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МЕРЕЖЕВІ МОДЕЛІ РЕГІОНАЛЬНИХ ЕКОНОМІЧНИХ СИСТЕМ

Актуальність. Моделювання розвитку регіональних економічних систем є актуальним завданням у зв'язку з реформою децентралізації системи управління і адміністративно-територіального устрою в Україні, яка передбачає надання більших повноважень регіонам та створює нові можливості для економічного розвитку територій.

Мета та завдання. Метою статті є моделювання регіональних економічних систем для виявлення їх оптимальної структури і чинників, які найбільшою мірою сприяли б їх розвитку, а також вивчення можливості застосування математичного апарату теорії графів.

Результати. Виявлені фактори, що сприяють розвитку регіональних економічних систем. Виявлено зв'язок децентралізації з мережевою структурою сучасної економіки. Введено поняття квазіфрактальної економічної системи. Показана можливість застосування апарату теорії графів для вивчення регіональних економічних систем. Наведені приклади завдань, пов'язаних з функціонуванням економічних систем, які можна формулювати і вирішувати в термінах теорії графів. Досліджено роль населення як сполучної ланки в регіональних економічних системах. Визначені основні параметри, що характеризують розвиток регіональних економічних систем: якісна складність і наявність замкнутих контурів. Виявлено роль топологічного сортування в вивченні структури економічних систем. Зазначено на взаємозв'язок між територіально-адміністративними одиницями і структурою регіональних економічних систем.

Висновки. При дослідженні регіональних економічних систем досить ефективним є структурний підхід із застосуванням апарату теорії графів, який дозволяє формулювати і вирішувати завдання, пов'язані з моделюванням цих систем. Вивчення структурних властивостей економічних систем дозволить виявити закономірності розвитку соціально-економічних систем і прогнозувати цей розвиток.

Ключові слова: децентралізація, регіоналізація, глобалізація, фрактальність, мережі, граф, самовідтворення, економічна система.

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NETWORK MODELS OF REGIONAL ECONOMIC SYSTEMS

Topicality. Modeling the development of regional economic systems is an urgent task in connection with the decentralization reform of the management system and administrative-territorial structure in Ukraine, which creates new opportunities for the economic development of territories.

Aim and tasks. The aim of the article is to model regional economic systems to identify their optimal structure and factors that would most contribute to their development, as well as to study the possibility of applying the mathematical apparatus of graph theory.

Research results. The factors contributing to the development of regional economic systems and the link between decentralization and the network structure of the modern economy are identified. The concept of a quasi-fractal economic system is introduced. The possibility of using the apparatus of graph theory to study regional economic systems is shown. Examples of problems associated with the functioning of economic systems that can be formulated and solved in terms of graph theory are given. The role of the population as a link in regional economic systems is investigated. The main parameters characterizing the development of regional economic systems are identified: qualitative complexity and the presence of closed cycles. The role of topological sorting in the study of the structure of economic systems is revealed. The relationship between the territorial-administrative units and the structure of regional economic systems is indicated.

Conclusion In the study of regional economic systems, a structural approach using the graph theory apparatus is quite effective. It allows to formulate and solve problems associated with the modeling of these systems. The study of the structural properties of economic systems will reveal the patterns of development of socio-economic systems and predict this development.

Keywords: decentralization, regionalization, globalization, fractality, networks, graph, self-reproduction, economic system.

Problem statement and its connection with important scientific and practical tasks. The decentralization of the management system and administrative-territorial structure in Ukraine requires a careful study of the mechanisms of functioning of regional economic systems and the links between them. In this regard, there is a need to model these systems, using, among other things, graph theory.

Analysis of recent publications on the problem. Many scientific researches are devoted to theoretical and methodological directions of formation and development of regional economic systems. Well-known foreign scientists have made a great contribution to the development of this topic: D. Bracchi, A. Weber, A. Granberg, K. Jean, W. Barnes, L. Ledebur [2]. The works of M. Castells [1], V. Inozemtsev, V. Popkov, and D. Berg [3] were devoted to the analysis of the network structure of society and economy.

A significant contribution to economic theory on the problems of regional development and strategic management at the regional level has been made by Ukrainian scientists, such as: L. Antonyuk, A. Amosha, Y. Bazhal, I. Blank, E. Beltyukov, B. Burkinskyi and other scientists.

Allocation of previously unsolved parts of the general problem. Despite the fact that various scientists [2], [3], [7] have tried to study regional economic systems in terms of their network structure, it is necessary to further develop this structural approach to create economic and mathematical models to solve practical problems of regional economy management.

Formulation of research objectives (problem statement). The aim of this study is to find out the possibility of modeling regional economic systems by means of graph theory to identify their optimal structure and factors that affect their stability and ability to self-reproduction.

