Economic and mathematical modeling in the regional development strategy analysis

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Abstract
The paper analyzes the prospects of economic and mathematical modeling in the analysis of the regional development strategy. The basis for the analysis of the regional development strategy is presented. A dynamic model for the analysis of the region's economic development strategy is also described.

Keywords: economic and mathematical modeling, economic and mathematical model, dynamic system of equations, regional development strategy.

1 Introduction
The problem of a present day, which affects the condition and the development of the Russian economy in general, is to ensure the stable and effective development of the regions. Any process that arises in such a complex system is influenced by a huge number of external and internal factors, usually having probabilistic nature, and the trajectory of the system develops as a result of the interaction of many processes (social, economic, productive, natural, investment, innovative etc.).

The study of the current condition of the regional economic system and the identification of possible directions for its development is determined by the fact that a region is a complex, multi-element, open dynamic system with a variety of internal and external links. This system reflects the degree of perfection of the economy method, the proportional relationship between all parts of the economy, as well as the level of utilization of the natural resource, labor and economic potential, which generally reflects the integration process and characterizes the complexity and balance of its development within a single economic space.

The economic relations that are being implemented in this process determine the ability to adapt and develop any territorial socio-economic system. The non-linear nature of the interaction of these connections makes it possible to ensure a normal reproductive process in the region. This circumstance explains the essential importance of the choice of the economic system development strategy for the formation of recommendations on the dynamic stability and stability of the functioning of the region.

Therefore, analysis of the development strategy of the region should be considered as studying the nonlinear behavior of a complex dynamic system that is a part (a subsystem) of the all-Russian economic system.

2 The basis for the analysis of regional development strategy
According to the generally accepted rules, the condition for the formation of any system is the presence of five main components, namely: characteristics of input parameters; transformation (a system-forming factor or a system object); characteristics of output parameters; internal and external relations (direct and reverse, positive and negative); restrictions from the external environment.

Since one of the main aspects of the analysis of the regional development strategy should be the achievement of efficiency (according to selected criteria) of its functioning and development, then the obligatory condition is to introduce into the system object (system) the control unit, which, through the control actions, would bring the state of the system in line with values of planned indicators and system goals.

In practice, the relationship between control actions, characteristics of input parameters and values of environmental factors is quite complex and non-linear. Often for systems of socio-economic nature, it does not subject to a strict formal description. Therefore, only on the basis of system analysis, it is possible to structure the economic system of the region in any aspect, which is determined by the specific direction of the research and the availability of the necessary information about the system object. The structuring of the region's economic system depends on the adopted variant of differentiating the criteria,
the "accents" of planning the development strategy for any territories, industries, industries or enterprises.

The system description of the object and its behavior depends not only on the properties of the constituent elements but also on their interrelations and mutual influence, i.e. from the structure of the system. The structure of the system acts as a way to organize it, and later as some abstraction created by the researcher. However, the decomposition (structuring) of the system into elements and connections between them is not determined by the wish of the researcher, but by the objective internal properties of the system itself.

The main tool for the study of stable (sustainable) functioning and development of the region's economic system is simulation (scenario) modeling as a tool for constructing not separate development trajectories, but a wide range of options for assessing the impact of various factors, the choice of targets and development strategies.

To find out the possibility of effective management of the regional economic development, it is necessary to determine the factors of influence that create conditions for a qualitative change in the organization of production in the region and the interrelations between them.

Different economists differentiate and evaluate the various sets of components of the structure of the regional economic system [1-3]. Among them, we can distinguish: administrative-state management system; environment and natural resources; basic production assets; labor potential; spiritual potential; financial assurance; infrastructure potential; innovative (scientific and technical) potential; investment or credit component; export opportunities of the region, etc.

The presented system of indicators of the region's economic development is one of the discussed and researched issues of forming a strategy for the development of the region to ensure the dynamic stability of the economic system. However, there is no a single set of indicators that fully reflects the state and effectiveness of the socio-economic development of the system considered. There are only recommendations for its formation on the following aspects: social (elimination of poverty, improvement of the demographic situation, improvement of the quality of education, level of health, etc.), economic (increase in investment attractiveness, increase in commodity markets, rate of change in industrial production, etc.), environmental (environmental safety, quality of natural resources, development of biotechnologies, etc.) and others [4-5].

