but there must be threshold values beyond which

regional development is critical. The method for determining these threshold values should also be developed. The development of an effective system of indicators of economic security is a complex theoretical and methodological problem.

The authors of the article found that on the basis of the proximity of the state of a particular subsystem to the boundary of its stability, that is to the point of bifurcation, it is possible to quantify the level of security of the system. The point of bifurcation is the moment of loss of predictability of changes in response to external influences.

Consider the regions of Ukraine from the point of view of the systemic development of time in terms of the characteristic feature – the gross regional product (GRP), and the system itself is the state of Ukraine, that is, the regional social and economic system of zero order (PCES 0). The toolkit of the measure of order and measure of chaos was developed by Vyatkin [2,3,4]. It is based on two information functions: additive negentropy ($I\Sigma$) and entropy (S). To describe the structural organization of the system, that is, the ratio of order and chaos in the synergetic theory, the R-function of the form is calculated [3]

$$R = \frac{I\Sigma}{S} = \frac{\text{order}}{\text{chaos}}.$$

Table 1 shows the gross regional product in the regions of Ukraine for 2004–2016 and calculates the R-function according to the methodology. It is believed that chaos (entropy) and order (information, negentropy) are equal to each other, but are directed oppositely.

The value of the R-function indicates which of the information functions prevails in the structure of the system: chaos or order. When $R > 1$, we have a predominance in the structure of the system of order, otherwise, when $R < 1$ is chaos. At $R = 1$, the chaos and order are balanced, and the structural organization of the system is equilibrium (synergetic) [3].

Calculations of the R-function based on the characteristic «Gross Regional Product» in US dollars have been made according to the same procedure in accordance with the methodology. According to the intervals, the value of the R-function can be concluded that the regions of Ukraine from the point of view of the systemic development in time on the characteristic feature – the gross regional product, each year show the stability of its development in the relationship and in the system of national economy. And they do not show the presence of chaotic development or synergistic development. It should be noted that the indicators of the R-function in the hryvnia value are slightly higher than the R-function in dollar terms. To further characterize the values of the R-function and their interpretation,

Table 1
Calculation of the R-function by the characteristic feature «Gross regional product»

	Gross regional product, UAH million ¹			Gross regional product, million dollars*		
	R-function	$I\Sigma$	S	R-function	$I\Sigma$	S
2004	3.3609	14.18	4.22	2.7886	11.76	4.23
2005	3.4451	14.53	4.22	2.8748	12.13	4.22
2006	3.5302	14.85	4.21	2.9781	12.53	4.21
2007	3.6718	15.29	4.17	3.1109	12.96	4.17
2008	3.7559	15.68	4.17	3.1090	12.98	4.17
2009	3.7202	15.61	4.19	3.0051	12.61	4.19
2010	3.7835	15.86	4.19	3.0591	12.82	4.19
2011	3.8245	16.10	4.21	3.1035	13.07	4.21
2012	3.8827	16.28	4.19	3.1630	13.27	4.19
2013	3.9221	16.37	4.17	3.1904	13.31	4.17
2014	4.0446	16.51	4.08	3.0739	12.55	4.08
2015	4.1160	16.83	4.09	3.0115	12.32	4.09
2016	4.2042	17.11	4.07	3.0583	12.45	4.07

Source: Calculated based on data Official site of the State Statistics Service of Ukraine: <http://www.ukrstat.gov.ua/> [5]. * – The calculation of GRP is based on the average annual value of the dollar to the hryvnia in the corresponding year of calculation. 1 – Data given without taking into account the temporarily occupied territory of the Autonomous Republic of Crimea, the city of Sevastopol and part of the zone of the anti-terrorist operation

it is necessary to calculate the intervals of the permissible values of negentropy and entropy [3]: S_{max} ; S_{min} ; $I\Sigma_{max}$; $I\Sigma_{min}$.

