Cognitive analysis of sustainable regional economic growth factors

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Abstract. In modern conditions of digital transformation of the economy, the task of ensuring sustainable, balanced growth of the region as a complex socio-economic system acquires a special role. One of the important areas of study of socio-economic systems is the analysis of patterns and trends in their development. The region should be considered as a complex system, consisting of a set of its subsystems and elements with many links. In order to solve this problem, we propose to use a cognitive approach to the study of the factors of sustainable economic growth of the region. This approach allows us to develop formalized models of interaction between various factors of complex, weakly structured systems. The aim of this research is to carry out a cognitive analysis of interregional and external factors of economic development, which allows highlighting their spatial location and the threats and risks of regional growth. Four resultant indicators of sustainable economic growth in the region are identified, and factor attributes are grouped into economic, social, demographic, and digital transformation indicators. The target factors of the cognitive map are defined, the connectivity analysis is carried out and the process of perturbation propagation in the graph is studied, which allows identifying the reserves for achieving sustainable economic growth in the region. The results of the study are explained in the cognitive maps of the interconnectedness of the region's growth factors.

1 Introduction

One of the most discussed issues attracting the attention of scientists and practitioners at the state, regional and local levels is the formation of sustainable economic growth driven by transformational processes based on the implementation of digital technologies. An adequate choice of techniques and tools for developing an optimal model of sustainable development of a particular territory should be based on socio-economic indicators of a quantitative and qualitative nature.

To solve these problems there are many private and general theoretical approaches and methods, which include: methods of expert, statistical, analytical identification, methods of graph theory, control methods, etc.

In recent years, cognitive analysis has become actively used to study the behavior of problem-oriented complex systems, which allows establishing cause-effect relationships and...
2 Materials and Methods

The ability to maintain a stable economic situation and improve the standard of living of the population in such a complex system as a region is assessed using various indicators. Economists have not come to a unified classification of regional development factors, let us give a number of examples, Table 1.

Table 1. The region's development factors.

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<tr>
<th>№</th>
<th>Authors</th>
<th>Factors</th>
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<tr>
<td>2</td>
<td>N.V. Ostrovsky [6]</td>
<td>1) economic—factors determining the dependence on external influences (energy and raw material sources, products, labor, consumers); 2) social—indicators of income and expenditures of the population, employment and unemployment, demography; 3) environmental—factors that allow assessing the availability of natural resources in the social and economic spheres, as well as the state of the environment.</td>
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<td>3</td>
<td>Kuznetsova O. В. [5]</td>
<td>1) &quot;objective&quot;, which include the place of the region in the general system of the territorial organization of the country, the type of development and level of development of the region, its economic and geographical position, natural conditions and resources, population and settlement, structure, level of development and features of the economy of the region; 2) &quot;subjective&quot;—state and municipal socio-economic policy.</td>
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<tr>
<td>4</td>
<td>A. G. Granbe</td>
<td>1) economic—indicators of competitiveness of leading enterprises and industries in the region, scientific and technical potential, human resources; 2) administrative—achievement of indicators of regional and federal programs; 3) organizational—transport factor and infrastructure; 4) territorial—factors of economic and geographical position of the region.</td>
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<tr>
<td>5</td>
<td>Petrosyants V.Z.</td>
<td>1) The quantity and quality of natural resources; 2) quantity and quality of labor resources; 3) amount of fixed capital (resource capital); 4) availability of advanced technologies.</td>
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<tr>
<td>6</td>
<td>Chelnokov I. V., Gerasimov B. I.,</td>
<td>1) financial—revenues of the budget, organizations, and population; 2) financial—source of regional funds; 3) financial—business environment; 4) financial—financial stability.</td>
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2) production indicators of financial and economic detail from determining types of economic activity in the region;
3) resources and raw materials – supply of the region with basic natural resources used for its needs, taking into account midterm and long-term perspectives;
4) consumer – consumer potential of the region’s population;
5) labor – qualitative and quantitative characteristics of labor resources and their educational level;
6) institutional – degree of development of key institutions of market economy;
7) Infrastructure – indicators of security and development of structural elements of the region (transport, production, engineering, social);
8) innovative – degree of development of R&D, their application, and financing in the region.

