Nonlinearity of Innovative Development and Digital Transformation of Industry in the Irkutsk Region

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Abstract: Trends in modern development and digital transformation of industry in the Irkutsk region in a non-stationary environment of geopolitical and innovative disturbances are discussed. From the perspective of fluctuations in the index of industrial production and the share of innovative goods, works, services in the total volume of goods shipped, works performed, services of industrial production organizations in the region, a brief analysis of the features of their dynamics is carried out and a conclusion is formulated about the high variability of indicators as a consequence of the increasing effect of disturbing factors of the global and the Russian economy. Along with this, from the standpoint of nonlinear dynamics and synergetics, the features of instable development and the problems of digitalization of industry in the Irkutsk region are revealed using the results of modeling the national economy under three scenarios of its receptivity to innovations and financing of the intellectual sphere. In conclusion, the directions of industrial development in the regional Strategy in the field of digital transformation of sectors of the economy, social sphere and public administration are characterized..

1 INTRODUCTION

In the current highly disturbed economic environment, the functioning of industrial enterprises is undergoing non-trivial transformations caused by the influence of obstacles and trends in the global and domestic economy. In the space of their destructive and innovative impact and chaotization of the regional industry, scientific interest in the theoretical, methodological and practical equipment of the technology of adaptive management of industrial enterprises in a non-stationary environment is growing. Meanwhile, with the rooting of non-linear views in the field of research of evolving economic systems, the absolutization and preference for their instable innovative development have become the subject of critical revision. And yielding to a balanced dual approach, it is legitimate to take advantage of the instrumental achievements of the teachings of nonlinear dynamics and synergetics on self-organization and instable development of such systems.

In this context, the trends in the variability of a number of indicators of the regional industry and its digital transformation within the framework of the innovative development of industry in the Irkutsk region are noteworthy. The use of mathematical modeling makes it possible to assess and interpret scenarios for the national economy's susceptibility to innovations with changes in the conditions for financing the country's intellectual sphere.

2 MATERIALS AND METHODS

The theoretical and methodological basis of the study was a symbiosis of natural science and economic teachings: nonlinear dynamics and synergetics, theories of evolution, chaos, stability and catastrophe, regional, innovation and production management, computer modeling technology.

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3 RESULTS AND DISCUSSION

The purpose of the study is to provide a trend analysis and interpretation of the nonlinear evolution of the regional industry of the Irkutsk region under the influence of geopolitical and innovative disturbances of the non-stationary environment and to discuss scenarios for modeling the development of the national economy in line with the priorities of innovative modernization and digital transformation of Russian industry.

The dominant imperatives of our time – the growing innovative modernization and digital transformation of the Russian economy and its industries – are accompanied by the updating and expansion of the agenda of ongoing scientific research, filling it with the design, production and development of intelligent production and management technologies. Meanwhile, the idea of promoting such developments has required a rethinking of the concept of innovation management, which primarily meets the conditions of a relatively regular and predictable, stationary environment. At the same time, adherence to the principles of systems analytics involves the development of theoretical, methodological and practical support for the processes of diffusion and innovation in industry on the basis of non-linear paradigms addressed to the nature of sudden and large-scale changes in the extraordinary behavior of systems.

Transitional processes against a disturbed background and the problems of forming an innovative economy explain the attractiveness of research topics on the stability of economic systems (Babkin, etc., 2017), analytics of the processes of ensuring the stability of innovative development in an uncertain and dynamic external environment (Khudyakova, etc., 2018), the influence innovations in industry on structural changes in the Russian economy (Akberdina, etc., 2021) and the formation of a new technological structure of economic organizations (Alekseeva, etc., 2020).

Publications on activating the innovation and investment potential of industrial enterprises in the regions (Vorontsova, etc., 2023), technological aspects of the formation of a unified information space of the enterprise and the transition from the data economy to the knowledge economy are devoted to the increase in scientific knowledge (Khitrova, etc., 2023), neurocomputerization of the production process, digital web transformation and promotion of digital products and technologies (Shtiller, etc., 2023), etc.

