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Structural Balance as a Basis of the Economic Sustainability of an Enterprise

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ABSTRACT

The article presents results of the analysis of the economic sustainability of Ukrainian machine-building enterprises in the context of new economic systems theory. The theory provides for priori division of the economic systems of all levels into four types based on their limitations in space and time – in this way object, environment, process and project systems are allocated. The author hypothesizes that the level of economic sustainability of the enterprise depends on the mutual balance of its internal subsystems of four types, and therefore may be determined on the basis of this balance measurement. For this purpose the special methods to determine the level of balance of the enterprise as an economic system have been developed. It is based on the index measurement of each type of subsystems by Principal Component Analysis (PCA) method, analytical calculation of the index of their perimetric interaction intensity and on their basis – determination the system balance index of tetrad structure of the enterprise. The results of econometric modeling based on these methods according to the 16 Ukrainian machine-building enterprises for the period of 2004-2015 confirmed the hypothesis and led to the conclusion about the systemic nature of structural imbalances. The obtained results will be the basis for developing recommendations for management aimed at maintaining the parity of subsystems of four types and in turn it will provide the economic sustainability of the enterprise.

Keywords**:** economic sustainability of the enterprise; structure of economic system; structural balance; structural theory of economic systems

1. INTRODUCTION

Broad categories of economic sustainability and a large number of methodological approaches to its studying caused the absence of its unambiguous interpretation even in the range of general systems theory. However, despite the interpretation, the general systems theory recognizes that the structure of the system plays a key role in ensuring of its sustainability. Therefore a systems approach of the socio-economic systems analyze is based largely on the selection and researching of their structure. Such specificity of systematic approach was aptly noted by the founder of the Club of Rome A. Peccei, who said that it was "dictated by the complex nature of the modern world, where the mutual relations between the individual components are often more important than the components themselves" [1].

This structural approach was the basis of our research of the economic sustainability of Ukrainian enterprises. However, from the works devoted to the study of the structural sustainability of the socio-economic systems, we can conclude that the main sustainability of the structure is seen in the context of the impact made by the neighboring systems and external factors, but not by the internal ones [2-5]. We made the focus on analyzing the balance of the internal subsystems of the enterprises, but before it we had revealed the mechanism of their interaction with the external system environment [6-7]. To structure the enterprise as a system and identificate its subsystems a new economic theory, formulated by Russian scientist G. Kleiner, was used [8-12]. He supports of the structural approach in the study of social and economic systems and notes that the key distinction of his theory "is to avoid the set-theoretic (endogenous) fundamentals of the systems and to enhance imaginative (exogenous) fundamentals of the system. ... We can say that there is the transition from set-theoretic systems theory to the theory of structural systems" [8]. The basic principles of structural theory does not run counter to the principles of general systems theory, this approach integrates neoclassical, institutional and evolutional approaches [9].

The theory is interesting and credible, but new, so it doesn't have a proper methodological, instrumental base and especially econometric treatment. Therefore, to justify adequacy and reliability it requires a more rapid development.

According to this theory, since in general any system is defined as a set of elements that form relatively stable structure in space and time, the fundamental characteristics of any system including economic, are the limits of that space and time. So, all systems that exist in the economy can be divided into four types based on their limitations in time and space:

- objects have limited extension in space and unlimited duration in time;
- environments have unlimited both extension in space and duration in time;
- processes have unlimited extension in space and limited duration in time;
- projects have limited both extension in space and duration in time.

All economic entities, regardless of their hierarchical level – state, regions, industries, enterprises and organizations, households, individuals – are the systems of the object type, as they usually have some spatial limits but they have not time limits [8-12].

The main idea of the interpretation of economic sustainability is that it is seen as a characteristic of tetrad – the group of four types of systems on a certain economic level. Consequently, tetrad is the minimal stable entity capable of independent existence and self-development. Sustainability of tetrad does not provide a permanent sustainability of systems that constitute it, but provides for a permanent complex compensatory mechanism of their interaction [6-8, 12].

Methodological concept outlined above is the basis of our research on economic sustainability of microeconomic systems, specifically industrial enterprises. The working hypothesis of the research is that the level of mutual balance of subsystems of four different types – object (*Ob*), environment (*En*), process (*Pc*) and project (*Pj*) – determines the level of sustainability of economic system. And therefore sustainability of economic system may be determined on the basis of this balance measurement. In the main part of the work we have tried to conduct a more rigorous test of this hypothesis, based on formal econometric analysis.