Source:
It should be noted that the inclusion of industrial and agricultural indicators requires an expert assessment, which should be based on the specifics of the region and the degree of development of its key industries. Thus, some regions, due to their natural and climatic conditions, do not a priori focus on agriculture, while others, due to historical conditions, have better chances to develop industry. There is no need to average and formalize this fact. As an auxiliary tool, it is possible to use information on the subject’s place in the Russian Federation according to the main socio-economic indicators [7].

The Federal Service for State Statistics identifies the main socio-economic indicators that characterize the constituent entities of the Russian Federation as:
• the area of the territory;
• population size;
• average annual number of employees;
• average cash income per capita (per month);
• consumer expenditures per capita on average (per month);
• average monthly nominal accrued wages of employees of organizations;
• gross regional product;
• investment in fixed capital;
• fixed assets in the economy (at full book value at the end of the year);
• the volume of own produced goods shipped, work done and services rendered using own resources by types of economic activity (industry);
• agricultural output;
• commissioning of dwellings;
• retail trade turnover;
• balanced financial result (profit minus loss) of the organization’s activity.

This paper then selects and classifies the various indicators that influence economic growth in the region and presents the relationships between the evaluated factors in the form of a graph. Such an approach will reflect not only the list of information (factors), but also the structure of the problem. Representation in this form becomes possible because, unlike a network graph, the links between the nodes do not necessarily reflect the precedence relations, but only express possible combinations of indicators of the project stages, and modelling allows determining the range of possible solutions, based on the structuring of the issue and analysis of the relationships between the parameters and components of the model.

The analysis methodology involves the following sequential steps.
1. In the first stage, factors are identified and a so-called environmental scan is carried out to quickly identify indicators or signals of potential change. The scan should provide

Source:
information on future opportunities and threats that affect the development of the region or municipality in varying degrees of progress or regression. Generally speaking, the following factors can be highlighted:

- **Political environment** – political stability or instability and its impact on municipalities; financial relations between the state and municipalities and degree of financial decentralization; evolving forms of direct democracy and civil society; existence of international and national programs to assist municipalities; relations with state, sectoral, regional and other institutions, partnerships with the municipality (court, prosecutors, police, banks, etc.), membership in interstate unions.

- **Economic environment** – GRP growth; inflation rate; investment activity; employment and unemployment rate; regional employment and unemployment rate; regional income level; external economic environment; profitability and productivity of businesses in the region; state of business structures; development of agriculture and industry; state policy to assist farmers; state policy to develop small and medium businesses; development of services; natural and geographical potential for tourism development; natural resources conducive to industrial development; soil and climatic conditions for agricultural development; transport accessibility and infrastructure; land reclamation facilities.

- **Social environment** – education system: regulatory framework, success of reforms, infrastructure; health system: legal framework, state, success of reforms; development of public services: quality, accessibility, coverage, infrastructure; quality of living environment – housing provision, housing stock; quality of working environment – existence of regulatory mechanisms; presence or absence of ethnic tensions and conflicts in the region; public policies: on ethnic tolerance; gender equality; development of forms of leisure, sports, and tourism; age structure of population; natural increase; migration processes; urbanization of settlements; quality of legislation in the field of culture; state policy in the field of culture – support, funding, investment; cultural level of population, degree of satisfaction with cultural needs.

- **Technological environment** – new production technologies; new information technologies; vertical and horizontal technology transfer; application of R&D and transfer of know-how; status of communication infrastructure – postal, telecommunications, radio, and television networks.

- **Legal environment** – national legislation on local government and its impact on municipalities; international legislation and its impact on municipalities; legal and regulatory opportunities for regional policy implementation.

- **Environmental environment** – national environmental policy and its impact on municipalities; availability and accessibility of national and international funding programs for municipal environmental projects; lack of inter-municipal pollution; degree of public support for compliance with environmental standards; status of water supply and sewerage network; energy networks – availability and status, energy efficiency and use of renewable energy sources.

2. The second stage is monitoring, which involves tracking a specific change in the environment over time. Its purpose is to track the evolution in the development of the relevant factors, to obtain sufficient data to help the authorities formulate their attitude to the weaknesses identified during the scan. Thus, during the monitoring phase, the search for data becomes more focused and systematic than during the scanning phase. In the second phase, it is advisable to use available statistical information from official sources, as well as the existing legal and regulatory framework for regional activities and their development.

