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Article

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Technology audit and production reserves

UDC 339.138:336.531.2
JEL Classification: O17, P10, P19
DOI: 10.15587/2706-5448.2021.239035
Article type «Reports on Research Projects»

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DEVELOPMENT OF AN INNOVATIVE METHODOLOGY OF RESEARCH OF SYSTEMS ON AN EXAMPLE OF A SHADOW ECONOMY AS AN INVARIANT OF SYSTEM OF ECONOMIC SECURITY OF STATE

The object of research is the shadow economy as structural component (invariant) of economic security of state on example of Ukraine. The level of shadowing of Ukrainian economy requires improvement of both: the system of indicators and mechanism of influence on the level of shadowing on the basis of using of fundamental constants of mathematics of harmony and principle of structural harmony of systems.

Under research, fundamental provisions and methods of the theory of safety studies, economic theory, theories of systems and structural harmony of systems, institutionalism, transdisciplinary nature were used. The theme of management of the system of economic security of the state is investigated from various scientific positions of classical science. At the same time, practically ignores the theory of synergetic, which is the synthesis of transdisciplinary approach, price approach, classical theory of systems, structural harmony of systems, theory of fractals and attractors and other components of theory of complexity.

Obviously, any system has metric characteristics inherent. The most widespread math constant found in nature is the Phidias number (Golden section). Measure is the most important component of all and any knowledge, without it any description of processes and phenomena will be incorrect. The law of measures, or the law of proportional distribution with its derivatives can be defined as law of projecting and organizing sustainable systems at all levels of hierarchical management. The structure of the system is the most conservative characteristic of it as opposed to the state of the system. The properties of the system as a whole are determined not only the properties of its individual elements, but also the properties of the structure of the system as whole. They depend on the existence of the system. The existence of the system retains these parameters in the process of adapting the system to external conditions and thus maintains the existence of the system itself.

Matching the metric quality system of economic security of the state and obtaining a conclusion on its stability and abilities to self-organization under the conditions of shadowing of the economy can be carried out by comparison. It is carried out using attractors representing a recurrent number of gold sections: 0.500 ...; 0.618 ...; 0.682 ...; 0.725, as well as – distractors: 0.5698 ...; 0.6540 ...; 0.7053. An integral indicator characterizing the state of any system is the relative information entropy by Shannon. Entropy testing of the system (calculation of relative information entropy) is a logical component of the innovative model of system research.

Keywords: *shadow economy, economic safety, transaction costs, diagnostic indicators, proportional distribution, entropy testing.*

Received date: 09.03.2021
Accepted date: 27.05.2021
Published date: 31.07.2021

How to cite
Yegorova-Gudkova, T., Bojko, M., Neustroiev, Y., Kostash, O., Pan, L., Shepitko, H., Beloborodko, V., Zvirkov, O., Kirilina, M., Matjukhina, I. (2021). Development of an innovative methodology of research of systems on an example of a shadow economy as an invariant of system of economic security of state. Technology Audit and Production Reserves, 4 (4 (60)), 41–45. doi: http://doi.org/10.15587/2706-5448.2021.239035

1. Introduction

Today shadow economy is one of the most important problems of developing of economic system of any country of the world and affects on the state of national economy, the prospects of its growth, the level of law and order, the quality of life of the population. The state and level of the shadow economy forms a threat to the country's economic security.

Under the shadow economy it is accepted to understand economic activity that develops beyond public accounting

ISSN 2664-9969

and control, and thus is not taken into account in official statistics. Shadow or informal, or hidden, or a criminal economy is inherent in the world economy, it covers all spheres of life of society. Only its share in GDP of different countries is unequal.

The level of shadow economy in the world is from 18 to 35 % of world GDP. According to the World Bank of GDP in the world, 2012 amounted to 71.66 trillion USD and shadow economy of the world amounted to 26 trillion USD [1]. In Europe, in 2013, the «shadow» level amounted to 18.5 % of GDP or within 2.15 trillion EUR [2]. Under the conditions of COVID-19 there was an increase in the shadow economy for predictive values. In 2020, the forecast of its volume was 336 billion EUR, and in fact, amounts amounted to 339 billion EUR, an increase of 3.0 billion EUR (which also shows that the shadow economy is a shock absorber of the crisis) [3].

