

Innovation Resonances in The Development of Industrial Water Management Ecosystems

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Abstract

This article presents the scientific and practical issue of achieving innovation resonance in regional industrial ecosystems, including the identification of sources and factors contributing to it. The study of this issue is grounded on the approach based on the methodology of economic and innovation growth, systems paradigm and structural analysis, the support framework of innovation development of the region, as well as the main provisions of the concept of business ecosystems with regard to the high-tech sector. The key idea of the original concept of determining the sources and factors of achieving innovation resonance in subsystems of industrial ecosystems, one of which is defined in the article as hydroelectric power (in particular, the water management system of the region), is to obtain an innovation response in the external environment as an indicator of the expected effectiveness and efficiency of industrial innovation. The basic platform of model tools in the mechanism to achieve innovation resonance and innovation response in industrial and related ecosystems of the regional economy (including the water management system) is an interrelated set of principles and methods that characterize the rational symbiosis of industrial ecosystems and allow identifying the resource reserves for the implementation of local and global goals.

Key-words: Industry, Water Management Ecosystem, Innovation Resonance, Innovation Response, Rational Symbiosis, Support Framework.

1. Introduction

The profound and widespread changes in the Russian economy under the influence of innovative modernisms in the industrial sphere, which have been greatly amplified by the coronavirus pandemic, have revealed several economic, theoretical, and methodological phenomena which to a certain extent complement and develop the provisions of neoclassical theory and neoinstitutionalism. These include: "a mechanism of resonance growth" of the economy [12], "the harmonization of innovation processes" [6, 19], "innovation resonance of industrial development" [1], "a system of synergistic relations" [11], etc. By their content, the listed characteristics in the industrial sphere are more suitable not just for the analysis of already formed trends, including innovation trends, but rather for the justification of strategic changes in the economy as a whole, occurring under the influence of these trends. In other words, they are important for investigating innovation resonance in all industrial ecosystems, in particular in the region's water management system (WMS), as well as innovation response in the related economic and social sectors.

2. Methods

The practice proves that the long-term prospect of competitiveness growth of the Russian economy is based solely on the implementation of the innovative scenario of industrial development as the basic platform of the entire economy based on qualitative shifts in all industrial ecosystems due to the harmonization of the ongoing innovative processes in them.

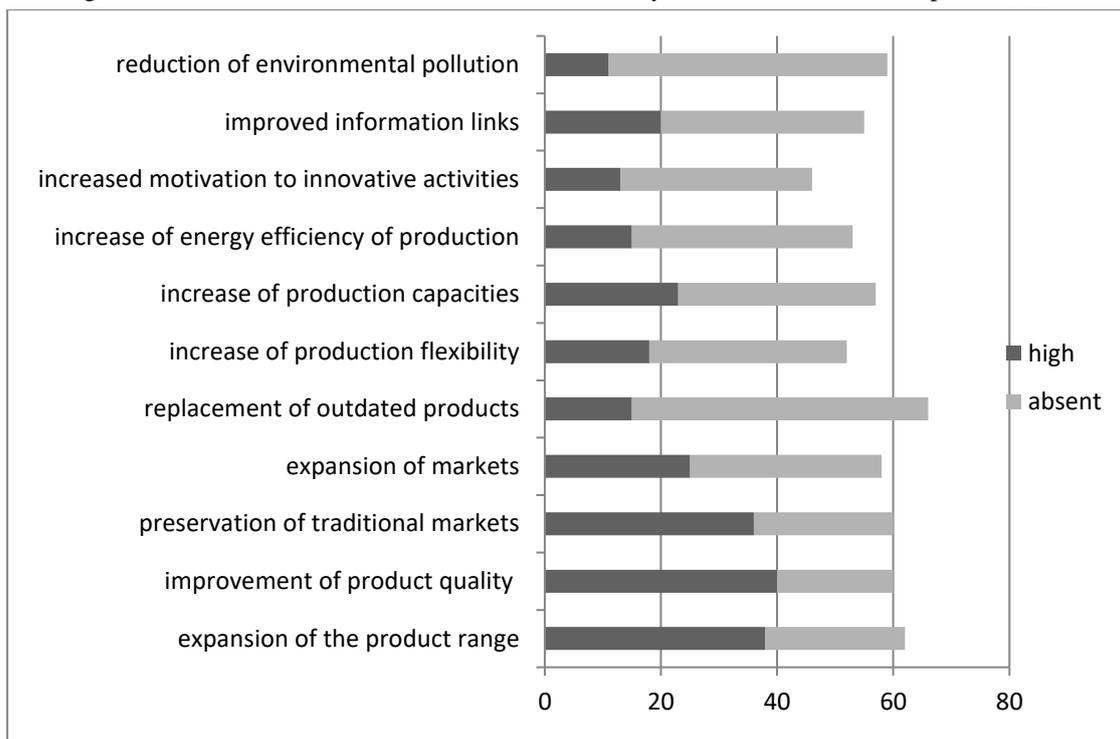
The justification of this conclusion is confirmed by the thesis formulated in the Strategy for Scientific and Technical Development of Russia about the necessity to develop research "in the field of understanding the processes taking place in society and nature, development of nature-like technologies, man-machine systems, and climate and ecosystems management" [13]. This document is based on the concept of the balanced and harmonious development of science, technology, and innovation institutions. This requires the formation of "healthy" industrial ecosystems, which are characterized by mutually beneficial (symbiotic) relations with the environment, resulting in the manifestation of innovation resonances both directly in industrial ecosystems and in related ones. At the same time, we believe that this innovation resonance should have a dynamic nature, illustrating the measurable high performance of the innovation potential of the industry.