3. The third stage is forecasting. The purpose of this stage is to provide possible parameters for the scale, direction, speed and intensity of change in the external environment.
3 Results and Discussion

Cognitive analysis of a complex socio-economic system such as a region is a multi-stage process and includes the following stages: development of cognitive models (from an initial cognitive map to more complex versions of cognitive models such as a functional graph); analysis of the cognitive model and study of properties of the complex system using it; scenario analysis, which allows identifying possible options for system development on the model [9, 10].

As a result, conducting a cognitive analysis allows:

• conduct a comprehensive analysis of all factors affecting the socio-economic development of the region;
• take into account poorly formalized qualitative factors as well as quantitative factors;
• analyze the dynamics of the region's sustainable development indicators;
• generate and test hypotheses about the social and economic situation in the region;
• conduct a scenario analysis of the development of the regional socio-economic system.

The cognitive model is a functional graph of the system under study \( G = \langle V; E \rangle \) in which the vertices \( V = \{V_i\} \), \( i = 1 \ldots k \) correspond to the factors of the system, and the arcs reflect the functional interaction between them \( E = \{e_{ij}\}, i, j = 1 \ldots k \). There are two types of causal interaction between factors: positive (direct) and negative (inverse) types. Each instance of interaction between systemic factors can be expressed in terms of both measurable (quantitative) and unmeasurable (qualitative) variables.

In this paper, the following indicators of sustainable development of the region were selected for further cognitive analysis based on the principle of maximum relevance:

Economic growth indicators (\( Y_i \):)

• per capita GRP (\( Y_1 \));
• per capita average cash income (\( Y_2 \));
• coefficients of natural increase (\( N_I \)) of the population per 1000 people (\( Y_3 \));
• the share of unprofitable enterprises (\( Y_4 \)).

Economic indicators (factors influencing economic growth (\( X_i \)):

• employment rate of the population (\( X_1 \));
• number of labor force (\( X_2 \));
• investment in fixed capital (\( X_3 \));
• commissioning of fixed assets (\( X_4 \));
• total floor area of residential premises per inhabitant on average (\( X_5 \));
• volume of innovative goods, works, services (\( X_6 \));
• number of organizations performing research and development (\( X_7 \));
• expenditures on innovation activities of organizations (\( X_8 \));
• number of enterprises and organizations (\( X_9 \)).

Social indicators (factors affecting economic growth (\( S_i \)):

• graduation of mid-level specialists, a thousand people (\( S_1 \));
• graduation of bachelors, specialists, masters, a thousand people (\( S_2 \));
• number of hospital beds per 10000 people (\( S_3 \));
• capacity of the outpatient and polyclinic organizations (\( S_4 \));
• number of doctors per 10000 people (\( S_5 \)).

Demographics (factors affecting economic growth (\( Z_i \)):

• average annual population (\( Z_1 \));
• life expectancy at birth (\( Z_2 \));
• demographic pressure coefficient (\( Z_3 \));
• migration rate per 10,000 population (\( Z_4 \)).

Digital transformation indicators (\( D_i \)):

• use of personal computers in organizations, % (\( D_1 \)).
• Use of broadband Internet access in organizations, % (D2);
• Use of personal computers in households, % (D3);
• Use of broadband Internet access in households, % (D4);
• Number of personal computers per 100 employees, units (D5);
• Expenditures on implementation and use of digital technologies, mln. (D6).

A simplified initial model of the cognitive map of the relationships between the growth indicators of a region is presented in Figure 1.

Fig. 1. A simplified model of a cognitive map of the relationship between growth factors in a region. Increasing economic performance has a positive impact on the region's social and digital environment. Improved social environment has a positive impact on both economic and social indicators. Demographic indicators have a positive impact on the economy and the social sphere, but demographic development has a rather negative impact on digitalization through the aging of the population and its working-age part, the frequent change of different generations, intellectual emigration. In turn, digital transformation has a positive impact on the growth of economic indicators and the development of the region, and a rather negative impact on the demographic situation, due to the presence of digital content aimed at reducing the value of family creation and childbearing, as well as reducing offline social interaction.

