ATLANTIS PRESS

Structural Entropy of Economic Systems

Arkady Sukhorukov [0000-0002-1608-3934], Olga Sukhorukova [0000-0001-7157-8270]

I. Sikorsky Kyiv Polytechnic Institute, Kyiv, Ukraine
* aris47@ukr.net

ABSTRACT

The results of the study contain methodological approaches to assessing structural factors affecting the development of the economy. The interrelation of structural deformations and entropy processes affecting the stability of the economic system and the economic security of the state is revealed. The features and economic parameters of countries with economies in transition are revealed, in which the sectoral and technological structure of the economy, the proportions of the balance of payments and trade balance are radically changing; structure of exports of goods and services; employment structure. The concept of "structural entropy" has been introduced into scientific circulation, which characterizes the narrowing of the sectoral structure of the economy and a decrease in synergetic opportunities for economic development. The reasons for the weakening of links between the elements of the economic system and the impact of structural deformations on the economic development of countries with economies in transition are considered. The analysis of the possibilities of economic development of these countries within the framework of regional integration is carried out, an assessment of the convergence of countries belonging to regional unions is carried out. The structural conditions of economic evolution and convergence are substantiated. Recommendations were developed for the formation of institutional and innovative mechanisms to ensure positive structural changes in the national economy. The proposals aimed at counteracting structural deformations and increasing the synergistic potential of systems are presented.

Keywords: Economic system, Structural factors, Entropy processes, Synergetic potential, Regulatory policy.

1. INTRODUCTION

Transitional countries choosing the paradigm of market development and moving to a new political and socio-economic system, as a rule, abandon protectionism and form an open economy. An open national economy is subject to global competition and cyclical fluctuations. In these conditions, the structure of the national economy is radically changing, which affects the internal cooperative ties and the structure of foreign trade. Structural deformations can threaten the stability of the economic system, provoke structural entropy and the loss of synergetic characteristics of the economy. Revealing the causes and consequences of structural deformations and entropy processes in transitional economic systems is an urgent scientific task.

2. RESEARCH METHODOLOGY

The study of the influence of structural factors on economic development has been the subject of research by many scientists [1-4]. In particular, P. Romer proved the advantages of the model of the growing variety of goods produced by the country's economy. Reinert argues that the structure of each country's economy must constantly expand through the introduction of new high-tech economic activities. Entropic processes can be contained by improving communications and developing information technology [5-9]. Thus, it is possible to neutralize the factor of information asymmetry in the markets. However, the main factor in restraining entropy processes is to expand the structure of the national economy and provide it with synergistic opportunities.

The studies of the authors of the article, carried out from the standpoint of a systemic, structural, comparative and institutional analysis, show that only a developed structure of the economy can provide reliable and high-quality growth in the welfare of society. The research results contain methodological approaches to assessing the structural factors of economic development, substantiation of the structural conditions for economic evolution, recommendations for the formation of appropriate institutional and innovative mechanisms.

3. RESULTS OF THE STUDY

The main risk for countries with economies in transition is the loss of integrity and structural diversity. Replacing successive economic reforms with "shock therapy" increases the risk of degradation in transition countries. In addition, shock therapy measures are designed for a short period and do not provide for strategic development [10].

If project management at the microeconomic level is effectively used and regulated by standards, then at the macroeconomic level there are no standardized procedures to justify reforms. Management methods within an open economic system of countries with economies in transition should meet the following basic requirements: the system should take into account cyclical and entropic processes; entropic processes must be resisted by the synergetic capabilities of the system; the system must be balanced in terms of the interaction of subsystems and management levels.

Structural entropy in systems is characterized by structural imbalance, loss of systemic integrity and synergistic opportunities. Entropic processes can be intensified by the cross-border spread of unfavorable situations in the context of a global crisis. A parallel study of the development trajectories of leading and transitional countries over the past decades shows that the crisis stage in developed countries is smoothed out, and transitional countries are experiencing unnecessarily long crises [11]. The convergence of countries with different economic systems can only be achieved through effective restructuring of the economies of countries with economies in transition.

Economic evolution should be considered, first of all, as a diversity of the structure of the economy, that is, the preservation of important and the deployment of new structural elements, taking into account the requirements of the modern market. The national economy is the result of long-term development and has certain geographic, resource, structural and institutional characteristics. The diversity of the structure of the economy contributes to the emergence of opportunities for obtaining a synergistic effect, the development of the most progressive form of international relations - industrial and scientific and technical cooperation, based on the technological compatibility of economies of different types.

Therefore, it is so important to systematically monitor the structural proportions of the economy. In particular, it is necessary to constantly analyze the sectoral and technological structure of the economy. Also subject to analysis: the structure of the balance of payments and trade; structure of exports and imports of goods and services; employment structure; public debt structure and convergence indicators. This makes it possible to assess the performance of the government in terms of compliance with socio-economic criteria.