The results of an assessment of the impact of industrial companies' innovation activities on the development of production in the industrial sector and related spheres (in particular, in regional

WMS, which provide strategically important water resources to industrial and all life processes in general) show that the manifestation of innovation response is more expressed in the expansion of the product range and improvement of their quality. At the same time, the introduction of industrial innovations has little effect on the replacement of outdated products, the decrease in environmental pollution (which is directly linked to the quality and quantity of water resources provided by regional WMS to consumers), the increase in production flexibility, the growth of its energy efficiency, and other production and technological changes (Figure 1).

Based on the data in Figure 1, we can say that industrial modernization projects of an innovative nature generate different in strength and direction innovation responses in both the internal and external environment, which can reinforce the existing imbalance in the functioning of industrial ecosystems of different hierarchical levels and sectoral specialization, in particular in the hydroelectric power sector.

Figure 1. Indicators of assessment of innovation activity results of industrial companies [4], %

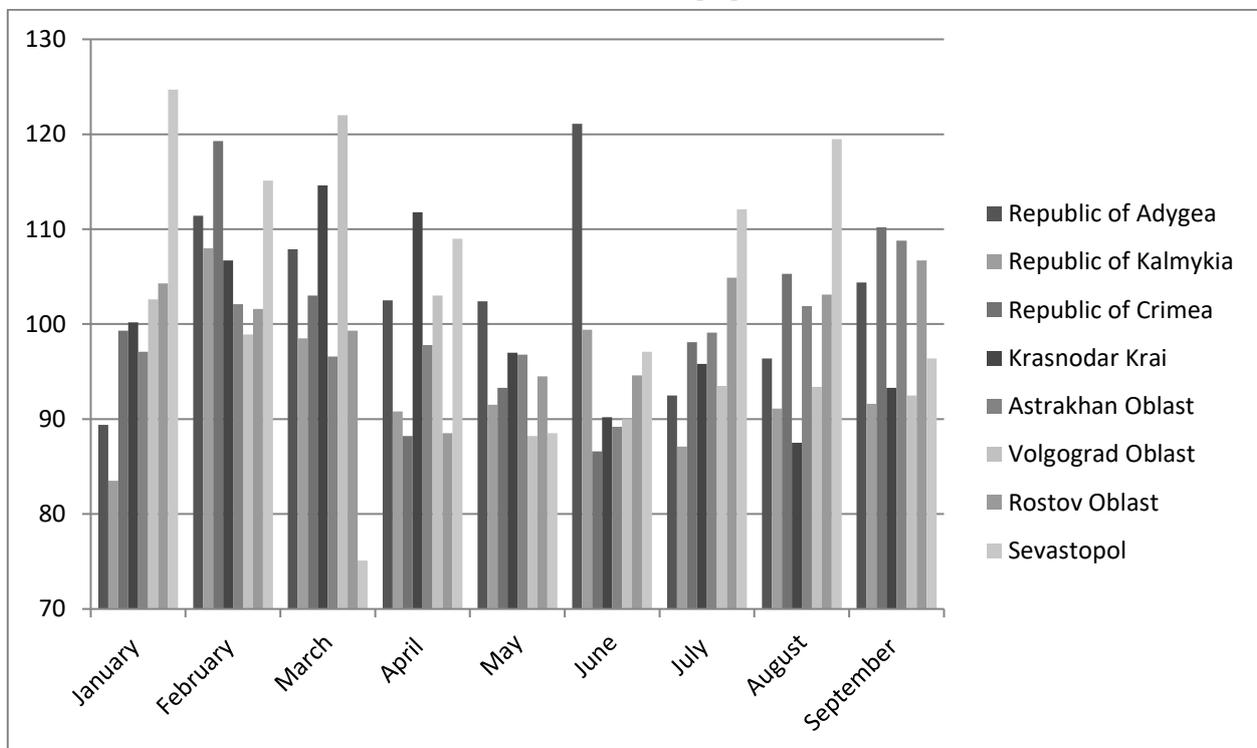


Besides, the objectively existing high differences in the levels of socio-economic development of the regions and the pace of development of their industrial ecosystems (Figure 2) are an additional reason for innovation imbalances in their subsystems, including regional WMS and water

management complexes (WMC) of the regions, which perform system-forming functions in the regional economy.

The available statistical data, as well as the results of the analysis of the current state of WMS in the regions of Russia, show that the real experience tests the high and increasing specific volume of water consumption in industry, exceeding the water requirements of the agricultural sector and the sphere of housing and communal services of the territory. Moreover, the volumes of water resources withdrawal for industrial needs are becoming more comparable with their availability even in periods of high flow and especially in years of low flow, which leads to a deficit in regional water balances.

Figure 2. Index of industrial production in the regions of the Southern Federal District, 2020, in % to the corresponding month of 2019 [16]