As a result of the analysis of existing interpretations of the regional system's economic structure, in our opinion, it is necessary to use an appropriate system of basic macro indicators, the application of which would enable:

- prompt and adequate response to the changes in economic external and internal environment;
- to identify and implement an appropriate choice of development strategy, to predict events developing alternative scenarios for their development:
  - to adopt reasonable scenarios based on the results of the analysis.

3 The dynamic model of the regional economic development strategy analysis

Following the above mentioned, it is proposed to use macro-indicators characterizing the rates of economic growth in the region for the effective functioning of the regional economic system and analysis of the development strategy. Three components of the structure of the economic system are highlighted, which affect the development of the region progressively or regressesively: labor, which is reflected in the dynamics of the population and labor force; financial - a growth of own capital (financial savings and production capacities); credit - attraction of credits.

Taking this into account and in order to analyze the region's economic development strategy, it is proposed to use the following system of differential equations:

\[
\begin{align*}
\frac{dY_1}{dt} &= \alpha Y_1 Y_2 \gamma Y_3; \\
\frac{dY_2}{dt} &= \mu (Y_1 + Y_2) - \beta Y_1 Y_3; \\
\frac{dY_3}{dt} &= \delta Y_1 - \Lambda Y_1,
\end{align*}
\]

The dependent variables of which correspond to the allocated components of the structure of the economic system of the region, namely:

- \( Y_1 = Y_1(t) \) which describes the share of the employed population in the region from its total volume in Russia (%) during the time \( t \) (labor resource);
- \( Y_2 = Y_2(t) \) is the share of the region's gross regional product from its total volume in Russia (%) for the time \( t \) (GRP);
- \( Y_3 = Y_3(t) \) is the share of loans granted to the region from their total volume in Russia (%) during the time \( t \) (borrowed loans);

\( t \) - independent variable.

Scalar quantities \( a, \gamma, \mu, \beta, \delta, \Lambda \) enter this system as constant (control) parameters.

Note that the coordinates \( (Y_1, Y_2, Y_3) \) of the economic event space can be described not only in fractions of its total volume in Russia (%) but also in fractions per capita (%) of the corresponding indicator, etc.

The nonlinear differential system (1) describes the behavior of the regional economic system in the coordinates "labor resource - gross regional product - attracted loans" for a time \( t \), and the economic development is reproduced mathematically for some period of time, starting from the moment to.

Equations of the dynamic model (1), which are based on the idea of a synergetic method of composing the main proportions and bilinear interaction, can be interpreted in the following way:
a) the growth of the labor resource ($Y_1$) per unit of time · its rate of change in the region is proportional to the GRP and the borrowed credit reflecting the region’s external attractiveness for the labor resource $Y_1$, namely $Y_1$ depends on the interaction of the two components of GRP and credits ($aY_2Y_3$). From this gain the part that determines the fluidity of the labor resource ($γ Y_1$) is subtracted:

b) the growth of the gross regional product ($Y_2$) per unit of time · its rate of change is proportional to the revenue received from the GRP and credit amount, and $Y_2$ depends on the efficiency of capital investments ($μ(Y_2 + Y_3)$) minus the part of the costs that is spent for payment of labor resource and a loan ($β Y_2$);

c) the increase in the granted loans ($Y_3$) per unit of time · its rate of change is proportional to the GRP size, and $Y_3$ depends on the GRP ($δ Y_2$) size minus the part that is associated with the loan servicing ($λ Y_2$).

Note that the dynamic system of equations (1) is based on the application of the fundamental principle of natural science, namely: the rate of change in the characteristics of the modeling object is proportional to the difference between the generating side (source, input) and cost (drain, exit). Using this principle, the Solow equation 

\[
\frac{dk}{dt} = sf(k) - (d + n + g)k
\]

- one-dimensional dynamic model [6] is orthodox in economic analysis: where the variable $k$ is the capital-intensity; $f(k)$ is the Cobb-Douglas function: $s$ is the saving rate; $d$ - depreciation coefficient; $n$ - population growth; $g$ - the degree of scientific and technical progress.