An outline of the main results and their justification. The decentralization reform carried out in Ukraine is objectively necessary, as it meets current trends in the development of society and the economy. Its component is an economic decentralization.

The development of regional economic systems is favored by the following factors:

- 1) the minimum transportation costs of enterprises in case of their concentration within one region
- 2) self-reproducing economic processes in the regional economy, which have a cycle structure
- 3) the presence of sustainable social ties, which promotes trust between subjects of economic activity and reduce the transaction costs.

In addition, it is important to note the binding between decentralization policy and the network structure of modern society and economy. A characteristic feature of modern society is its network structure. This is usually associated with the development of information technology [1]. In particular, economic processes in modern society are organized according to the principle of networks [2] to a large extent. It contributes to their intensification and mutual influence. We observe that the frequency of interactions between two nodes is higher if they belong to the same network [1], and changes in one part of the network immediately cause changes in another [2].

Decentralization of management is an essential property of any network structure. Its manifestations are such outwardly opposite processes as regionalization and globalization, which are in dialectical unity. Economic networks are open structures that can expand indefinitely by including new nodes if they have similar production tasks [1]. Networks can develop both in depth (regionalization) and in breadth (globalization). V. Barnes and L. Ledebur [2] consider a new economic paradigm, according to which it is economic regions that are the structural units, “building blocks” of the national economy. At the same time, they emphasize that the national system of economic regions is open and in connection with other national economic systems. In fact, economic regions are becoming particles of the global world economy. In connection with the foregoing, we can conclude that the decentralization of the management system and the administrative-territorial structure is nothing more than bringing the management structure in line with the structure of the economy.

Any modern economic system can be considered as a hierarchy of networks in which individual networks are nodes from the point of view of a higher level network [3]. At each level, the network structure locally has the following form:

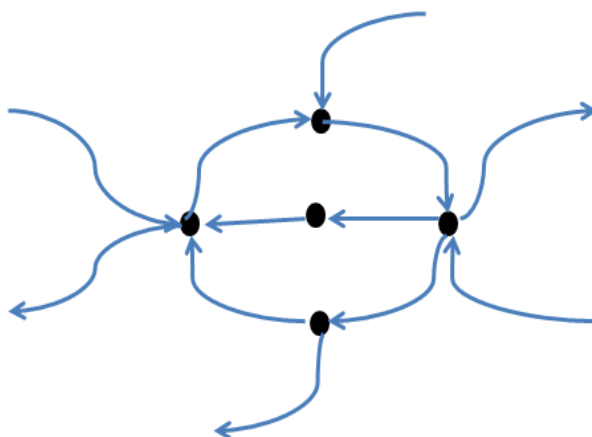


Fig. 1 Types of connections in the local economic system.

Elements of the subsystem can interact in different ways with the external environment, as shown in Fig. 1. We see that our system has the property of self-similarity in a somewhat loose sense, therefore it can be called quasifractal [4].

As a mathematical apparatus describing the network economy, one can naturally choose graph theory. A network (in the mathematical sense) will be called an oriented connected graph without cycles. The network we are considering is not, generally speaking, a transport network [5]. In economics, the vertices (nodes) of the network correspond to enterprises or local economic systems. The arcs (oriented edges) correspond to connections between them, which are expressed in the movement of goods from one enterprise (system) to another. Arc flow is the value of the corresponding product.

Let us now consider the regional economy as a local network, which is a subset of some comprehensive network. Note that a network is by definition connected. We have accepted this assumption consciously. The presence of closed commodity circuits (cycles) in the local network can be considered [3] as the basis for the stability of a local network. Cash flows are generated inside of these cycles that feed the regional economy and ensure its self-reproduction.

The concept of self-reproducing (autopoietic) systems was borrowed by economists from biology [6] and this analogy turned out to be quite effective [7]. Until now, economics has focused on the financial performance of enterprises, rather than the structure of their relationships. At the same time, it is a structural approach that can generate new ideas in economic management at all levels. For example, when investing in a region, you can direct funds in such a way that the maximum number of cycles occurs and thereby stimulate the development of the regional economy. Apparently, this can be achieved primarily due to the manufacturing industry. In addition, with this approach, there is additional justification for the need to diversify the range of products by regional enterprises. The fact is that diversification provides additional opportunities for building local closed product circuits. It seems that the structure of the network itself

imposes management decisions on us. In the words of M. Castells: "The power of structure is stronger than the structure of power."

It is possible to formulate various problems in terms of graph theory, for example:

- 1) What is the minimum investment needed to build a cycle in this economic system and what structure of the expanded network will be optimal?
- 2) How to maximize the flow along a certain path (cycle)?
- 3) How to find all the cycles in a given network?
- 4) How to optimize transport routes in the network?