The calculation of the R-function and the intervals of permissible values \dagger of negentropy and entropy is just indicative of the existence in the Ukrainian economy of the proximity to the boundary of its stability, where loss of predictability is possible. In the theory of systems, the term «point of bifurcation» describes the state of the system, when

any small influence can lead to any major changes in the state of the system.

Calculations of the intervals of permissible values \dagger of negentropy and entropy are given in tables 2 and 3.

It is clear from the calculations that the value of entropy in both cases (for GRP in UAH million and GRP in US \$ million) is within the limits. The value of entropy (measure of chaos) averages 4.08–4.22 with the maximum allowable value for both cases – 4.755, that is, it approaches its maximum threshold value.

Stepanov V., proposing to use the quantitative estimation of the conditions of uncertainty by determining the entropy in the theory of risks in assessing the projects of ecologization of the economy, notes that it is obvious that the higher the value of entropy approaches the maximum threshold, the greater the level of nonlinearity [6]. He also notes that increasing the degree of uncertainty about the manifestations of events leads to an unreliability of the characteristics and assessments of the systems and, thus, reduces the validity of management decisions that are taken on their basis.

The significance of negentropy is within the normal limits. That is, the system is in the range of values more prone to the rule of uncertainty, which is proof of the manifestation of the nonlinearity of the development of modern regional processes with their laws. From the interim calculations ($m\log_2 m$) it is evident that statistically the regions such as Dnipropetrovsk region, Donetsk, Kiev, Kharkiv regions and Kyiv are being knocked out. However, the significance of negentropy, which is within the limits of the norm, does not allow us to conclude that there is an irreversible dominance of chaos over the order.

Only in the central interval of domination as

Table 2
Intervals of permissible values of negentropy and entropy of the R-function on the characteristic feature «Gross regional product, million UAH»

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
S_{max}	4.755	4.755	4.755	4.755	4.755	4.755	4.755	4.755	4.755	4.755	4.755	4.755	4.755
S_{min}	0.0015	0.0012	0.0010	0.0008	0.0006	0.0006	0.0005	0.0004	0.0004	0.0004	0.0004	0.0003	0.0002
$I\Sigma_{max}$	18.395	18.750	19.053	19.458	19.854	19.800	20.046	20.312	20.476	20.538	20.597	20.923	21.186
$I\Sigma_{min}$	13.642	13.997	14.299	14.704	15.10	15.046	15.291	15.556	15.722	15.783	15.842	16.168	16.431

Table 3
Intervals of permissible values of negentropy and entropy of the R-function on the characteristic feature «Gross regional product, million dollars»

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
S_{max}	4.755	4.755	4.755	4.755	4.755	4.755	4.755	4.755	4.755	4.755	4.755	4.755	4.755
S_{min}	0.007	0.006	0.004	0.003	0.003	0.004	0.004	0.003	0.003	0.003	0.005	0.005	0.005
$I\Sigma_{max}$	15.976	16.340	16.727	17.119	17.151	16.797	17.007	17.274	17.456	17.482	16.630	16.400	16.516
$I\Sigma_{min}$	11.228	11.591	11.977	12.368	12.399	12.046	12.256	12.522	12.704	12.730	11.879	11.651	11.766

an order over chaos, and chaos over the order is reversed. The value of the R-function for all the years studied is greater than 1. That is, the entire system RSES 0 for the production of the gross regional product, according to the value of the R-function is a process ordered and rigidly regulated (we have a rule order in the whole system). The results clearly demonstrate the orderliness and stability of the system through state intervention. That is, the stability of the system, in this case, depends on state interference, and the system itself can not be self-regulated. Umanets T., describing the mechanism of ensuring the economic self-sufficiency of the region [7], proves that centralized management of the economy in practice demonstrated its failure and thus gave impetus to its improvement and development.