The level of the shadow economy affects the conditions of dynamic socio-economic development of society and is an important component of influencing the state of national security.

Despite large number of research covering various aspects of the shadow economy and ensuring the state of economic security of the state, the problem of countering the shadow economy in the system of provision of economic security is not systematically analyzed and not explored. Also, the problem of forming and improving the methodological basis for managing economic crime management is not considered, especially methods of systemic and synergistic management, as well as a transdisciplinary approach in studies of these phenomena.

The experience of market economy with a high level of institutionalization shows that the development of institutional infrastructure of developed countries promotes sufficiently effective control of the state of the shadow economy. For example, the Law of Sainberns-Oxley, which was introduced in the United States in order to counteract the conversion of companies [4]. According to the provisions of the transactional analysis of R. Coase – the lack of institutions in countries in a state of transformation is replaced by contracts regulating business relations and form the level of transaction costs of the firm [5]. It should be noted that the level of the shadow economy is significantly distinguished in the countries of a developed market economy and other countries. Therefore, let's believe that the diagnosis of the state of the system and its quality should be given to the presence of properties of stability and self-organization. Development of an innovative model of the study of the state of the economic system, including the system of economic security of the state and its invariant – the system of the shadow economy can be used in relation to both developed countries and transformational economies. Sustainability and self-organization of the economic system is the purpose of any state.

Consequently, *the object of research* is chosen by the shadow economy as a structural component (invariant) of the state economic security system on the example of Ukraine.

The main threats of Ukraine's economic security are:

– business on state resources;

– energy dependence and high energy intensity of production;

– decline in production;

– loss of traditional external markets;

– curtailment of fundamental research in the field of science and poll-design developments (SPDD);

– growth of hidden unemployment;

– criminalization of the economy and increase external debt.

Shadow is not a sign of the backwardness of the transition economy [6]. Shadow is a natural response to the share of society for bureaucratic permanence and the high cost of entering the legal market. The shadow economy has a dual nature: on the one hand, it is due to uneven, cyclic development of the economy. On the other hand, it is a consequence of the behavior of an individual, which significantly affects the specifics of the shadow economy as an economic phenomenon.

Shadow economic relations deform a system of economic relations of any level, based on the fact that there are new relationships that make a destructive effect on the playback mechanism. Therefore, the analysis of socio-economic processes taking place in society, without taking into account the influence of shadow economic relations, will be incomplete, one-sided, and therefore unsystematic. From the point of view of the general theory of market and free interaction of demand and supply, the shadow sector of the economy should be considered as partially deformed element of market system based on the mechanism of appropriation of additional profits.

The supervantage of shadow sector is provided by the peculiarities of the mechanism for the formation of production costs and services, evasion of taxation, reducing the level of transaction costs compared to legal activities. The main source of excess income in the shadow sector of the region is an artificially underestimate level of expenses in general and transaction expenses separately, formed on the basis of many factors. The level of expenditures determines the value of demand on a specific sectoral shadow market, the level of transaction costs is determined by the efficiency of the use of market mechanism [7–9].

Thus, *the aim of research* is to develop an innovative methodology for studying and operating systems with the properties of stability and self-organization based on a transdisciplinary invariant-variable approach.

2. Method of research

It should be noted that the lower the level of economic development, the stronger the tax pressure on the subjects of economic relations. There is a harmonious level of revenue and expenses, respectively, should plan receipts and taxes. In modern times, subjects of economic activity must give in the form of various taxes and accruals of almost 70–90 % of their income, which negatively affects the possibility of reproduction of activity and inhibits the growth rates. Disharmony in economy stimulates the movement of business in a shadow, in order to optimize transaction costs [8, 9]. The analysis shows that with an increasing in tax – the tax component of the budget filling is reduced; it is proof of violation of the principles of harmony.

The methodology of administration of the shadow economy as a structural invariant system of economic security of the state should include the following steps [9]:

1. Implementation of classification of indicators affecting the state of economic security for invariants and variations provides an opportunity to differentiate the significance of the indicator for influencing the general state of economic security of the state and concentrate

on the invariants of the system.