With the aggravation of interstate relations and sanctions pressure from Western countries and the United States, the space of the world and Russian economies is changing qualitatively, experiencing unprecedented pressure from competition in commodity markets, disruption of material, technical and financial flows between countries. The “invasion” of these disturbances into the economic environment of the Irkutsk region entails wide fluctuations in the indicators of its functioning, in particular, the index of industrial production of the region in 2011-2023, which reveals high unevenness in the range from 97.0% in 2023 to 109.4% in 2012 and fragmented cyclicity.

The trend of change in this index shows its sharp drop from 112.7% in 2013 to 103.0% the following year due to the outbreak of the financial crisis, after which its monotonous growth was replaced in 2017 by a decrease and increase, starting in 2020. This variability of the index is explained by the weak protection of the regional industry from the vicissitudes of the market and the complicated situation on the world markets for the sale of industrial products.

Against this “raging” disturbed background, the dynamics of the indicator of the share of innovative goods, works, services in the total volume of goods shipped, works performed, services of industrial production organizations of the Irkutsk region does not exceed 3 percent and is instable, having a large amplitude of fluctuations values from 0.1% to 3.0%.

It is known that in the concept of synergetics, the phenomena of self-organization and the emergence of order in nonlinear systems are generated by the dissipation and interaction of ordered and chaotic processes. As a result, the cooperative behavior of parts of the system is accompanied by a change in its stable and instable stages and the emergence of fundamentally new properties of the system. In continuation, we note that the effect of fluctuations on it in a disturbed environment not only excites the system and undermines its stability, but over time, organization grows in the chaotic system and it gains stability. The universality of synergetic patterns provides a logical basis for the desire to comprehend them in the knowledge and interpretation of the perestroikas of self-organizing economic systems in interaction with the innovative environment. “Nonlinear thinking” masters economists when they step into the world of slow and fast, smooth and abrupt changes in the nonlinear behavior of economic systems.

In the course of evolution, innovative fluctuations in the business environment can significantly shake the dynamics of the stationary functioning of an industrial enterprise, triggering the transition process of introducing promising projects on it. In particular, the production and implementation of technological and product innovations can introduce anomalies into the smooth flow of production activities of an enterprise: disruptions in the supply of purchased equipment or components, disruptions in the intra-shop flow of material resources and modernization or "linking" of the manufacturing technology of innovative products, pauses in the transition to its release or development of serial (mass) production, etc. Obviously, this kind of deviation from the prescribed mode of operation serves as a source of chaos and metamorphosis in the evolution of an industrial enterprise.

The concept of nonlinear dynamics allows that even small external influences lead to radical perestroikas in the activities of an industrial enterprise with branching trajectories. However, having information about the bifurcation point, it becomes possible to influence the evolutionary process of the enterprise (Akhromeeva, etc., 2007, p. 16).

The hypothesis that the pattern of increasing orderliness and efficiency of an enterprise's activities is inherently cyclical, dictated by the nonlinear evolution of an industrial enterprise within the framework of the interpretation of the theory of perestroikas looks very plausible (Arnold, 1990, p. 100). Thus, its innovative modernization with the application of entrepreneurship (Fig. 1, axis P_1) entails a wave-like ascent to higher economic efficiency (axis P_2) with a change in stable states. At the same time, with the available resources and efforts of managers, it is necessary to first remove the enterprise from an ineffective ("bad") stable state, and then, with its loss, along a curvilinear trajectory, direct the evolution of the enterprise to the target ("good") stable state.

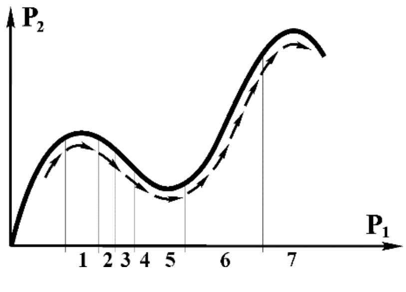

Figure 1: Perestroika economic system from the point of view of the theory of perestroikas (Arnold, 1990).

And paradoxically, it is easier for an underdeveloped industrial enterprise to undergo such a metamorphosis, since it is less resource-intensive to transfer it at the initial stage to an instable mode of operation due to the relative weakness of the forces that keep the enterprise in a "bad" stable state.