Such a ratio of entropy values close to the threshold and the value of the R-function, more than 1, proves the existence of significant regional development disparities in the system of the national economy of Ukraine. With an increase in the value of the R-function in 2015–2016 we have an increase in the value of negentropy. This means, as if we were approaching the threshold values of entropy, in the state economy one could expect a «bifurcation explosion» and the subsequent dispersal of possible states of system development. Chaos is an indicator of adaptation to changing environmental conditions and preparation for different development options in the future [8]. Shkrabak I., in studying the strategic management of the economic development of territorial entities, notes that chaos is the stimulus and impetus of evolution and the way out of the «evolutionary impasse» [8]. At the same time, chaos is the force of destruction and the power of formation, which may have a set of different possibilities for future structuring of the system. Shkrabak I. emphasizes that the concept of «subject-object of management» gradually leaves the position and gives place the concept of self-organization, that is, in the management comes the period of domination of the synergistic approach [8].

The tendency to increase non-aggression also increases the stability and orderliness of the system, but somewhat discourages the implementation of various perspectives. That is, for $R > 1$ the system is

ordered, $R < 1$ is chaotic, $R = 1$ is a synergistic system (self-development). The author of the dissertation thinks that orderly and chaotic systems are not stable.

Quite successfully describes the corridor for the development of the economic system researcher Chimitova A. [9]. It indicates that the development of the economic system is a transition to a qualitatively new level and may be accompanied by degradation, that is, the development and decay of the system can take place simultaneously, depending on which process will pass faster, we will get such a state of the system. Using calculations, one can depict the corridor for the development of the regional socio-economic system of the 0th order during 2007–2016 as follows (Figure).

The phenomena depicted in Figure 1, it describes as follows [9]. Frustration represents the destruction of the integrity of the system without the possibility of reverse development or restoration. The crisis is characterized as a violation of the interconnections of the subsystems, the structural change of the system, the decline of processes of development and the growth of negative phenomena.

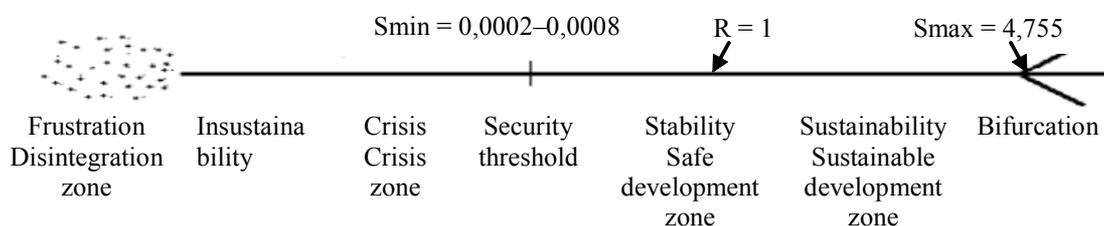
The security threshold is the threshold, which is the beginning of destructive processes and beyond which safety comes. Stability is a dynamic balance that involves economic growth. Sustainability is characterized by the presence of processes of self-development, the ability to maintain a stable internal structural and functional organization.

Bifurcation is an indicator of qualitative uncertainty, when a single and integral quality collapses and disappears in the instant, yielding to the possible new qualities [9].

Thus, ordered systems are not stable for a long period of time, stability is noted only for a short period of time, and they are very susceptible to crisis phenomena. From the study of the dynamics of Ukraine's GDP, the cyclical development is evident, namely, the system's perturbation is noted in 1995–1996; 1999; 2009; 2014 years That is, the stability of such rigidly regulated regional socio-economic systems is noted only for 5–10 years [10,11].

Conclusions

The performed research and calculations of the sustainability of systemic development in time on the characteristic feature of the gross regional product



Corridor of the development of the regional socio-economic system of the 0-th order during 2007–2016*

(* – author's presentation by source [9])

give an opportunity to conclude that the development of regional economies in time and structure of the national economy of Ukraine is a process strictly regulated by the state, which does not correspond to the main principle of the system – self-development and contradicts the laws of development market economy. And regional systems themselves are within the corridor of a safe level of the system, but they are not stable for a long period of time.