If in a particular case we are considering a transport network [5], then we can also pose the problem of maximum flow and minimum cost flow.

Some of these problems are solved by mathematical methods. For example, task 3) is solved using the DFS (depth-first search) algorithm [8], and task 4) leads to the well-known Steiner problem of finding the shortest network connecting a given finite set of plane points. For other problems, mathematical terms allow only a short and precise formulation of the problem, and the solution requires a detailed economic analysis and the use of additional technologies. Moreover, this is not excluded even in the case when it is possible to find an exact or approximate solution to the problem by mathematical methods. For example, a practical solution to problem 4) in addition to the mathematical approach [9] requires effective control (in particular, the implementation of a GPS monitoring system).

In addition to the presence of cycles, such a parameter of the regional economic system is of interest as its complexity, which we will consider as a measure of economic development "in depth", the number of stages of processing of raw materials. We propose the concept of complexity as the average length of the path (cycle) in the network. This understanding of complexity is of a qualitative nature, in contrast to such quantitative network parameters as order (number of vertices) and size (number of arcs). The qualitative complexity of the system and the presence of closed cycles in it are related factors. With increasing complexity of the system and increasing the variety of manufactured goods (services), the likelihood of the formation of new paths in the network, including closed ones, increases.

An interesting effect can be obtained if the population is included in the network along with enterprises as a separate node. Having examined the networks corresponding to various local economic systems, we can notice the star-shaped geometrical structures in the center of which there is a vertex corresponding to the population:

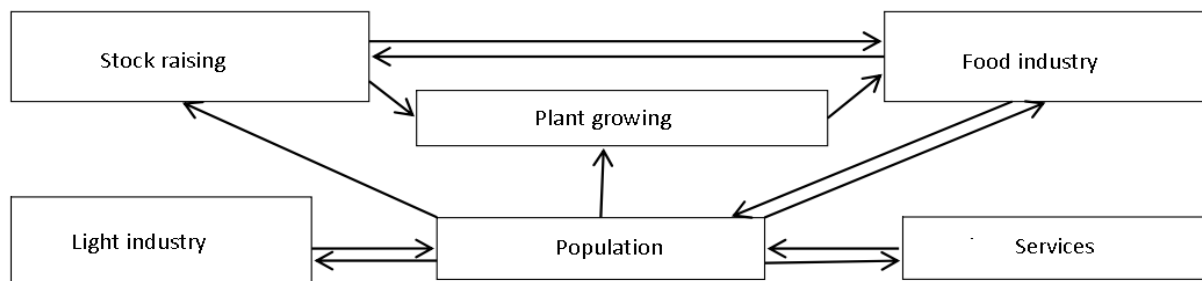


Fig. 2 Population as an element of the regional economic system *

* - compiled from the materials of article [3].

Figure 2 shows a typical scheme of this kind, which leads us to the conclusion about the important role of the population: it plays the role of a connecting link in the network, and ensures the network connectivity in the mathematical sense. Therefore, for the development of the regional economic system, it is important to produce goods and services to meet the needs of the population included in this system. Moreover, small and medium-sized businesses play a significant role here: the local market is just that niche in the economic system that it is able to occupy.

It seems important to identify factors affecting the specialization of the regional economy. These can be considered:

- 1) the availability of sources of raw materials
- 2) historical conditions
- 3) natural and geographical conditions
- 4) the location of the region relative to the flow of goods.

An equally important task for the analysis of the regional economy is to find enterprises that determine the economic specialization of the region. To solve it, it may be useful to use graph theory, namely, topological sorting [8] of the corresponding network. At the same time, we get several levels that form the hierarchy of the network. The first level will automatically include enterprises (peaks), which are sources, “growth points” of the regional economy that determine its specialization.

If the network contains cycles, then topological sorting in the strict sense is impossible. In order to implement it, you will have to perform some transformations on the network to eliminate cycles. For example, neglect low flow arcs.

Conclusions and perspectives of further research. The process of decentralization must be considered in connection with the network structure of the economy. When modeling regional economic systems, a structural approach using the apparatus of graph theory is effective. It allows you to formulate and solve practical problems associated with the functioning of these systems. These tasks can be related to regional investment policy, stimulating the intensive economic development of regions and interregional relations, building a logistics infrastructure in the region, etc.

And finally, back to the question we started with, about the correspondence between administrative and economic transformations. Considering the above, it would be reasonable to assume that each of the territorial-administrative units formed during the reform will correspond to the existing economic network in the region, which is branchy enough and does not break up into separate subnets.

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