This indicates the necessity of advanced development of regional WMS, based on innovative technologies of production and distribution of limited water resources. At the same time, "the dual nature of WMC — as the most important infrastructural elements for the provision of water resources to all spheres of the economy and as production systems that exploit the nature of resource sectors" [8], determines the ambivalent nature of the sources of innovation resonances in their subsystems.

These objective factors determine an important scientific task that we set: to study the essence, economic nature, and principles of balanced development of industrial ecosystems of

different sectoral specialization; to identify sources, factors, conditions, and resource reserves of achieving innovation resonances in the structural hierarchy of the industrial sector of the economy, as well as in related spheres.

In modern research, the concept of business ecosystems is most common in the high-tech sector. At the same time, several scientists in their studies consider business ecosystems as a factor in the innovative development of the country and its territories [2, 5, 7, 9, 10, 17, 18, 20, 21]. In our opinion, according to this understanding, the industrial ecosystem is a dynamic system, which forms a special environment that enhances the processes of innovation, technology, and human capital reproduction. As a consequence, it is the achievement of innovation resonance in its subsystems and the corresponding response in the external environment.

We define innovation resonance as the spatial and temporal balance of structural and functional proportions of the scale and directions of innovation activity in individual subsystems of the industrial ecosystem (including basic ones, such as WMS) in relation to the overall range of innovation development of the region as a super-system.

This definition is consistent with the thesis that "the mechanism of innovation resonance of the regional industrial system is based on the combination and interaction of state regulation, innovative business, and its infrastructure, as well as fundamental and applied research in the field of high modern technologies. The main difficulty in creating such a mechanism consists in determining the means and ways to ensure the effective implementation of scientific and technological programs for the development and mastering of knowledge-intensive resource-saving technologies that allow industrial enterprises to carry out the economic production cycle in the mode of expanding the scale of innovation implementation and dissemination" [1].