2. The use of the Laffer model allows to evaluate in which the contour zone (for example – taxation, or shadowing of economy) are indicators, in a zone of constructive or destructive, and make appropriate conclusions.

3. Universal indicator that characterizes the state of the system with the properties of self-submitting is the relative information entropy – an integral index, the value of which mathematically correspond to a generalized golden sections or fractions of units.

Nodes of a measure of a recurrent number of golden sections, namely: 0.5000 ...; 0.6180 ...; 0.6823 ...; 0.7245 ..., are attractors for integrated systems, in particular – for relative information entropy as a measure of any structurally complex system. These values are the basic characteristics of non-equilibrium resistant, stationary states of complex systems self-organizing and evolved outside the balance, wherein the relative entropy is 1 [9–11].

4. The measure of information of event is the logarithm probability of this event taken with the opposite sign: $-\log p$. But the logarithm of the incredibility of this event can also be: $-\log(1-p)$. Multiplicity of these measures $\log(1-p)=k\log p$ follows the equation: $pk+p-1=0$. Its roots: 0.500 ...; 0.618 ...; 0.682 ..., when k=1, 2, 3, ... and there are nodes of measure p – generalized golden ratios. If the state of the system for which the value of the integral measures correspond to the numbers of the attractors, then the growth of chaos is the minimum and maximum increase in the organization, order, structural harmony and systematic quality [10–12]. If the integral measure takes value from number of distractors, then there is an increase in dynamic chaos. Entropy becomes an expression of the amount of information related to the distribution of the components of the system. Normally permanent, that is, being attributed to its maximum value, it is gaining like:

$$\bar{H} = -\frac{1}{\log n}\sum_{i=1}^{n} p_i \log p_i, \qquad (1)$$

where n – the number of system components.

Entropy, as a measure of chaos and structural diversity, in addition to the organization, order, monotonity R, along with it, satisfies the law of conservation: $\bar{H}+R=1$.

The hypothesis relative to ability to project a stable system is based on the primary drafting, or in supporting the artificial system in order to re-register a set of mathematical constants of Nature [9, 13].

Comprehensive study of the phenomenon of self-organization of the system of economic security is a promising direction of modern theoretical studies and has a significant application.

5. Economic backgrounds, which should analyze economic security as a self-organized system, are transaction costs. It is the comparison of the price of legality and illegality of use by a market mechanism initiates the possibility of improving the management system.

6. An indicator of the availability of problems in the system of management of the economic system in general and the system of economic security of the state is the shadow economy and its level. Business chooses between the cost of legality and illegality. And it also belongs to reflection of integrity.

7. The constant of golden ratio and its mathematical derivatives relate to structural invariants, attractors to be focused on the production of artificial super- systems and their components.

8. Stages of the methodology of drafting a sustainable system of economic security of the state:

8.1. Assessment of the status of the system (for example — the system of economic security of the state).

8.2. Evaluation of the temporary interval between the emergence and pleasure of the need (in a particular system).

8.3. Estimation of structural and functional state of the system.

8.4. Estimation of the level of vertical integrity of business in terms of branches and sectors of the economy and the share of value added in GDP; using a price approach.

8.5. Comparison of evaluation results with attractors representing a recurrent number of gold sections: 0.500 ...; 0.618 ...; 0.682 ...; 0.725.

8.6. Control of the reliability and viability of the system (evaluation of deviations).

8.7. Testing the system: entropy (calculation of relative information entropy), corresponding to fractal-cluster constants and the law of elementary synthesis.

8.8. Formulation of a restructuring project (reengineering) system.

8.9. Implementation of the project and assessment of the conformity of the conditioned system on the structural and functional conformity of the golden crossing constant and its derivatives.

9. In order to compare the correctness of the conclusions on system stability or instability, fractal-cluster constants should be used. According to them, as well as with the Laffer's model, it is possible to build the contour of constructive and destructive in terms of state economic security.

10. Also, the results of verification can be obtained by graphical data, if to get a strange Lorentz attractor [9].

3. Research results and discussion

According to the information presented in the previous section, it is possible to conclude that such methodology in modern times is not used. Let's consider how the shadow economy and the state sector of the economy in Ukraine are interact with the help of classical correlation analysis (Fig. 1).