In order to develop a cognitive map of the region's economic growth indicators, it is necessary to build cognitive models of internal interrelationships of economic growth factors.

A model of the cognitive map of interrelationships of demographic indicators is presented in Figure 2.

Fig. 2. A cognitive relationship map model of demographic indicators (Zi).
Life expectancy (Z2) has a positive effect on population (Z1) and a negative effect on the population pressure coefficient (Z3).

Let us consider the model of cognitive map of social indicator's interrelation presented in figure 3.

Fig. 3. Cognitive social indicator relationship map model (Si)

The factors of graduation of mid-level specialists (S1) and graduation of bachelors, specialists, masters (S2) have a positive impact on the number of doctors (S5). At the same time, the factors number of doctors (S5) and number of hospital beds per 10000 people (S3) have a direct positive impact on the capacity of outpatient and polyclinic organisations (S4).

Fig. 4. A cognitive relationship map model of digital transformation indicators (Di).

Figure 4 shows that an increase in expenditure on the adoption and use of digital technologies (D6) has an overall positive impact on indicators of digital transformation of the regional economy, such as: use of personal computers (D1) and broadband Internet access (D2) in organizations, use of personal computers and broadband Internet access (D4) in households, number of personal computers per 100 employees (D5).
Figure 5 presents a model of interrelationships between economic indicators. There are numerous relationships between economic indicators, so the level of employment (X1) is positively influenced by: the number of economically active population (X2), the amount of innovative goods, works, services (X6), the number of organizations that perform research and development (X7), the costs of innovative activities of organizations (X8) and the number of small and medium enterprises (X9). Fixed capital investment (X3) is positively influenced by the following factors: employment level (X1), number of economically active population (X2), number of organizations that carry out R&D (X7), expenditures on innovation activity of organizations (X8) and number of small and medium enterprises (X9). Fixed asset's renewal factor (X4) is positively influenced by investments in fixed assets (X3), as well as by the number of organizations performing research and development (X7), costs for innovation activities of organizations (X8) and the number of small and medium enterprises (X9). The factor of total living space per inhabitant on average (X5) is positively influenced by the number of economically active population (X2) and employment rate (X1). There is a positive cyclical relationship between the factors X7 and X8: growth of the factor X7 contributes to the growth of X8 and vice versa. After determining the level of interaction of factors at different levels, each arc of the cognitive map represents a functional interaction, i.e. the cognitive model can be represented as a functional graph, which together reflects the interaction of factors in the economic, demographic, digital and social subsystems. Taken together, the cognitive model of sustainable development, reflecting the interaction of factors in the economic, demographic, digital and social subsystems, is presented in Figure 6.
In addition to the interactions that occur between factors within the different subsystems (economic, social, demographic and digital), there are external interactions, namely:

- In addition to economic factors, the employment rate is positively influenced by social indicators such as the number of bachelors, specialists, masters and the number of doctors per 10,000 inhabitants;
- The workforce is positively influenced by the increased output of mid-level professionals, bachelors, specialists, masters, and the capacity of outpatient organizations, while the use of personal computers and broadband Internet access in organizations has a negative impact on this factor;
- The volume of innovative goods, works, and services is influenced by the use of personal computers in organizations, the use of broadband Internet access in organizations, as well as the output of bachelors, specialists, masters, and the average annual number of populations;
- Investment in fixed capital has a positive correlation with the cost of introducing and using digital technologies and the growth of the average annual population;
- Bachelor's, specialist and master's degrees are positively correlated with the number of enterprises and organizations carrying out research and development;
- The average living space per inhabitant is directly related to demographic pressure and migration rates;
- The capacity of outpatient clinics is influenced by the number of employees, the number of enterprises and organizations that carry out research and development and the number of personal computers per 100 employees;
- The cost of introducing and using digital technology helps to reduce the demographic indicator – the number of hospital beds per 10,000 people.

It is possible to determine probable situations in the system under study by examining the resulting cognitive graph, namely, identifying cycles in it. Cycles in cognitive graphs are divided into stable, which contain an even number of negative edges, and unstable with an odd number of negative edges. Unstable cycles reveal either an ever-expanding and growing...
negative or an ever-growing positive character regarding the phenomenon under study in the system. In stable cycles, there are influences that do not allow the negative or positive phenomenon in the system to unfold, having a restraining character.

