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Modeling of innovative processes of regional development

Моделирование инновационных процессов регионального развития

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Abstract

Innovative processes in the development of the region are essential. It's necessary to effectively investigate and manage them. In Russia, increased requirements for innovation, innovative digital interactions, and infrastructures. The purpose of the work is system analysis and modeling of regional development processes, testing of the built model. The evolutionary potential of the region is also being explored. The work uses methods of system analysis, decision-making, mathematical modeling, situational and comparative analysis. For stable and dynamic regions, various system goals of innovative development are considered: corporate, business-oriented, functional, production, etc. The main results of the article: analysis of systemic problems and solutions for the innovative development of regions, the construction and study of a model of dynamics of evolution, potential and indices in the conditions of a variety of innovative changes (diffusion, innovation, investment, etc.). Uncertainties in the environment (restructuring in the region) are also taken into account. The task of identification of the constructed model, possibility of situational forecasting and support of strategic management with its help is considered. The test example for the model takes into account the dynamics of funds and the consumption of the situation. The dynamic characteristics of regional innovation should lead to qualitative changes, and the sustainability of the region is determined by the dynamic relationships of structures. Therefore, it's important to consider synergistic interactions such as "region – innovation – investment – evolutionary potential". The model we have discussed can also be complicated and improved by complicating the submodels involved and the modeling hypotheses considered. But in this form, it's suitable for relevant situational modeling.

Key words: management, innovation, efficiency, sustainability, evolution, systems analysis.

Аннотация

Инновационные процессы в развитии региона имеют важное значение. Необходимо эффективно исследовать их и управлять ими. В России возросли требования к инновациям, инновационным цифровым взаимодействиям и инфраструктурам. Целью работы является системный анализ и моделирование процессов регионального развития, тестирование построенной модели. Также изучается эволюционный потенциал региона. В работе используются методы системного анализа, принятия решений, математического моделирования, ситуационного и сравнительного анализа. Для стабильных и динамичных регионов рассматриваются различные системные цели инновационного развития: корпоративные, бизнес-ориентированные, функциональные, производственные и др. Основные результаты статьи: анализ системных проблем и решений для инновационного развития регионов, построение и исследование модели динамики эволюции, потенциала и

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показателей в условиях разнообразных инновационных изменений (диффузии, инноваций, инвестиций и т.д.). Также учитываются неопределенности внешней среды (реструктуризация в регионе). Рассмотрена задача идентификации построенной модели, возможности ситуационного прогнозирования и поддержки стратегического управления с ее помощью. Тестовый пример для модели учитывает динамику средств и ситуацию потребления. Динамические характеристики региональных инноваций должны приводить к качественным изменениям, а устойчивость региона определяется динамическими взаимосвязями структур. Поэтому важно учитывать синергетические взаимодействия, такие как "регион – инновационный – инвестиционный – эволюционный потенциал". Модель, которую мы обсуждали, также может быть усложнена и улучшена за счет усложнения задействованных подмоделей и рассмотренных гипотез моделирования. Но в этой форме он подходит для соответствующего ситуационного моделирования.

Ключевые слова: менеджмент, инновации, эффективность, устойчивость, эволюция, системный анализ.

Introduction

Innovative processes of the digital economy are relevant in the problems of regional development. Due to intense competition, companies, together with social and intellectual capital, began to create more advantages than at the expense of natural resources (Fagerberg, 2002). Long-term sustainability and adaptability are more important than financial security.

Innovation is the main source of well-being and a condition for sustainable development. In the absence of innovation, the structural and dynamic sustainability and predictability of the development strategy (Porokhovsky & Sorokin, 2021) of the regional system suffer, because there are often no qualitative changes other than technological.

It’s relevant to model innovative development, all technological progress in the region. Innovative processes are associated with social, environmental and economic, as well as humanitarian processes (Kleiner, 2018) and therefore affect all areas in the region.

It’s important to take into account innovative processes in regional development models, investigate synergistic processes (Smorodinskaya, Katukov, & Malygin, 2019), as well as digital transformations (Kochetkov, 2018).

Theoretical bases

"Innovation" is interpreted (Gurman, 2003) formally as a process focused on targeted model change, as its identification "for the situation". According to the theory of systems (Kaziev, 2007), development comes with a change of target installation, under the influence of innovation and with the constant goal of functioning.

The region functions or evolves for certain goals, to achieve sustainable development over a projected period of time and using specified resources, which are usually always limited. Not only material and financial resources are important, but also digital, organizational (Bondarenko, 2019).

For regions with an innovative portfolio, you can set and implement various goals:

1) corporate, for example, determining their positions in the national economy and priorities of innovation policy;
2) business-oriented, for example, providing adaptation potential and competitive opportunities in the long term;
3) functional, for example, creation of "managerial" guidelines (for procurement, re-equipment of production, introduction of innovations, etc.);
4) production, for example, determination of methods of management of key enterprises, strategic production.

Various approaches (strategies, tactics) to the innovative development of the region are considered (Table 1).