In other words, the macroeconomic and global challenges of recent years orient the vector of further research into the issue of industrial ecosystem development in the direction of working out the factors and conditions of achieving innovation resonance in them to form a balanced framework of innovation development of the regions. Considering that the industrial policy of innovation development is not expressed in a set of individual local projects but involves a long-term process of structural changes in industrial ecosystems, several researchers pay special attention to the institutional factors and conditions that determine the effectiveness of this process. At the same time, in the context of achieving balanced innovation development of the industrial ecosystem, it is important to represent the institutional environment in the form of a special kind of matrix. This clarifies its multifunctional nature, where an ordered set of economic, ideological, political, and other institutions is designed to provide sustainable intra-system interrelationships in the industrial

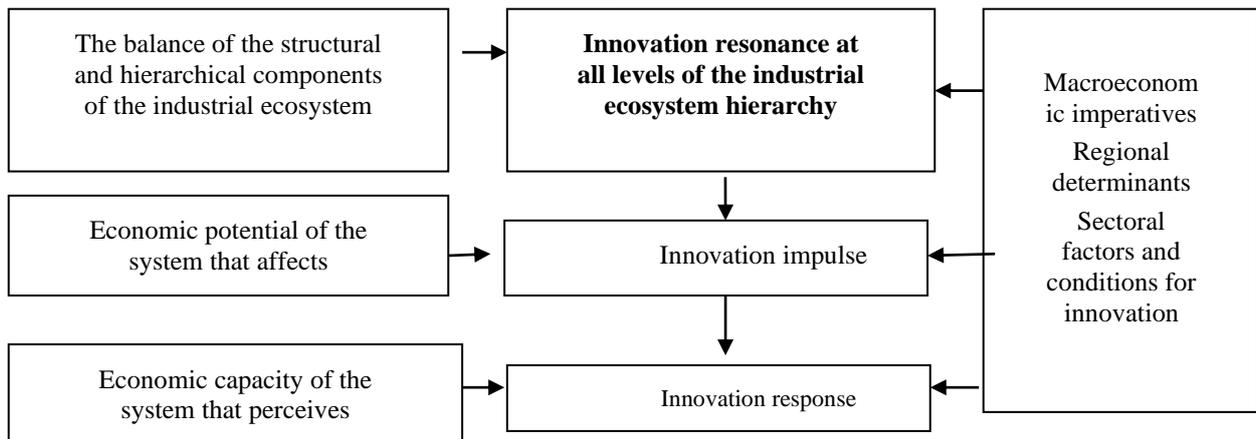
ecosystem to support innovation processes in it, as well as its links with the environment to initiate innovative development.

3. Results and Discussion

The scientific idea put forward in the study conducted by us is that the innovative development of industrial ecosystems is ensured only in the presence of innovation resonance in its industry subsystems, which, in turn, generates certain socio-economic effects both in the industrial ecosystem itself and in the environment. In this context, the opinion of A.N. Skiba deserves attention, who rightly notes that "the results of studies of isolated effects cannot claim objectivity and scientific value if their relationship with other objects is not considered. Most importantly, in the behavior of isolated objects, it is impossible to detect the effect of positive feedbacks that cause these effects, the impact of which does not fit into the framework of established notions and stereotypes. This refers primarily to the multiplicative growth effect of the output features of the considered system. It is of most interest to determine the forces and conditions that cause the resonance effect. The most significant influence is caused, on the one hand, by the input-output parameters of the system (i.e. direct connection signals) and, on the other hand, by its dynamic potential, determined by its ability to self-organize and the consistency of inter-element interactions. That is, the external environment constantly supplies the system with the means for its development and maintenance of order. In its turn, the internal environment adequately perceives them and transforms them into outgoing flows of matter, information, energy, raw materials, products, innovations, etc." [12].

We define these processes as an innovation response, which can vary in strength and content depending on the factors and conditions that determine the state of the economic potential of the industrial ecosystem and the perceiving system. The higher the level of economic potential, the stronger the innovation response is provided when innovation resonance is achieved in the system. However, even if the economic potential is high, the innovation response may not arise in the absence of innovation resonance in the ecosystem (Figure 3). Therefore, the study of factors and conditions for achieving innovation resonances in the context of their emergence and impact on individual components of the structural hierarchy of the industrial ecosystem acquires important theoretical and practical significance.