The purpose of this article is to provide the results of this hypothesis verification by econometric analysis according to the 16 Ukrainian machine-building enterprises for the period of 2004-2015.

2. RESULT

2. 1. Identification of Industrial Enterprises' System Structure

For measuring the balance of enterprises systems structure have been identified and its components, which can be attributed to the object, environment, process and project subsystems of the enterprise, have been allocated. Specific set of the elements of these subsystems for an industrial enterprise are listed below:

- object subsystem *(Ob)* includes the totality of the employees, management, business holders, departments of the enterprise;
- environment subsystem *(En)* is represented by social and cultural spheres of enterprise and includes its internal standards, regulations, rules, institutions, communication, climate and culture;
- process subsystem *(Pc)* is represented by sphere of industrial and economic processes that take place at the enterprise and includes its technology, information, management, logistics, business processes;
- project subsystem *(Pj)* includes the totality of the investment and innovative projects, programs, events, intentions of the enterprise, including its restructuring and reformation.

The main roles of these subsystems in ensuring the sustainability of the enterprise are shown below:

- role of the object subsystem is to ensure continuation of the enterprise existence during the time and within the occupied part of the space;
- role of the environment subsystem to ensure continuation of the enterprise existence during the time and its unlimited functioning in the space;
- role of the process subsystem to ensure continuation of the enterprise existence within the allocated time and its unlimited functioning in the space;
- role of the project subsystem to ensure continuation of the enterprise existence within the allocated time and within the occupied part of the space.

Identification of the elements of the enterprise subsystems structure it was expedient to allocate parameters by which they can be evaluated.

2. 2. Evaluation of Balance of Industrial Enterprises' System Structure

We have developed the methods and conducted econometric assessment of balance of 16 Ukrainian machine-building enterprises for the period of 2004-2015 (total sample consisted of 192 cases). It was based on the measurement of structural proportions of objective, environment, process and project subsystems of enterprise for each case.

Index estimates of subsystems were carried out by application of Principal Component Analysis (PCA) based on the set of selected parameters. The parameters were selected considering the availability, completeness, credibility and timeliness of empirical data for its assessment. Determination of parameters was based mainly on regrouping of the output statistics and because of that the most part of them represents quantity data. Thus, for estimation of object subsystem index were selected 11 parameters, which were reduced to 6 components; for environment subsystem index – 13 parameters, which were reduced to 8 components; for process subsystem index – 9 parameters, which were reduced to 5 components and for project subsystem index – 16 parameters, which were reduced to 8 components.

To determine the index of subsystems based on the results of PCA the method of assessing the distance to the critical level were used. To this end, for each subsystem "the worst sample" has been defined. It is multidimensional critical point, which reflects the worst set of values of all output parameters that characterize the subsystem. As a result of factor analysis using PSA large sets of parameters for each subsystem were reduced to a few components, the critical point reflects to the worst sets of values of all components.

Then the index estimates of subsystems for all of the analyzed cases can be interpreted as a function of weighted distance to the critical point. For each of the subsystems it can be calculated by the formula:

$$I_{sys} = \frac{\sqrt{\sum_{a=1}^{A}\left[\lambda_a\left(t_{a_n} - \min_n t_{a_n}\right)\right]^2}}{\sum_{n=1}^{N}\lambda_a},$$

I_{sys} – index of subsystem (is determined for each of them),

t_{a_n} – a-coordinate of the n-enterprise in the space of factors (principal components),

$\min_n t_{a_n}$ – minimum value for a given factors for each subsystem,

λ_a – the ratio of eigenvalues (characteristic roots) for a given factor for the subsystem,

A – number of factors allocated for the subsystem modeling by scree plot instrument[1],

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[1] *The scree plot is a useful visual aid for determining an appropriate number of principal components. The scree plot graphs the eigenvalue against the component number. To determine the appropriate number of components, an "elbow" in the scree plot are looking for. The component number is taken to be the point at which the remaining eigenvalues are relatively small and all about the same size*

N – number of enterprise.

Application of the PCA method in the research allowed us to determine the indexes of subsystems of each type for each enterprise. To integrate the results of modeling generalized indexes of object subsystem (I_{Ob}), environment subsystem (I_{En}), process subsystem (I_{Pc}) and project subsystem (I_{Pj}) were determined They were calculated for the group of analyzed enterprises by the arithmetic mean formula. The results of a generalized index of each type subsystems determination are presented in **Table 1.**

Table 1. A generalized index of subsystems of each type for the group of analyzed enterprises.