There are the following cycles in the cognitive graph of influencing factors on regional dynamics:

- An increase in the employment rate (X1) leads to an increase in the total living space per inhabitant on average (X5) and in the labor force (X2) – as the condition improves in at least one vertex, the condition in the others improves, hence the cycle is unsustainable.

- (X6) → (X1) → (X9) – volatile cycle.

- (Z1) → (S3) → (S4) → (Z2) – volatile cycle.

- (Z4) → (Z1) → (X5) → (X2) → (X9) → (Z4) – volatile cycle.

- (S1) → (X2) → (X9) → (X3) → (X1) → (X9) → (Z4) – volatile cycle.

- (D6) → (D1) → (X6) → (X1) → (X9) → (D6) – volatile cycle.

Thus, instability indicates the presence of cyclically in the structure of the system under analysis. This indicates the need to introduce control actions, which in turn can change the nature of the relationship between the factors in the model and bring the system to a steady state.

4 Discussions

There is a wide-ranging debate in the scientific literature on the analysis of regional sustainable development factors. All the factors of regional development are usually divided into the following categories:

- External and internal; economic and non-economic; extensive and intensive; controlled and uncontrolled. However, the use of only the economic aspect in identifying the groups of factors of sustainable economic growth of the region does not allow us to take into account the features of the region as a multidimensional, complex socio-economic system. We have generalized the existing approaches within the framework of each identification attribute of the region and singled out the following categories of factors: economic, social, demographic, and digital transformation factors.

The identification of regional economic growth factors is the basis for decision-making on the management of such a multidimensional socio-economic system. There are complex relationships between factors and conditions for balanced growth of the region. Cognitive analysis methods allow us to evaluate these relationships. This method allows us to classify the factors into positive and negative ones. Moreover, not only those factors that initially have a strong influence can have a stimulating effect, but also seemingly insignificant factors in their aggregate can lead the system to sustainable balanced development. At the same time, the agglomeration effect that can be created by a combination of insignificant factors is most often not amenable to regulation, which requires assessing it as an objective given.

On the basis of the above, taking into account the theoretical analysis of research in the field, from the perspective of balanced regional economic growth, the analysis of the influencing factors should be conducted in terms of a cognitive approach, which as a result allows for:

- carry out a comprehensive analysis of all factors affecting the socio-economic development of the region;
- to take into account poorly formalized qualitative factors as well as quantitative factors;
- to analyze the dynamics of sustainable development indicators in the region;
- generate and test hypotheses about the social and economic situation in the region;
- conduct scenario analysis of regional socio-economic system development.
5 Conclusion

According to prevailing economic views, the sustainable growth of a complex socio-economic system such as a region needs to be assessed using various indicators. Economists have not come to a unified classification of regional development factors. In the studies of foreign scientists in the field of determining the factors of regional economic growth, two aggregated groups of "soft" (quantitatively unmeasurable) and "hard" (quantitatively measurable) factors are distinguished. This classification is "flexible" and allows taking into account the impact of digital transformation on the sustainable growth of the region. In practice, the analysis of a region as a complex system combines mixed methods and approaches. Despite the popularity of cognitive maps, there is currently no consensus in the literature on the way to identify the important factors influencing and determining the situation under study.

Nevertheless, cognitive mapping techniques are useful both for understanding the cognitive processes of complex socio-economic systems and for managing their internal interrelationships. The study of the factors of sustainable growth of the region should take into account that the development of the region relies on different sets of factors and conditions, which should ensure a balanced relationship between the structural elements of the regional economy. Therefore, the present study proposes four basic resultant indicators: GRP per capita; average per capita income; coefficients of natural increase (NI) of the population per 1000 people; the share of unprofitable enterprises. Among the factor attributes, 9 economic indicators, 5 social, 4 demographic and 6 indicators of digital transformation were identified. The cognitive map of influence factors on the dynamics of the region's development allows us to objectify the processes taking place in the region, and to trace the interrelations of different spheres, which are themselves independent systems with their own laws, processes and concepts.

6 Acknowledgments

The research was carried out within the state assignment of Ministry of Science and Higher Education of the Russian Federation (theme № FZUU-2023-0002).

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