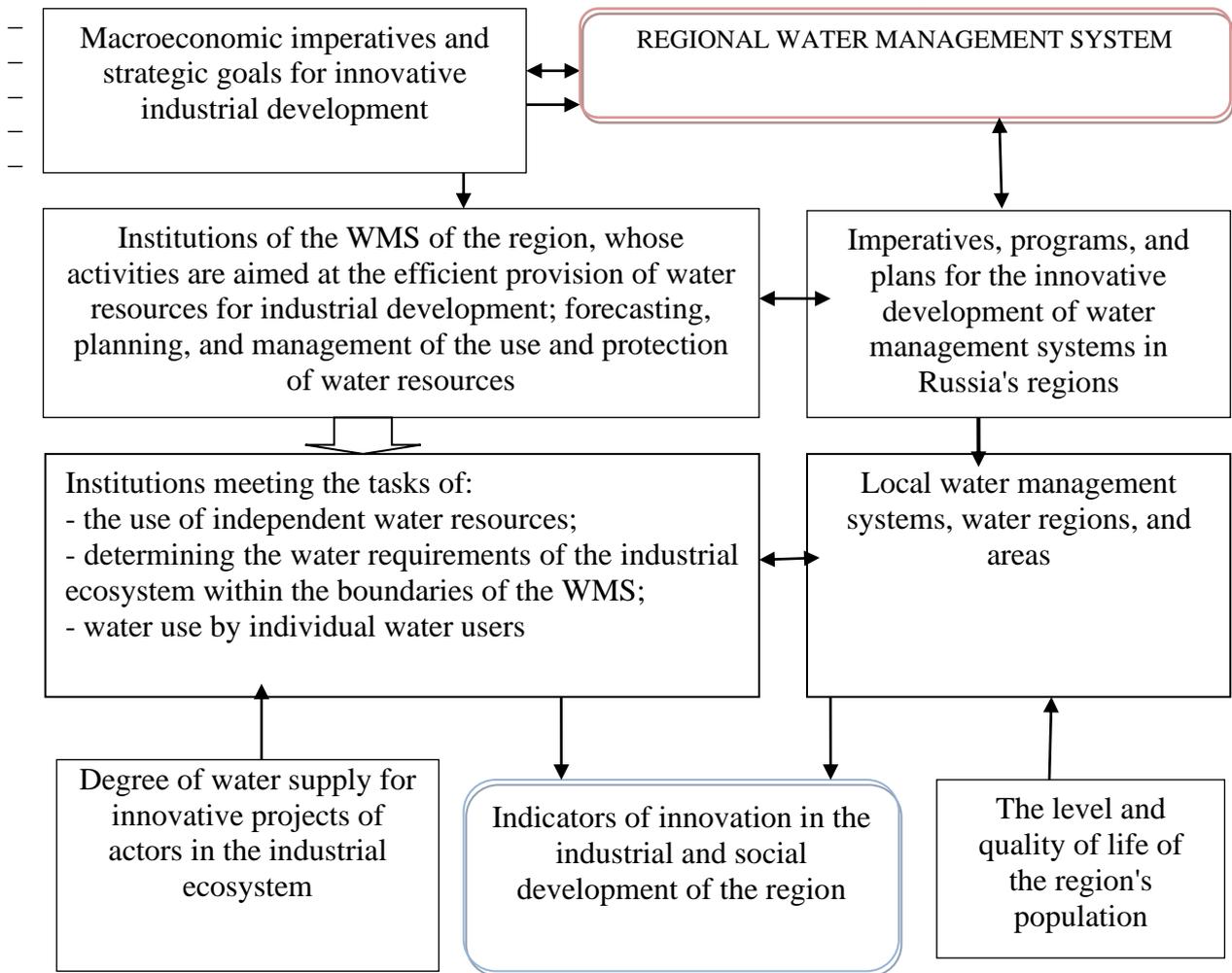
Figure 3. The mechanism for creating innovation resonance in the industrial ecosystem and innovation responses in related spheres



In particular, the study of the structural and hierarchical components of the industrial ecosystem allows determining the correspondence between the available industrial capabilities and the objectives of strategic change, as well as identifying the type and strength of interrelationships that lead to the formation of innovation responses in the perceptual system. The latter can be individual components of the industrial ecosystem itself (e.g. agro-industrial complex, regional WMS, service sector, in particular, healthcare, which demonstrated a high multiplier effect of industrial innovation during the coronavirus pandemic, etc.), as well as the external environment. Thus, it becomes possible to manage industrial ecosystems in accordance with the trends of innovation development with regard to the innovation response formed by them in the process of functioning.