Subsystem type	*A generalized index of subsystem by years*											
	2004	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
Objects (I_{Ob})	0,91	0,91	0,90	0,89	0,89	0,86	0,83	0,86	0,87	0,79	0,79	0,81
Environments (I_{En})	0,44	0,44	0,41	0,45	0,47	0,48	0,46	0,47	0,47	0,41	0,33	0,40
Processes (I_{Pc})	0,48	0,47	0,46	0,46	0,43	0,40	0,37	0,37	0,44	0,43	0,43	0,39
Projects (I_{Pj})	0,71	0,68	0,68	0,68	0,65	0,67	0,69	0,70	0,66	0,71	0,69	0,71

The results of the econometric modeling and evaluation show that the ratio between the values of generalized indexes of the subsystems during the period was generally the same. The graphical display of ratio between the values of generalized indexes for the group of enterprises demonstrate the advantages of object and project subsystems in the overall structure of tetrad by each period as shown in **Figure 1**.

It confirms that in general for twelve years structural disproportions were very similar in nature. The most severe was the object subsystem – its share in overall structure of tetrad fluctuated within 33,9-37,4% (the average was 35,8%). The second subsystem by severity was the project – its share fluctuated within 27,3-31,0% (the average was 28,5%). Environment and process subsystems had almost the same, relatively lower severity. The share of environment subsystem fluctuated within 14,5-20,3% (the average was 18,1%), process subsystem – within 15,4-20,1% (the average – 17,6%.)

Based on the obtained indexes of the subsystems, the new indexes that characterize the intensity of interaction between the neighboring subsystems: objects and environments, environments and processes, processes and projects, projects and objects, were analytically determined. The character and features of interaction between the systems in tetrads are presented in more detail in [6,9,11].

The set of parameters which define indexes of the intensity of interaction between the neighboring subsystems was determined by the settlement-graphical way with the method proposed by M. Rybachuk [13]. To do this factor two-dimensional space in the Cartesian coordinates has been constructed for each case. More detailed our way of using this method is described in [7].

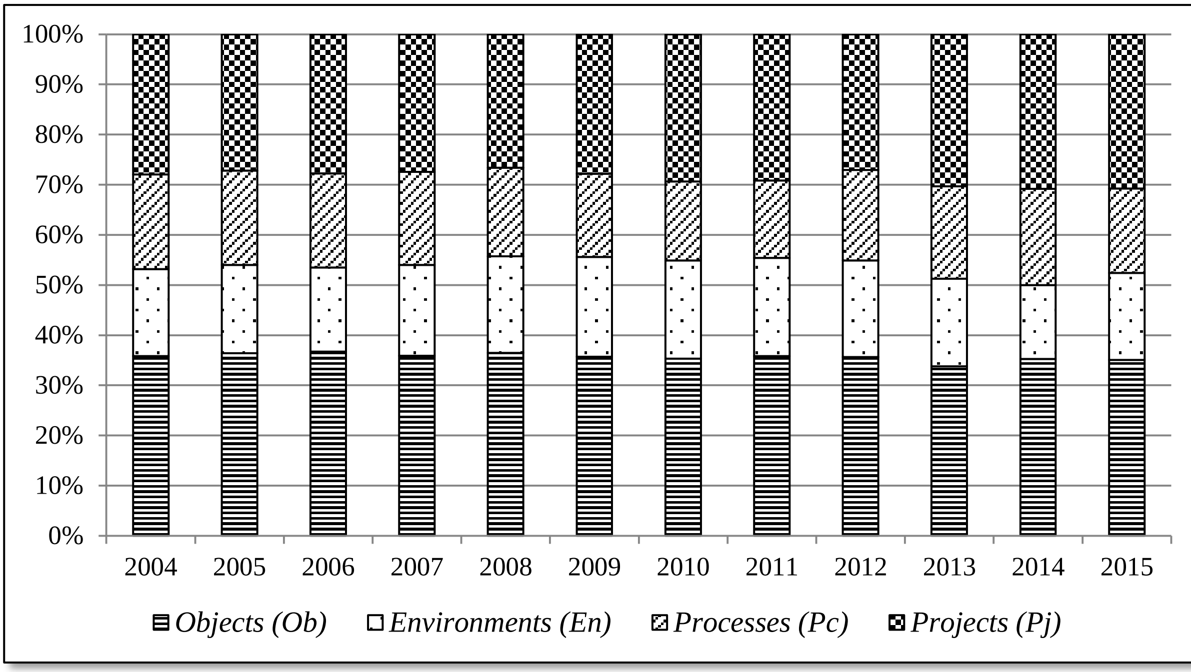

Figure 1. The share of each subsystem in overall tetrad structure of enterprises (generalized data)[2]