For ease of comparison, let's provide a schedule of changes that reflects the share of the state sector of Ukraine's economy in percentage terms in 8 years (Table 1), which contains an indicator of the share of the state sector of the Ukrainian economy (Fig. 2).

To detect the degree of dependence of one indicator from another, a method of correlation analysis was used:

$$r = \frac{n\sum xy - \left(\sum x\right)\left(\sum y\right)}{\sqrt{\left(n\sum x^2 - \left(\sum x\right)^2\right)\left(n\sum y^2 - \left(\sum y\right)^2\right)}}, \qquad (2)$$

where n is the number of years in the analyzed period; x and y are economic indicators, the relationship between which is explored.

For convenience, all calculations data were listed in Table 2. In addition, an analysis of the dependence of the level of the shadow economy was conducted, from the share of the state sector of the economy.

ISSN 2664-9969

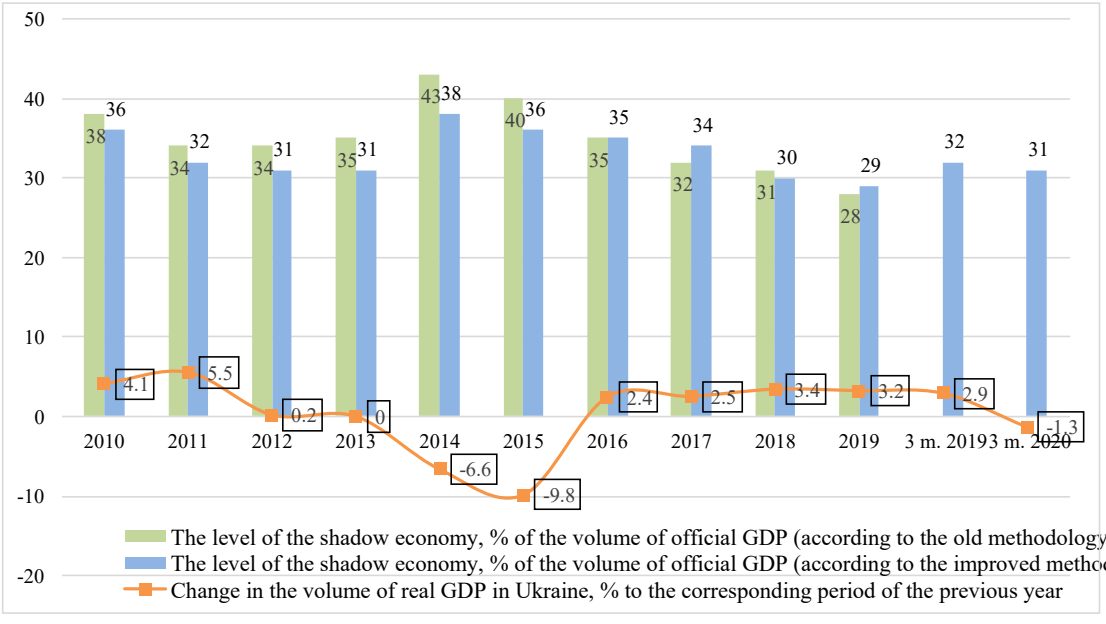

Fig 1. Level of the shadow economy of Ukraine in the period 2010–2020 [9]

Table 1

Share of the public sector of the Ukrainian economy

Period	2012	2013	2014	2015	2016	2017	2018	2019
Частка, %	16.3	11.3	10.3	9.8	9.6	9.4	8.9	8.3

Note: developed based on data [9]

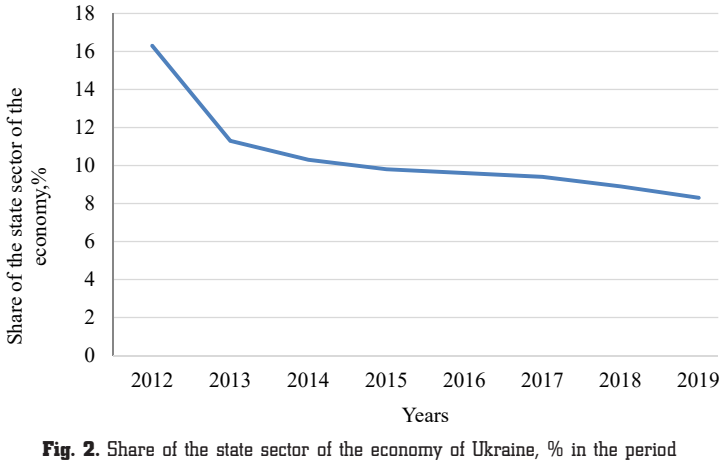

Fig. 2. Share of the state sector of the economy of Ukraine, % in the period 2012–2019 [9]