The synergetic theory, on the contrary, indicates that the system is self-developed. Ability to self-development is one of the fundamental properties of the system. That is, the system must be adaptive and be within the range of the value of the R-function, where the rule of both order over chaos and chaos over the order are mutually reversed. From the dynamics of the R-function in the hryvnia equivalents, we see only an increase in state intervention in the management of the economy. The dollar equivalent of the R-function also tends to increase.

Thus, with increasing state interference in the economic complex of the region there is an increase in the orderly system with a simultaneous decrease in entropy, which leads to a delay in the development of the RSES in the zone of «evolutionary impasse» and makes it impossible to transition to the concept of self-organization.

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КІЛЬКІСНИЙ ВИМІР РІВНЯ ЕКОНОМІЧНОЇ БЕЗПЕКИ РЕГІОНАЛЬНОЇ СИСТЕМИ НА ОСНОВІ ІНСТРУМЕНТАРІЮ МІРИ ПОРЯДКУ ТА ХАОСУ

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В статті досліджено можливість застосування інструментарію міри порядку та хаосу при кількісному вимірі рівня економічної безпеки регіональної системи. Зазначається, що існування умов нелінійності регіонального розвитку вимагає детального дослідження методів та підходів до управління територіальним розвитком з позиції синергетичного підходу. В статті доводиться, що для виміру економічної безпеки регіональної системи необхідно запровадження порогових оціночних значень. Авторами статті виявлено, що на основі близькості стану певної підсистеми до кордону її стійкості, тобто до точки біфуркації, можливо кількісно оцінити рівень безпеки системи. Розраховано коридор розвитку регіональної соціально-економічної системи та виявлено, що при посиленні втручання держави в господарський комплекс регіону відбувається посилення впорядкованості системи з одночасним зниженням ентропії, що призводить до затримки розвитку РСЕС в зоні «еволюційного глухого кута» та унеможливорює перехід до концепції самоорганізації та нового технологічного укладу. Доведено, що розвиток економік регіонів у часі та структурі національної економіки України є процес жорстко регульований державою, що не відповідає головному принципу системи – саморозвитку та суперечить законам розвитку ринкової економіки.

Ключові слова: регіональна система, економічна безпека регіону, соціально-економічний розвиток, регіон, синергетичний підхід.

**КОЛИЧЕСТВЕННОЕ ИЗМЕРЕНИЕ УРОВНЯ
ЭКОНОМИЧЕСКОЙ БЕЗОПАСНОСТИ
РЕГИОНАЛЬНОЙ СИСТЕМЫ НА ОСНОВЕ
ИНСТРУМЕНТАРИЯ МЕРЫ ПОРЯДКА И ХАОСА**

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В статье исследована возможность применения инструментария меры порядка и хаоса при количественном измерении уровня экономической безопасности региональной системы. Отмечается, что существование условий нелинейности регионального развития требует детального исследования методов и подходов к управлению территориальным развитием с позиции синергетического подхода. В статье доказывается, что для измерения экономической безопасности региональной системы необходимо введение пороговых оценочных значений. Авторами статьи установлено, что на основе близости состояния определенной подсистемы к границе ее устойчивости, то есть к точке бифуркации, возможно количественно оценить уровень безопасности системы. Рассчитано коридор развития региональной социально-экономической системы и обнаружено, что при усилении вмешательства государства в хозяйственный комплекс региона происходит усиление упорядоченности системы с одновременным снижением энтропии, что приводит к задержке развития РСЭС в зоне «эволюционного тупика» и делает невозможным переход к концепции самоорганизации и нового технологического уклада. Доказано, что развитие экономик регионов во времени и структуре национальной экономики Украины является процессом жестко регулируемым государством и не соответствует главному принципу системы – саморазвитию, а также противоречит законам развития рыночной экономики.

Ключевые слова: региональная система, экономическая безопасность региона, социально-экономическое развитие, регион, синергетический подход.