In this context, we note once again the dual nature of several perceptive systems, in particular the region's WMS, which is, on the one hand, a natural ecosystem that provides a systemic resource (water) for the functioning of industry and, on the other hand, a part of the region's industrial sector (Figure 4).

Figure 4. The duality of the economic nature of the WMS as a subsystem of the region's industrial complex



The methodological basis for the research of the issues of achieving innovation resonance in industrial ecosystems, as well as innovation response in related areas is formed by the methodology of economic growth analysis, the methodology of structural analysis, and the systems paradigm. The study was based on the principles of:

- a resource-based approach to investigating the rationality of symbiotic relationships in an industrial ecosystem;
- a functional and hierarchical approach in investigating the factors and conditions for the emergence of innovation responses in subsystems of the industrial ecosystem;
- a process-based approach that focuses on processes that provide the implementation of management interventions aimed at achieving innovation resonances in the structural elements of the industrial ecosystem;

– a system-synergetic approach that allows considering the development of industrial ecosystems as a result of the self-organization of a complex structure in conditions of modernization transformations.

Resource reserves of achieving innovation resonances in industrial ecosystems

The study of conditions leading to innovation resonances in industrial ecosystems is based on the functional and hierarchical approach, which identifies the structural components of the region's multilevel economic potential and assesses the dynamics of their development. The analysis of structural dynamics allows identifying the weak points in the processes of innovative industrial development, substantiating the limiting factors, and identifying the reserves for the use of resources. On the other hand, the existing structure of economic potential of the industrial ecosystem generates certain innovation impulses that determine the strength and direction of innovation responses in the perceiving systems.

The methodological basis for the study of structural dynamics can be an inter-industry balance, the model of which allows us to study the coherence of development of different sectors of the regional economy (raw materials and non-raw materials, production and financial, etc.) and identify changes in the dynamic properties of the industrial ecosystem. Besides, the model of inter-industrial balance allows us to timely identify the limiting factors of balanced development, which limit the opportunities of the industrial ecosystem for innovative development.

In modern practice, the methodology of the input-output model by Leontief is the most widespread. The demonstration of the possibilities of using Leontief's model in its dynamic variation to study input-output proportions in regional systems, presented in the work of E.L. Toroptsev et al., shows that achieving innovation resonances is possible even if one of the components slightly deviates from the total development trend. The system remains capable of self-producing growth, which will be balanced by the fact that "the components defined by negative eigenvalues will fade, and growth will obey one component of the trend with a positive eigenvalue" [15]. The main constraint on development will be an error in the allocation of limited resources, when excessive allocations of resources (in particular, financial resources) to some economic activities lead to the underfunding of others. As a result, the economic system will be forced to import scarce goods, including those that it could effectively produce.

It means that the achievement of innovation resonances in the industrial ecosystem, first of all, is provided by the effective resource exchange between its subsystems, as well as with the

environment. Leontief's model allows creating and controlling the proportions of development of all types of economic activities in the industrial ecosystem with a given growth rate.

To achieve innovation resonances, all elements of the industrial ecosystem must be closely interconnected which implies a continuous circulation of resource flows. The management of the industrial ecosystem is poly-outlined, which is due to the diversity of processes at different levels of the hierarchy.

From the perspective of the resource approach, the main processes taking place in the industrial ecosystem represent the resource exchange between multiple actors of different types and levels of hierarchy at each stage of the added value chain. For these processes to lead to innovative resonances and help trigger self-organizing and developmental processes in the industrial ecosystem, they need to be provided along the entire chain (Table 1).