Table 2

Estimated data for correlation analysis

Period	x	y	xy	x^2	y^2
2012	34	16.3	554.2	1156	265.69
2013	35	11.3	395.5	1225	127.69
2014	43	10.3	442.9	1849	106.09
2015	40	9.8	392	1600	96.04
2016	35	9.6	336	1225	92.16
2017	32	9.4	300.8	1024	88.36
2018	31	8.9	275.9	961	79.21
2019	28	8.3	232.4	784	68.89
r=0.1667	Σx=278	Σy=83.9	Σxy=2929.7	Σx^2=9824	Σy^2=924.13

Note: developed based on data [9]

The algorithm of counteraction to the shadow economy and managing economic security processes requires the introduction of an innovative system of indicators that can characterize the quality of the shadow economy system. To do this, it is necessary to significantly change the mechanism of formation of the system of evaluation criteria based on a transdisciplinary approach, namely the introduction of such characteristics measures as attractors, distractors and relative information entropy [9].

At the same time, it is necessary to effectively use the methodology of economic-law analysis of R. Coase in order to project transaction costs in the conditions of the planned initiation of legislative environment changes as an instrument of negative impact on the shadow economy based on the use distractors of measures of shadow economy [8, 9]. Implementation of economic sanctions as a law will facilitate the growth of transaction costs in the shadow sector, which will reduce its competitiveness and volume reduction.

It is necessary to form modern methodological principles for the detection and substantiation of methods for evaluating the scope of shadow economy in the state economic security system and the development of a counteraction strategy. The methodology should be based on a transdisciplinary approach that is derived from the general principles of the Universe. Such a methodology can become the nucleus of the theory of natural-like management and artificial intelligence in administering a shadow economist [9, 13, 14].

The restrictions of this study may be accessible to statistical data, as well as their correctness.

The use of the model in practice will develop «contours» for each of the indicators of state economic security and compare them with active threshold values that are most often established by expert estimates and comparison.

The indicator of relative information entropy is a universal integral index that mathematically diagnoses the state of the system.

An example of such a diagnosis may be the study of scientists of the Zurich University [15] regarding the efficiency

of functioning and management of the largest transnational corporations (TNCs) in the world. According to its results, the following characteristics were obtained as a strange Lorenz attractor [16, 17] and the Golden section.

According to the results of the study, the method of diagnosing the state of various economic systems may be developed. In the conditions of creation in Ukraine, the State Bureau of Economic Security, such methodology can be developed for this institution, since the achievements of the necessary and adequate level of economic security of the state are the basis for socio-economic growth.

4. Conclusions

During the study, it was discovered that disharmony, which is regulated by the framework of economic activity is one of the factors of shadowing of the economy. In fact, in the market space of the country, two markets are legal and illegal, with their own volumes of demand, proposals, equilibrium prices and expenses. Since the volume of demand, supply volume, and the level of equilibrium price are the main guidelines of the behavior of sellers and buyers, then these landmarks stimulate the development of the illegal market of any branch of the country's economy. As a result, there is a violation of the basic principles of rational competition based on the socio-justifiable value of the ratio of expenses (as well as transaction costs) and production benefits. The coexistence of legal and shadow markets orientates the subjects of economic relations on the socio-destructive level of profitability. This becomes the main factor in maintaining opportunities for the growth of the economy of regions and economic growth of the country's economy in general.

The results of the study will be useful for researchers and practitioners who are interested in the topics of ensuring system stability, providing it to the properties of self-organization and self-harmonization, to diagnosis of their state and the propagation of artificial systems with given characteristics corresponding to mathematical constants of nature and are noospheric in shape and content.

The scientific novelty of the study is to develop an innovative methodology for the study and projecting of sustainable systems based on a transdisciplinary invariant-variable approach.

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