Similar to the above, to integrate the obtained results generalized indexes of the intensity of interaction between the objects and environments (*int (Ob-En)*), environments and processes (*int (En-Pc)*), processes and projects (*int (Pc-Pj)*), projects and objects (*int (Pj-Ob)*) have been determined. They were calculated for the group of analyzed enterprises by the arithmetic mean formula. The results of generalized indexes of the intensity of interaction between subsystems determination are presented in **Table 2.**

Table 2. A generalized index of the intensity of interaction between subsystems for the group of analyzed enterprises.

Pair of interacting subsystems	*A generalized index of the intensity of interaction by years*											
	2004	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
int (Ob-En)	0,51	0,52	0,51	0,52	0,54	0,55	0,55	0,56	0,54	0,50	0,47	0,52
int (En-Pc)	0,37	0,37	0,36	0,37	0,37	0,37	0,35	0,35	0,37	0,36	0,34	0,34
int (Pc-Pj)	0,49	0,49	0,50	0,48	0,46	0,45	0,45	0,44	0,46	0,50	0,54	0,48
int (Pj-Ob)	0,64	0,63	0,65	0,63	0,63	0,63	0,65	0,65	0,63	0,64	0,67	0,66

[2] *The ideal structure, which complies the optimal level of economic sustainability, corresponds to the equivalent severity of the four subsystems at the enterprise, i.e. the share of each subsystem should be about 25%*

The results of the modeling and evaluation show that the ratio of levels of intensity of interaction between the subsystems for the group of enterprises was generally almost the same. The graphical display of this ratio is shown in **Figure 2**.

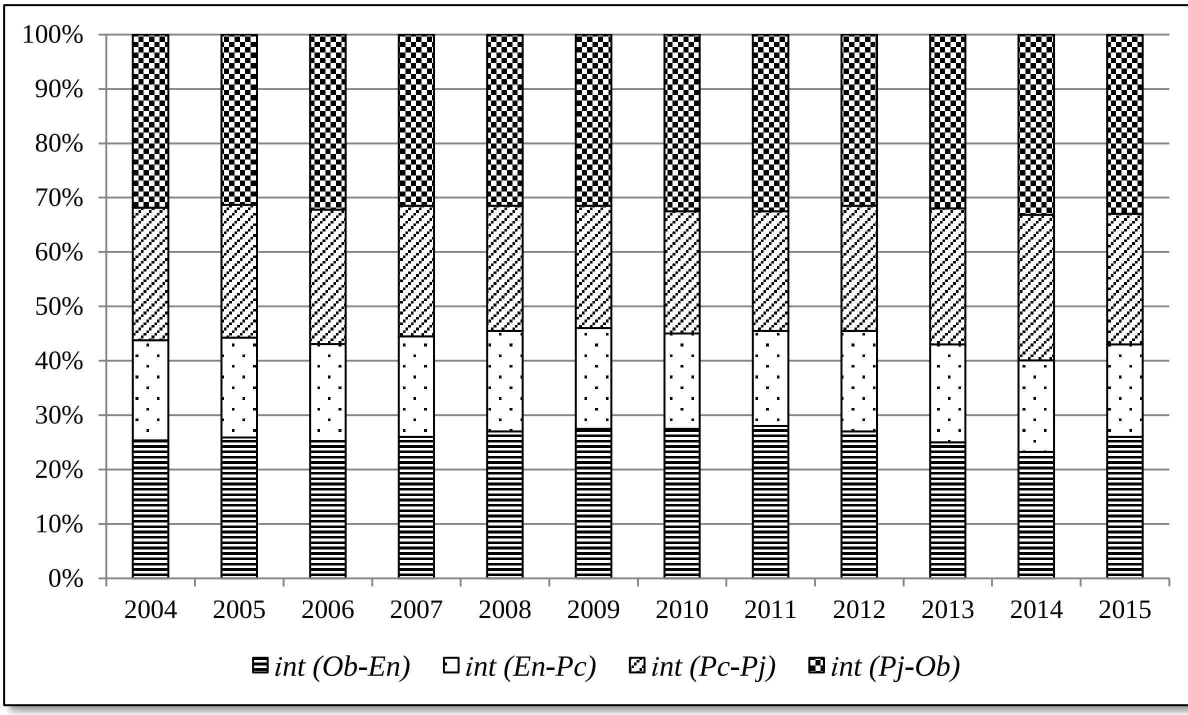

Figure 2. The ratio of the intensity of interaction between subsystems in each pair (generalized data)[3]

Finally, value of the intensity of interaction between subsystems allowed us to determine the index of system balance of tetrad, which determines the level of economic sustainability of enterprise.