Table 1 Conditions for the emergence of innovation resonances at individual stages of the added value chain in the industrial ecosystem

Steps in the added value chain	Subjects of resource interactions	Conditions for the emergence of innovation resonance
Research and development	producers of innovation — industrial ecosystem — consumers of innovation	- consistency of the development targets of individual subsystems of the industrial ecosystem, as well as their alignment with national scientific and technological development priorities in general - consistency of supply and demand for innovative products and services
Production	industrial companies — manufacturing and financial infrastructure — industrial companies	- consistency of management impacts on industrial ecosystem capacity with the internal dynamics of its development - consistency in the proportions between the availability and use of innovative resources
Logistics and sales	suppliers — industrial companies — consumers of innovation	- consistency in the proportions between the availability and use of innovative resources - consistency of supply and demand for innovative products and services
Service and after-sales service	industrial companies — consumers of innovation	

Resource reserves of the achievement of innovation resonance are expressed in the target-oriented influences (institutional, informational, industrial-technical, etc.) on the processes of resource flow circulation in the direction of achieving the balanced development of individual

components of the industrial ecosystem. At the research and development stage, the most important thing is to ensure the necessary amount of investment in the practical implementation of these ideas to achieve the targets of development of individual subsystems of the industrial ecosystem, as well as their relevance to the priorities of national scientific and technological development as a whole. A public-private partnership mechanism can be considered as the main mechanism for addressing this challenge, allowing for the sustainability of resource provisioning processes by linking individual participants in innovation projects into added value science and production chains.

Another important task is the orientation of scientific research towards market demand. This task can also be achieved through the development of partnerships, where industrial companies will use external resources to develop new technologies and produce innovative products that are competitive in internal and external markets.

At the stage of production, the main conditions for achieving innovation resonance are coordination of managerial impacts on the potential of the industrial ecosystem, considering the internal dynamics of its development, as well as the balance of proportions between the availability and use of innovative resources. The solution to this problem lies in the technological integration of economic structures that form the industrial ecosystem. It is important to pay attention to the personnel component of the resource potential of enterprises in the imperatives of intellectualization of production. The resource provision of production of a new type should rationally combine tangible and intangible resource flows.

The logistics and sales stage is particularly important when the borders of industrial companies are expanding their presence in the geographical space. Modern technologies of integration interaction between economic agents also act as an initiator of the emergence of innovative resonances at these stages. The progressive practice of industrial integration shows that linking individual groups of economic entities on various integration platforms reforms value chains, significantly reducing the innovation cycle [23].

In the service and after-sales phase, the trend towards digitalization of manufacturer-consumer interactions with increased customization processes is most evident. As feedback, this implies the need to develop platform-based interactions between the industrial ecosystem and the external environment. The balance in the development of the industrial ecosystem at this stage is ensured by the consistency of the main parameters of functioning and innovative characteristics of the environment in which consumers of innovative products are developing. As noted by L.M. Davidenko and others, "the development of professional, digital, and entrepreneurial competencies of

personnel is the main steps in building platform interaction that provides an optimal correlation of resources of ecosystem participants" [3].

4. Conclusions

A determining factor in the economic growth of the national economy is the presence of a high-tech industrial sector characterized by sustainable indicators of innovation activity. Industrial ecosystems can provide an innovative orientation of economic transformations in other sectors and spheres of activity by generating multiplicative effects (innovation responses), the strength and direction of which largely depend on achieving innovative resonance in the structural elements of the industrial ecosystem.

Structural changes in the industrial ecosystem arising in the process of development should affect all of its components, ensuring the consistency of ongoing transformations, as well as the balance of resource flows. This is due to the system-wide properties of the economy when each component ensures the performance of a particular function, and disruption in its development due to resource scarcity leads to the inhibition of the emergence and manifestation of innovation resonance. At the same time, regardless of which component is resource-limited in the processes of production/implementation of innovations, the manifestation of innovation resonances can be suspended or reduced. Vice versa — a targeted managerial impact aimed at improving the balance of innovation processes in all structural and hierarchical components of the industrial ecosystem will contribute to achieving the expected innovation response in related industries and areas of activity, as well as in the region as a whole.

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