The parameters $a$, $γ$, $μ$, $β$, $δ$, $λ$ included in the system of equations (1), in accordance with the synergetic approach, are constant (controlling) parameters reflecting:

- $a$ - external attractiveness of the region;
- $γ$ - turnover of labor resources in the region;
- $μ$ - influence on the efficiency of investments;
- $β$ - labor resource in the region and the amount of costs for it;
- $δ$ - influence on the GRP volume of the region;
- $λ$ - the ability of the region to pay a loan on obligations taken.

These parameters will be called generalized coefficients, which consider both quantitative and qualitative factors.

Let us describe these basic generalized coefficients in detail and describe what factors are involved in them.

Factors that determine the external attractiveness of the region ($a$). This group of factors affects mainly the process of GRP formation and attraction of funds (credit). These factors include the tax burden, a rate of inflation, investment climate: scientific and innovative activity, an income of the population in the region, the rate of growth (decrease) in profits of profitable enterprises.

Factors that determine the labor resource of the region and the amount of costs for it ($β$). This group of factors might include: the level of salaries, arrears in salaries payment, level of social protection, social security of the population and health protection, the region's ability to attract labor, number of active enterprises, business entities, households in the region, training and staff training (vocational guidance work, retraining of specialists, training of employees) and others.

Factors that determine the turnover of the labor resource in the region ($γ$) reflect the structure of the working population, the development of consumer markets and infrastructure, the availability of adequate resources for the normal functioning of the working population in the region. These factors include the population in the region, unemployment rate, a level of morbidity, the volume of retail turnover of enterprises, disposable income in the region per capita, technologies associated with the registration of citizens seeking for a job, and others.

Factors that affect the effectiveness of investment ($μ$). The main criterion for the effectiveness of capital investments is the level of profit earned on invested capital, which ensures a minimal level of income and covers the risk of the investor. The main factors that determine the level of attractiveness of the region for investment include: net profit (loss) of large and medium-sized enterprises, competitiveness of products in the domestic and foreign markets, rates of change in industrial production, current liabilities by types of economic activity, level of education of the population: level of costs on technological innovation, acquisition of R&D, etc.

Factors that affect the GRP volume ($δ$). The main indicators of the region’s successful development is GRP, which is an indicator of the region's self-financing, the formation of savings to ensure the development strategy. The main factors of this group include: income from the volume of goods sold (goods, services) enterprises, the commodity structure of the region's import and export, flexibility of capital, a rate of circulation of capital, development of new types of products, a level of development of innovative technologies, etc.

Factors that affect the ability of the region to repay a loan on liabilities ($λ$). To determine the attractiveness of the region regarding the investment of funds or its lending, it is necessary to investigate the efficiency of using existing capital, the volume of direct and capital investments, the creditworthiness of the region, and others. The main factors that reflect the ability of the region to repay the borrowings include: the level of independence of the region, the level of subsidy, volumes of FDI, capital investments, outflow of FDI, introduction of advanced technological processes, the volume of new orders for production, availability and capacity of its own markets: the sale of goods (services), income and expenses of the population, the level of tax and administrative pressure on business entities, etc.

As we can see, the coefficients ($a$, $γ$, $μ$, $β$, $δ$, $λ$) of the dynamic economic-mathematical model (1) simultaneously cover a rather large range of factors. Therefore, there is an urgent need to reduce this number. It can be achieved, firstly, by excluding the factors being out of interest to the expert; secondly, by combining several indicators into a generalized (consolidated) one. Often, the problem is solved by constructing a generalized coefficient, which, in our
opinion, is appropriate. However, it creates certain difficulties when the coefficient integrates indicators that have different significance for the decision-maker. As a result, it becomes necessary to consider all these features when forming a generalized coefficient. The methods of expert appraisal (so-called expert procedures) are usually used to determine it.

4 Conclusion

The presented dynamic economic-mathematical model (1) describes the modeling object as a system in which the economic factors or components of the economic system interact, to which the integers correspond (dimensionless characteristics). However, considering the interaction, the system of equations (1) must also be dimensionless. Therefore, in the course of analyzing the region’s economic development strategy, the question arises: what results will the dynamic system (1) give if the dependent variables of the model will have different dimensions. In this case, a special part is played by the procedure of reducing their variables to dimensionless quantities, which will be the prospect for further research.

References