If we denote *a = int (Ob-En), b = int (En-Pc), c = int (Pc-Pj), d = int (Pj-Ob),* indexes values form a four-dimensional space, and the point *S (a, b, c, d)* in this space indicates the position of each enterprise in terms of its system balance. According to the specific of our methods, the system is balanced, when $a_0 = 0{,}5$, $b_0 = 0{,}5$, $c_0 = 0{,}5$, $d_0 = 0{,}5$. So the point $S_0\ (a_0, b_0, c_0, d_0)$ reflects the ideal position of completely sustainable enterprise. Based on such considerations, numerical value of Euclidean distance from the point *S* to the "ideal" point S_0, which acts as index of system imbalance, was evaluated. On its basis the index of system balance as the difference between the maximum possible value of index of system imbalance and the one that had been calculated for each case was determined. The results of the calculation are generalized in **Table 3**.

To verify the hypothesis that the level of economic sustainability of the enterprise can really be determined on the basis of index of system balance of four internal subsystems

[3] In the ideal tetrad, which complies the optimal level of economic sustainability of enterprise, the intensity of interaction between subsystems in all pairs is approximately the same, i.e. its level should be about 25%

measurement and to identify the level of reliability of the results we found it necessary to conduct a correlation analysis. The statistical interrelations between the index of system balance and the results of calculations of already known financial ratios, which are commonly used as the indicators of sustainable enterprises, were analyzed. To reduce the set of financial ratios to a single integral indicator of financial stability the method of fuzzy logic was used. The results of the calculations of integral indicator of financial sustainability for each of the analyzed cases are also presented in **Table 3.**

Table 3. A generalized index of system balance and a generalized integral indicator of financial stability for the group of analyzed enterprises.

Indicator	*A generalized values by years*											
	2004	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
Index of system balance	0,84	0,85	0,84	0,83	0,84	0,82	0,83	0,80	0,76	0,76	0,73	0,73
Integral indicator of financial stability	0,40	0,39	0,39	0,41	0,42	0,37	0,35	0,33	0,32	0,34	0,31	0,29

Statistical correlation between the generalized index of the system balance and the generalized integral indicator of financial stability were assessed using Pearson's coefficient. Pearson's correlation coefficient for the period of 2004-2015 for these indicators was 0,901. Accordingly, we may conclude that the statistical correlation between the indicators is linear and close and the index of enterprise's system balance really reflects the level of its economic sustainability. The hypothesis has been confirmed.

3. CONCLUSIONS

The economic sustainability of the enterprise is ensured the coherent implementation of the system functions by each of four subsystems, which are the foundation of functionality of the tetrad. The infringement of functionality is reflected in dysfunctioning or hyperfunctioning of some subsystems comparing to the others and their mutual perimetric imbalance. Consequently the infringements of functionality lead to a violation of the economic sustainability. We also used the methods that allow us to formalize and graphically display the types of the balance infringements, which may occur in the system and determine the reducing of the enterprise sustainability.

Based on the research, we have identified the general systems and structural imbalances which are inherent to Ukrainian machine-building enterprises. Over-severity of the objective subsystems is indicating the ineffectiveness of segmentation of enterprises' employees, their low workload, incoordination of departments, ineffectiveness of administrative and management activities and expenses and so on. Over-severity of the project subsystems primarily is indicating the ineffectiveness of innovation and investment activities at the enterprises, inefficient mechanism of selecting projects for implementation and their discrepancy to strategic priorities of the enterprises. Lack-severity of the environment subsystems is indicating the weakness of the organizational culture of the enterprises, high degree of uncertainty, unfavorable organizational climate. And lack-severity of the process subsystems is indicating the fragmentation, diminution of the main production activities of the enterprises and their low efficiency. Further researches should be focused on the development of methods of management of economic systems, which are differentiated by the type of tetrad structure. Such methods should be directed to the maintenance of the parity of object, environment, process and project subsystems in general economic system. It is base of economic sustainability of system.

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