Theoretically and practically valuable results were obtained in the process of modeling the development of higher education in Russia, taking into account the susceptibility of the economy to innovations (Akhromeeva, etc., 2007, p. 442 – 444). Based on the views of nonlinear dynamics and UN statistics, the problem of forecasting the industrial development of the country and the contribution of science and education to it was solved on the basis of computer analysis of discrete mapping for three variables: resources, production (gross domestic product) and science with education. The macromodel showed that two key variables determine the modeling picture: the lag time, which characterizes the time interval from the success of science and education to the reaction of the economy to them (from 3 to 5 years), and its susceptibility to innovations.

Visually, the three modeling scenarios illustrate the macroeconomic trajectories presented in Fig. 2-4. Using their curves, one can estimate the dependence on time (*t*-axis in years) of resources (dashed curve), production volume (solid curve) and scientific and technical potential (dashed curve) in conventional units.

It is striking that in an economy that is not receptive to innovations (despite the active development of science), the surge in production volume (Fig. 2) quickly fades away, while in an economy that is receptive to innovations (Fig. 3), there is a "technological breakthrough" and substitution influence of resources in the intellectual sphere.

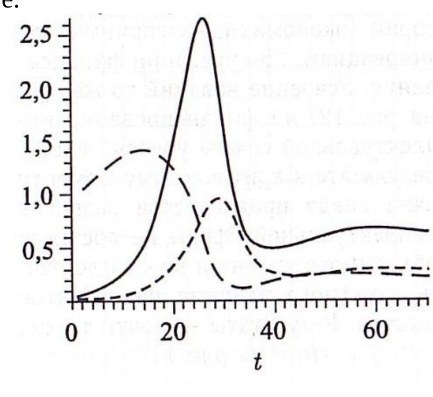

Figure 2: Macroeconomic trajectory immune to economic innovations (Akhromeeva, etc., 2007).

Finally, in an economy receptive to innovations, when funding for science and education is cut in half (Fig. 4), rapid growth in production volume is replaced by a decline. With the formation of a kind of “vicious circle” with direct and feedback coverage, the intellectual sphere does not “feed” innovations to the economy, and the latter degrades and limits financial investments in the intellectual sphere.

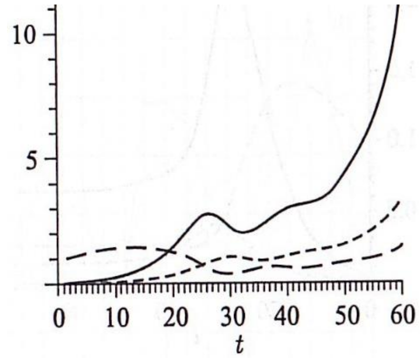

Figure 3: Macroeconomic economic trajectories, receptive to innovations (Akhromeeva, etc., 2007).

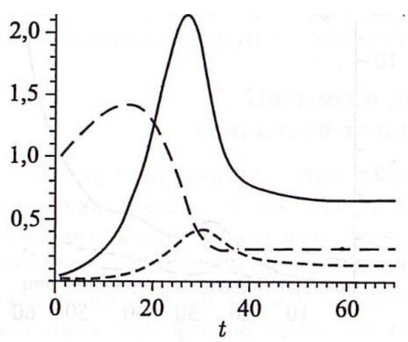

Figure 4: Macroeconomic economic trajectories, receptive to innovations, when funding is cut (Akhromeeva, 2007).

The economy of the Irkutsk region in this aspect does not yet inspire much optimism, but it provides valuable material for analytics: usually inertial in a stationary environment, now the region’s industry is subject to the influence of destruction and evolves nonlinearly with low susceptibility to innovations. Under the pressure of stress disturbances, the basic indicators of the Baikal region industry vary widely, demonstrating a range of trends in their changes and the instability of the observed values.