Table 1.
Classification of concepts "innovative regional development"

Type of development	Content of development
Evolutionary	Maintenance of the target level of economic development
Revolutionary	Sequential (High) Single-Step Change of Key Performance Parameters
Adaptive	Controlled ("by parameters," "flexible") gradual development
Intensive	Change of innovation potential through efficient production facilities and relationships
Aggressive	Revolutionary, accompanied by the capture of new markets, acquisitions and mergers, etc.
Sustainable	Evolutionary, achieving financial self-reliance values at or above regional averages
Extensive	Evolutionary, but only with quantitative changes in production and economic indicators
Innovative	Evolutionary (sometimes revolutionary), based on innovation, innovative potential

An example of a detailed study of the innovative development of the Volga regions is given in the work (Nikonorov, Solovyeva & Sitkina, 2020). The collection of articles (Drobyazko, 2017) addresses the issues of systemic ties of society, economics, science and technology.

It's also important to consider structural innovation processes (Salikhova, 2019). Structural adjustment will help "escape" from disasters, investigate the behavior of the system near the bifurcation point. Without taking into account synergistic features, it's impossible to model and predict the long-term development of the region.

Methodology

From methodological positions, the original model can be very complex and large, as for a multi-industry (multi-product) balance sheet model, the number of states is equal to square of the number of variables or the number of industries (according to the complexity theory of systems and algorithms).

The complexity of the identification algorithm will be of order $O(n^2)$, so you should be able to aggregate (disaggregate) the description of the system, the model.

Let $a = (a_1, \dots, a_N)$ be the vector of the model being identified. The set of indices I of parameters a^i is divided into subsets $I_j, j = 1, \dots, m_j$.. Each parameter is mapped w_j:

$$w_j = \left(\sum_{i \epsilon I_j} \frac{\Delta a^i}{|a_0^i|}\right) \frac{1}{m_j},$$

$$\Delta a^i = |a^i - a_0^i|,$$

where a_0^i – the initial value (the value at the beginning of the observation). Therefore, w_j is the average percentage of changes in group *j*, the so-called innovative group or cluster index.

The inverse disaggregation takes place according to the formula:

$$a^i = a_0^i(1 + w_j \alpha_{ij}),$$

$$\sum_{i \in I_j} |\alpha_{ij}| = 1,$$

$$i \in I_j.$$

The value $|\alpha_{ij}|$ is the weight of the distribution of the general innovation effect in group j between its individual parameters.

The sign of α_{ij} is defined by the meaning (for example, "–" - costs, "+" - stock recovery, labor productivity).

Weights $|\alpha_{ij}|$ are given by rules, for example, by the distribution function according to a random law, heuristic-expert, etc.

The model describes the dynamics of innovative indices, which are due to the diversity and diversity of sources of innovative changes, in particular, we indicate the following:

1) "free," such as the diffusion of innovation (Sahal, 1981);
2) "innovations," the type of investment in main production for its expansion and modification;
3) "targeted," such as investments in R&D, staff training, etc.

Uncertainties and conventions are present in the model, changing coefficients is the result of restructuring, and not replacing methodology or technology. It's necessary to consider the extreme values of innovative indexes corresponding to world achievements.

In order to ensure sustainable innovation processes in the region, it's important that key structures and resource flows operate effectively. Using situational analysis and predictive analytics (Vaibhav, 2018), the region can analyze forecasts and forecast scenarios.

Mechanisms of regional strategic decisions (on adaptation, management, evaluation) provide personal responsibility for performance, innovation, creativity in solving digital technological problems. They provide an effective situational approach to forecasting the development of processes and systems in the region.

Results

The model we are considering includes a number of submodels, but we are interested in innovative processes. The following differential matrix description of the innovative submodel is proposed.

$$w'(t) = -(d + H_i + H_d)(w - \bar{w}(t)),$$
$$w(0) = 0,$$

where d is the vector of active innovations (diagonal matrix); $\bar{w}$ – world-class significance; H_i, H_d – matrices of the impact of investments related to the expansion of production and diffusion of innovation.

The pace of innovation is limited, but can be expanded by fixed assets (investments in them):

$$\frac{dk^d}{dt} = u^d - \delta^d k^d, \quad 0 \le d \le Y^d,$$

where k^d, Y^d, u^d, δ^d are parameters characterizing fixed assets, capacities, investments and depreciation rates.

Free innovations (H_d) are not costly, the investment component (H_i) is also, except for fund-forming.

The costs associated with active innovation (d) require a special constructive display. The possibilities of an innovative submodel model involve the assumption of setting and researching optimization tasks, for example, maximizing the accumulated income, minus environmental and social benefits.

For clarity, let's look at an aggregated economic model, complemented by an innovative block.

Let's consider the model of system (region) development taking into account innovations. It's similar (Gurman, 2003), but does not take into account changes in the environmental environment (so far we are not interested, although connecting the submodel of ecology isn't difficult):

$$v = (1 - a)y - u - bd,$$

$$k'(t) = u - \delta k,$$

$$w'(t) = d(\overline{w}(t) - w),$$

where

$$0 \le y \le Y,$$

$$k'(t) \ge 0,$$

$$d \ge 0,$$

$$k(0) = k_0,$$

$$w(0) = 0.$$

Here *y, d* reflect the output, the pace of innovation; *v* - final consumption, *k, Y, u, δ* - fixed assets, capacity, investments and depreciation rate; *a, b* - specific ratios of direct costs in the production and innovation sectors; the values of $w, \overline{w}$ are defined by us above.