Within the framework of the system for ensuring the economic security of the state, first of all, it is necessary to monitor the ratio of the contribution of various sectors of the national economy to the formation of gross domestic product (GDP).

The example of Ukraine clearly shows that in an open economy and as a result of global competition, the real sector of the economy, in particular the country's industry, is gradually losing its competitiveness in world markets. The share of agriculture in the structure of Ukraine's GDP increased (in 2010 it was equal to 8.42%, at the end of 2019 - 9.01%), the share of industry over the same period decreased from 21.60% to 16.43%, the share of the service sector increased. from 69.98% to 74.56%. Thus, the share of services has almost reached 75%, which, according to D. Bell, is the main indicator of the formation of a post-industrial society [12].

The contradiction is that the post-industrial economy cannot compensate for the loss of positions in industrial sectors. In the structure of Ukraine's merchandise exports, the growth of the share of agricultural products is even more noticeable, at the end of 2010 it amounted to 14.1%, at the end of 2020 - 38%. During the same period, the share of chemical products in merchandise exports decreased from 8.1% to 5.5%, the share of metallurgy products decreased from 33.7% to 18.5%, the share of engineering and transport equipment products decreased from 17.8% to 11.1%.

In connection with the formation of a post-industrial economy in Ukraine, the structure of Ukrainian exports of services is of interest. The share of transport services increased significantly (from 3.82% in 2010 to 43.97% at the end of 2020). The volume of tourism services decreased over the same period from 63.58% to 2.42%, which indicates, first of all, the stagnation of the tourism industry. The share of construction services also decreased (from 3.09% to 0.59%). The share of services related to the use of intellectual property decreased from 3.87% to 0.82% due to the outdated technological structure of the national economy and a decrease in the country's competitiveness in the scientific and technical sphere. A positive trend was the growth in the share of information and communication services (from 0.34% to 25.90%).

Asymmetry of economic relations between countries with economies in transition and developed countries leads to the formation of an unfavorable structure of exports and imports of countries with economies in transition, a negative balance of their foreign trade and a deterioration in the balance of payments. This trend is typical for the indicators of Ukraine's foreign trade (Table 1).

Table 1 Balance of payments and trade balance of Ukraine for the period 2010 - 2020 (mln USD)

Indicator name	2010	2013	2018	2019	2020
Balance of payments	5031	2023	2877	5980	1979
Trade balance	-3982	-15634	-11378	-12511	-1677

The study logically leads to conclusions about the negative impact of the irrational sectoral structure of the economy and the structure of the country's foreign trade on the level of employment, indicators of debt security and indicators of economic convergence of a given country in relation to other countries. in this region of the world.

The unemployment rate in Ukraine remains high, given that the pressure on the labor market is to some extent offset by high labor migration. In addition, the unemployment rate is gradually increasing (Table 2).

Table 2. Employment rates in Ukraine

Indicator name	2010	2013	2018	2019	9 months 2020
Employed working age population	65,5	67,3	66,1	67,6	65,9
Unemployed population of working age	8,9	7,8	9,1	8,6	9,7

Debt security indicators of Ukraine remain unsatisfactory. In particular, for the period 2010-2016. Public debt increased from 34.7% to 81.0% in relation to GDP. Despite the decrease in the level of public debt in recent years, as of 01.01.2021 it remains at the level of 67.3%. Practice shows cases when Ukraine could not cope with the payment of public debt, as soon as the level of this debt exceeded 30% in relation to GDP. Loans, even with the lowest interest rates, do not support the development of an economic system if it is not attractive for investment. The economy cannot effectively use loans if the country does not have reliable points of application and favorable institutional conditions for real investment.

The European integration of Ukraine was aimed at bringing the country's development parameters closer to the level of development of other countries. However, the real indicators of convergence, calculated according to the IMF and other international organizations, show that the level of socio-economic indicators in Ukraine lags significantly behind the indicators of other European countries (Table 3).

According to the conclusion of J. Sachs and E. Warner [13], the economic convergence of a country is impossible if this country "precariously protects property rights, if there is an unstable situation in the country caused by revolutions and civil unrest, or there is a protracted war".

Table 3. Indicators of economic convergence of Ukraine relative to other European countries

Macroeconomic indicators	Germany	France	Poland	Ukraine
GDP per capita (according to purchasing power parity), USD	56278	49435	34431	13341
Average salary, euros	2531	2225	890	288
Budget revenue, billion USD	1729,2	1334,9	236,5	55,6
Expenditure side of the budget, billion USD	2038,3	1609,7	297,2	66,7
Budget Deficit to GDP, %	8,18	10,77	10,46	7,81
Research costs,% to GDP	3,09	2,20	1,21	0,47
Health expenditure per capita, USD	5472	4690	979	228

The national economy can for a long time by inertia to show business activity, despite all the troubles caused by the dependence of the development of countries on the institutional system that has developed historically [14]. The principles that allow countries with low development parameters to survive for a long time are: the presence of a hyperselective effect, due to which individual institutions, despite their weak competitiveness, nevertheless retain certain market niches; the principle of heterogeneity, which explains why systems with a diverse structure, containing dissimilar elements, adapt most rapidly to abrupt changes [15].