Returning to the dynamics of innovative development of industry in the Irkutsk region, we note the non-linear nature of changes in the indicator of the share of costs for innovation activities in the total volume of goods shipped, work performed, and services in 2010–2022 with intermittent growth rates. At the same time, comparing it with the dynamics of the level of innovative activity of organizations, we find the same trend: asynchronous variation in rates in 2014–2015 and 2018–2020 and synchronous in other years.

In general, the country’s digital transformation is gaining momentum as a national priority: according to the Russian government, in 2022 the digital maturity of the most significant sectors of the economy and social sphere reached 65.8% against the planned 56.2%, the share of mass digital socially significant services is 99.97 % against the planned 65.0%, and the share of households with broadband Internet access is 86.1% against the planned 80.0%. The volume of investments in domestic IT solutions also exceeded expectations, amounting to RUB 521.9 billion with an increase of 157.4% against the planned 156.0%.

An optimistic scenario for digital transformation with expanded government support, provision of investments and financing of full-fledged commercial projects aims to create conditions for the immediate creation of alternative solutions and software. Whereas in a pessimistic scenario with increasing negative trends and insufficient government support, the advancement of digital transformation will lose its previous pace, burdened by the timing of import substitution and the speed of development of new products. The outflow of a significant number of IT specialists from Russia, as well as the limited resources of Russian IT companies, integrators and equipment manufacturers when creating digital transformation tools, cannot be ruled out.

The dominant vector of innovative development of the regional industry obliges us to accelerate the digitalization of the socio-economic space of the Baikal region. Adopted in 2022, the Strategy in the field of digital transformation of sectors of the economy, social sphere and public administration of the Irkutsk region, among the existing development reserves, fixes the problems of processing big data and their objectivity, on the basis of which management decisions are made, as a result of the lack of integrated information systems, as well as insufficient dissemination of tools and practices for using data for making management decisions.

According to the mentioned Strategy, in a tense situation of unpredictable geopolitical risks and a deterioration in the price situation in commodity markets, insufficient volumes and inefficient use of financial resources, a high degree of depreciation of fixed assets due to the lag in digital transformation in regional industry, economic losses increase. Among them are low labor productivity and efficiency of production capacity, irrational use of resources, a long cycle of bringing products to market, the lack of a single source of complete and reliable information on the financial and economic activities of industrial enterprises, the complexity of processes for ensuring cybersecurity and the safety of data of industrial enterprises, undeveloped and insufficiently developed research base in the industrial sector.

It is expected that during the implementation of the Strategy measures the following promising technologies will be introduced: artificial intelligence, digital communications, big data technologies, etc. Thanks to this, stimulating demand for industrial products in the domestic market will be achieved, creating conditions for increased investment in research and development – design work (including the development of new industrial technologies) and increasing the level of cooperation between Russian enterprises, stimulating the integration of Russian manufacturers into global supply chains and exports of industrial products. The strategy provides for the creation of digital passports of industrial enterprises on the platform of the state industrial information system with an increase in the share of large and medium-sized manufacturing enterprises in the region that have generated digital passports in this information system.

4 CONCLUSIONS

The main trends in innovative development and digital transformation of the Russian economy are influenced by intense flows of geopolitical and innovative disturbances, saturating the non-stationary space of industrial enterprises with destructive influences and motivating incentives for digitalization and gaining the advantages of a new technological order. A quick analysis of regional industrial dynamics reveals the features and phenomena of the dynamic picture of changes in indicators of industrial production and the manufacture of innovative products in the Irkutsk region.

In a space replete with tricky interferences, the functioning of regional industry is subject to nonlinear evolution and industry development trends are instable with poor susceptibility to innovations. With the involvement of concepts and analytics of nonlinear dynamics (Akhromeeva, etc., 2007; Chuprov, 2016) and synergetics (Prigogine, etc., 2005; Haken, 1985), tools for mathematical modeling of transition processes, understanding and argumentation of metamorphoses and perestroikas of activities and digital transformation of regional industrial businesses in a highly disturbed economic environment.

Further research is intended to create theoretical, methodological and applied tools for ensuring adaptation and innovative development of industrial enterprises based on the use of principles and models of theories of evolution, chaos, stability and catastrophe (Moiseev, 1987; Gleick, 2023; Arnold, 1990; Chuprov, 2021).

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