We believe that the labor resources of *T* are proportional to the population of *L*. A more complex connection is also possible in the model.

Discussion

Consider a test, hypothetical example:

$$a = 0.2, b = 0.1, \delta = 0.05, d = 0.1, Y = 1.0, \overline{w} = 1.0, k_0 = 1.$$

Then we get the system:

$$\begin{cases} v = 0.8y - u - 0.01, \\ k'(t) = u - 0.05k, \quad k(0) = 1, \\ w'(t) = 0.1(1 - w), \quad w(0) = 0. \end{cases}$$

Solving the independent last equation of the system, we obtain:

$$w(t) = 1 - e^{-0.1t}.$$

To solve the second equation, we set a simple investment law (linear law):

$$u = 0.08k.$$

Then, solving the second equation, we get:

$$k(t) = e^{0.03t}.$$

We will determine the production according to the law:

$$v = 0.04k - 0.01.$$

Figure 1 shows the dynamics of funds and consumption of the hypothetical (test) situation considered.

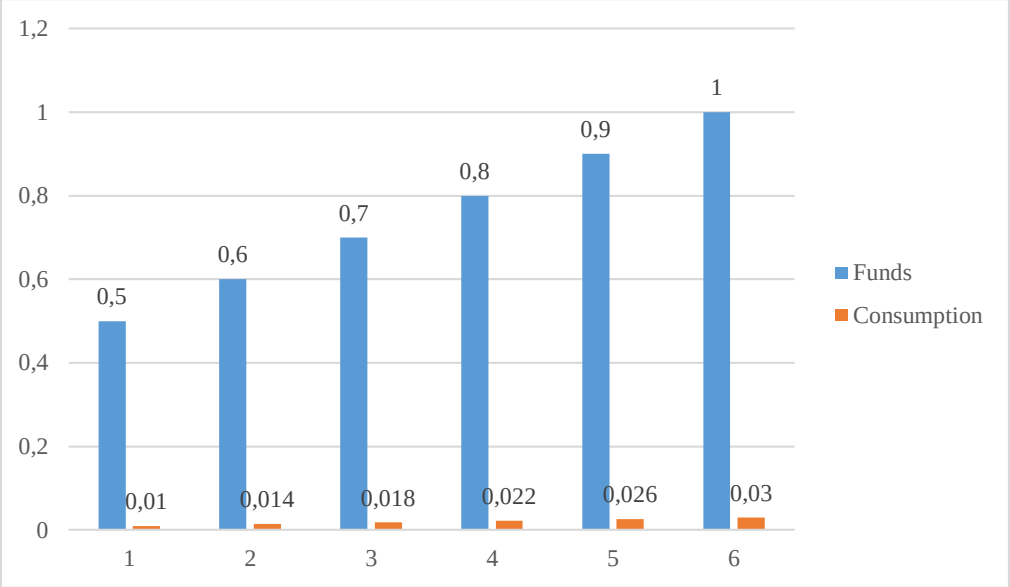

Figure 1. Dynamics of funds and consumption (test situation)

Models of innovative regional development should take into account factors of chaos and destruction of old structures (Katukov, Malygin, & Smorodinskaya, 2019).

In a complex system such as a regional economy, uncertainty increases, problems become poorly formalized (more precisely, poorly structured). Therefore, it's necessary to assess the impact of risk situations, apply intelligent approaches, neuro-economics systems are especially useful (Montague & Berns, 2002).

The evolutionary diversity of innovation in the region provides:

1) strategic advancement;
2) unifying attitude towards the regional market;
3) predictability (e.g. reliability);
4) discipline;
5) determination, competence of management;
6) reasonable attitude to trends;
7) sustainability of growth, innovative attractiveness and activity.

In the modern digital, evolutionary economy of the region, without relevant analytics, effective innovative procedures and processes are impossible (Zhukov & Komarov, 2017). Web analytics, a comprehensive analysis of regional projects being created or functioning, isn't possible. Taking into account the wishes and sentiments of consumers, a professional and responsible approach at all stages of the development of regional projects are the main values.

Conclusion

Quantitative changes in regional innovation should lead to qualitative changes in regional life. In an innovative region, sustainability depends on the dynamic relationships of regional structures. Regional development is a dynamic and continuous complex process, multi-criterion and multi-agent.

To ensure flexibility in times of crisis and uncertainty, regional entities should pre-adjust key indices, such as working capital and receivables. The search for support, "confidence points" and confidence-building among stakeholders in the region can be an important factor in the growing evolutionary potential of the region.

Innovation significantly affects the evolutionary potential of the system (region). The model we built is tested only on a model, hypothetical situation, but it can be complicated, for example, by connecting blocks of environmental and digital technologies, accounting for unemployment and demography.

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