The study shows that only the structural diversity of the economic system can provide agility, diversification, decrease in entropy and obtain a synergistic effect in the management process. The convergence of the development parameters of countries of different levels of development is possible as a result of the co-evolution of the economic systems of these countries, their participation in the

implementation of effective production, innovation and logistics projects. To this end, countries with economies in transition must maintain technological compatibility with developed countries in specific sectors of the respective region of the world [16-18].

On the contrary, the asymmetric nature of international relations leads to the structural entropy of the economic systems of countries with economies in transition. The evolutionary development of countries with economies in transition can occur only through diversification of the structure of the economy, the acquisition of flexibility in markets and rapid adaptation to innovative changes [19].

Evolutionary development, if we understand by it the expansion of the diversity of the economy, should be based on methods that ensure systemic reform of all sectors of the economy and their mutual capitalization.

The real sector of the economy in transition needs modernization based on the model of "open innovation" [20], which provides for the interaction of large, medium and small companies, as well as individual innovators. Support for innovative development should be carried out through state regulatory policy, the formation of a system of state grants, tax incentives and tax holidays for companies reinvesting profits in innovation. The development of digital modernization of industry requires the harmonization of the initiatives of countries with economies in transition with the initiatives of the European Union (Digital Agenda for Europe, Single Digital Market).

The alignment of regional disparities is possible through the joint implementation of several development directions. In particular, it is necessary to develop a strategy for the country's specialization and the formation of a single industrial complex based on closed value chains in the form of national and cross-border clusters. It is also necessary to involve the country in the European policy of specialization based on the Smart Specialization Platform - the S3 platform. To train professional managers capable of working in the conditions of national and international clusters, it is necessary to develop and implement special training programs.

The development of the institutional foundations of economic evolution requires the formation of long-term strategies for the development of the industrial complex and a constant dialogue between the state and industry associations on customs policy.

The role of international communication projects is significantly increasing, which should ensure: acceleration of transportation; optimal tariffs for transportation; transportation safety; multimodality; development of logistics infrastructure; improving the rules of international transport; joint investments.

For the innovative modernization of the transport industry in Ukraine, it is necessary to comprehensively implement the following measures:

- develop a national combined transport program and ensure its integration with the European multimodal network (TEN-T);

- to strengthen the role of air transport and seaports in increasing the efficiency of transport corridors based on multimodality;

- update the program for the development of transport corridors, a network of logistics centers and multimodal transport operators;

- to develop a long-term strategy for the development of transit potential, providing for an increase in the efficiency of servicing transnational routes;

- develop a long-term logistics strategy to improve transport compatibility, increase transport speed and stimulate energy efficiency projects.

4. CONCLUSIONS

The main characteristic of economic evolution is an increase in the degree of complexity and diversity of the structure of the economy. In a transitional economy that is influenced by global competition and is not properly integrated into international cooperation, the structure of the economy can narrow and simplify. First of all, this concerns the technological structure of the economy. In connection with this phenomenon, the authors of the article introduced the concept of "structural entropy of economic systems" into scientific circulation.

The conclusions and proposals of the article are aimed at the systemic elimination of structural deformations, the creation of opportunities for obtaining synergistic effects in the real sector of the economy, and the leveling of regional imbalances within the country. Proposals can be implemented in a comprehensive manner, subject to the basic principles of investment policy. These principles are: the principle of compliance with the investment rate in relation to the gross domestic product; the principle of chain capitalization of industries; the principle of combining investment with innovation; the principle of optimal placement of investments in the regions of the country; the principle of the integrated use of investment potential through the creation of industrial parks, national and international clusters.

Within the framework of the mechanism of the structural evolution of the economy, the main directions for the accumulation of investments, priority areas and conditions for their complex use are proposed due to the parallel implementation of institutional and technological changes in the national economy. Ways

of solving these problems are also proposed, taking into account national and international economic security. Further research can be aimed at a deeper study of the problems of structural entropy, taking into account the specifics of individual countries.

REFERENCES

[1] Lukinov, I.I. (2002), *Evolyutsiya ekonomicheskih sistem* [Evolution of economic systems], Ekonomika, Moscow, Russia, 568 p.

[2] Heiets, V.M. (2011), *Strukturni zminy ta ekonomichnyi rozvytok Ukrainy* [Structural changes and economic development of Ukraine], IEP, Kyiv, Ukraine, 696 p.

[3] Romer, P. (1986), "Increasing Return and Long Run Growth", *Journal of Political Economy*, vol. 94, No 5, pp. 1002-1037.

[4] Rainert, E. (2018), Yak krainy zbahatyly i chomu bidni krainy lyshaiutsia bidnymy [Yak krainy zbahatyly i chomu bidni krainy lyshaiutsia bidnymy], Tempora, Kyiv, Ukraine, 452 p.

[5] Sukhorukov, A.I. and Sukhorukova, O.A. (2018), "Institutional and communication mechanisms of international economic convergence of Ukraine", Naukovyi visnyk Uzhhorodskoho natsionalnoho universytetu. Seriia «Mizhnarodni ekonomichni vidnosyny ta svitove hospodarstvo», vol. 17, part 2, pp. 100-103.

[6] Alakbarov, R.G. (2020), "Method for Effective Use of Cloudlet Network Resources", *International Journal of Computer Network and Information Security,* vol. 12, №5, pp. 46-55.

[7] Fajri, A. and Sinaga, A. (2020), "Implementation of Business Intelligence to Determine Evaluation of Activities (Case Study Indonesia Stock Exchange)", *International Journal of Information Engineering and Electronic Business,* vol. 12, № 6, pp. 51-67.

[8] Muhammad Junaid Arshad, Muhammad Umair, Saima Munawar, Nasir Naveed, Humaira Naeem (2020), "Improving Cloud Data Encryption Using Customized Genetic Algorithm", *International Journal of Intelligent Systems and Applications,* vol. 12, №6, pp. 46-63.

[9] Muhammad Zulqarnain, Rozaida Ghazali, Muhammad Ghulam Ghouse, Yana Mazwin Mohmad Hassim, Irfan Javid (2020), "Predicting Financial Prices of Stock Market using Recurrent Convolutional Neural Networks", *International Journal of Intelligent Systems and Applications,* Vol. 12, No. 6, pp. 21-32.

[10] Stiglits, Dzh. (2003), *Globalizatsiya: trevozhnyie tendentsii* [Globalization: alarming trends], Natsionalnyiy obschestvenno-nauchnyiy fond, Moscow, Russia, 304 p.

[11] Sukhorukov, A.I. (2019), "International economics: security of economic system and transboundary crisis", *Confrontation and Cooperation: 1000 years of Polish-German-Russian Relations,* vol. 5, pp. 35-44.

[12] Bell, D. (2004), *Gryaduschee postindustrialnoe obschestvo. Opyit sotsialnogo prognozirovaniya* [The coming post-industrial society. Experience of social forecasting], Academia, Moscow, Russia, 944 p.

[13] Saks, Dzh. D. and Vorner, E. (1995), "Economic convergence and economic policy", Voprosyi ekonomiki, №5, pp. 13-38.

[14] Maevskiy, V. (1997), *Vvedenie v evolyutsionnuyu makroekonomiku* [An Introduction to Evolutionary Macroeconomics], Yaponiya segodnya, Moscow, Russia, 11 p.

[15] Sukhorukov, A.I. and Ostapchuk, D.O. (2014), "Synergetic mechanism of formation of the system of economic security of the state", Ekonomichnyi chasopys XXI, №1-2, pp. 19-23.

[16] Chesbrough, H. (2006), *Open Business Models. How to Thrive in the New Innovation Landscape,* Boston: Harvard Business Review Press, 272 p.

[17] Gaurisha Sisodia, Kapil Sharma, Shashikant Gupta (2018), "Intuitionistic Fuzzy Weighted Sum and Product Method for Electronic Service Quality Selection Problem", *International Journal of Modern Education and Computer Science*, №9, pp. 33-43. DOI: 10.5815/ijmecs.2018.09.05.

[18] Rinku Sharma, Reema Ganotra, Sangeeta Dhall, Shailender Gupta (2018), "Performance Comparison of Steganography Techniques", *International Journal of Computer Network and Information Security,* № 9, pp. 37-46. DOI: 10.5815/ijcnis.2018.09.04.

[19] Vijaya Kumar, S. and Nagaraju, C. (2018), "Fuzzy Entropy based Impulse Noise Detection and Correction Method for Digital Images", *International Journal of Image, Graphics and Signal Processing,* № 3, pp. 36-46. DOI: 10.5815/ijigsp.2018.03.05.

[20] Wang LinLin and Chen Yunfang (2017), "Diversity Based on Entropy: A Novel Evaluation Criterion in Multi-objective Optimization Algorithm", *International Journal of Intelligent Systems and Applications*, № 10, pp. 113-124. DOI: 10.5815/ijisa.2012.10.12.