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Differentiated Approach To Government Support Measures In Industrial Ecosystems As State Industrial Policy Principle

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Abstract
Industrial policy in the Russian Federation principles include incentive measures application in the industrial sector and ensuring their rational combination to achieve the targets and indicators established by strategic planning documents. This article provides a scientific justification for differention necessity on government support measures for various types of industrial ecosystems in Russia. Amidst global economic transformations driven by digitalization, production localization, and technological leadership pursuit, industrial ecosystems have become a crucial factor in ensuring sustainable development and industrial competitiveness. The article proposes industrial ecosystems classification based on their innovativeness and productivity levels, allowing to adapt government support measures according to each ecosystem specific characteristics. Based on statistical data analysis on Russian industrial clusters from 2020 to 2023, we identify different ecosystems types, ranging from traditional manufacturing to high-tech industry leaders. For each industrial ecosystem type, specific government support measures and tools are proposed, including legal, economic, and organizational mechanisms, as well as incentives for cooperation, enabling them to adapt to changing conditions, unlock their potential, and ensure resilience. The study demonstrates that a differentiated approach to government support, considering industrial ecosystem development level, can serve as the foundation for an effective industrial policy formation.

Keywords: *industrial ecosystem, cluster, industrial policy, government support, differentiated approach, innovativeness, productivity, digitalization, sustainable development, cooperation.*

Introduction

Economic development trends, including supply chain restructuring, economic potential redistribution, production localization, ESG agendas, and the pursuit of technological leadership, highlight the need to revise industrial management approaches. In this context, industrial policy plays a crucial role as a tool for economic growth and innovation, aiming to establish a balanced and self-sufficient industrial sector (Gamidullaeva, 2023; Mitschek et al., 2024; Dube et al., 2024).

In Russia, industrial policy encompasses legal, economic, and organizational measures to enhance industrial potential and ensure competitive production (Federal Law). The relationship between industrial policy and development factors is determined by their impact on industrial priorities and strategic initiatives effectiveness. Key factors shaping Russia's industrial policy include increasing industrial output and labor productivity, regulating industrial product prices, reducing asset depreciation, promoting innovation, strengthening financial stability, reducing dependence on borrowed funds, and minimizing environmental impact through waste management. Beyond technological upgrades and import substitution, proactive management approaches are essential for industrial ecosystem development.

A proactive industrial policy based on reindustrialization and technological sovereignty now serves as both a transformation tool and a response to crises, ensuring sustainable economic competitiveness (Mityakov et al., 2023). Government support for industrial clusters plays a central role in this process. The concept of an industrial cluster is federally recognized in Russia. According to Federal Law No. 488-FZ "On Industrial Policy in the Russian Federation" (2014), an industrial cluster comprises industrial entities linked by geographic proximity and functional interdependence. However, digitalization, globalization, and innovation necessitate rethinking traditional cluster models, historically seen as regional industrial development tools.

Network-based interactions now reflect broader economic and technological changes. As industrial clusters evolve, they form more complex and flexible industrial ecosystems. These ecosystems emphasize symbiotic relationships where participants not only coexist but also actively share resources (Titova, Ziglina, 2021).

An industrial ecosystem is a system of interacting actors, including companies, government agencies, research and educational institutions, and other stakeholders, collectively driving innovation, economic growth, and sustainability (Mityakov S.N., Mityakov E.S., 2024). Unlike clusters, where geographic proximity is key, ecosystems are united by a shared vision guiding their development and mission. Clusters primarily feature formal relationships, whereas ecosystems have a dynamic composition, integrating participants from different industries with complementary skills and resources, fostering self-organization and trust.

Industrial ecosystems create tightly integrated supply chains with high cooperation levels, leading to intense intermediate product exchange and joint technology development. Cooperation degree within a cluster can indicate its transformation into an ecosystem, measurable as the ratio of internally used production to total output. This ratio is typically higher in ecosystems, demonstrating stronger integration. Another key distinction is innovation focus. Ecosystems revolve around new projects that drive participant collaboration, whereas clusters often concentrate on traditional production. Ecosystems rapidly adopt new technologies and business models, advancing import substitution and enabling members to swiftly respond to market changes while creating high-value products.

Despite their potential, industrial ecosystems face challenges requiring government support, including high transaction costs (coordination, communication, and management expenses), trust-building, interaction standards, infrastructure and technology investment needs, workforce training, and weak integration into global supply chains.

Understanding the shift from clusters to ecosystems and its drivers is crucial for shaping effective industrial policies and supporting manufacturing enterprises. Over 150 industrial clusters currently operate in Russia, uniting manufacturing organizations to optimize supply chains, accelerate innovation, and enhance competitiveness. Some clusters exhibit clear ecosystem traits. Government support for transitioning from traditional clusters to advanced ecosystems will expand the technological base, diversify the economy, improve market positions, attract investment, and secure alternative funding sources. Only comprehensive and targeted government support can help industrial ecosystems overcome existing challenges, adapt to changing conditions, and realize their full potential.

Studies hypothesis suggests that a differentiated approach to state support for industrial ecosystems, based on their classification according to innovation and productivity levels, can enhance their efficiency and resilience. In our view, tailored legal, economic, and organizational measures implementation for each industrial ecosystem type, ranging from traditional to innovative, will increase the public policy effectiveness, foster a favorable environment for cooperation, reduce transaction costs, stimulate innovation, accelerate advanced developments in production adoption, and optimize resource utilization.

The objective of the study is to justify differentiated approach feasibility to state support for industrial ecosystems by classifying them according to productivity and innovation activity levels. To achieve this goal, the research focuses on identifying industrial ecosystems key development factors and substantiating their classification, assessing the alignment of existing state support measures with industrial ecosystem types, and developing recommendations for improving industrial policy to enhance the efficiency and sustainability of these structures.

Literature Review

Differentiated approach to state support for industrial ecosystems necessity is determined by their sectoral, regional, and strategic specificities. This approach makes it possible to account for specific industries and regions characteristics, ensuring optimal resource allocation and stimulating innovation (Honchar et al., 2024). For instance, funding for research and innovation under EU framework programs is distributed unevenly across European countries and institutions, underscoring the importance of regional and sectoral approaches (Piro, F. N., Seeber, M., & Wang, L., 2024). In Kazakhstan, industrial support measures are adapted for single-industry towns, considering their economic and social needs (Akbergenova et al., 2022). In Russia, state support for the industrial sector aligns with territorial development priorities and promotes entrepreneurial activity (Karpunina et al., 2017; Inayata et al., 2023; Grosu et al., 2021).

In recent decades, industrial ecosystems effective management has become particularly relevant. Ensuring their efficiency is a critical task for both individual countries and the global economy. Increasing attention is being paid to legal, economic, organizational, and other measures aimed at improving such formations performance (Krasnov A.E., Sapogov A.A.). Active and targeted state support maximizes industrial ecosystems potential and creates synergies that accelerate import substitution and reindustrialization.

From a legal perspective, a key aspect is the establishment of specialized coordinating structures, such as government agencies, development funds and institutions, industry associations, coordination councils, and interdepartmental commissions, responsible for managing ecosystem interactions and aligning efforts toward shared strategic goals. These structures play a crucial role in consolidating ecosystem participants, minimizing fragmentation, and achieving synergetic effects through joint activities. Unlike isolated enterprises, coordinated structures create a unified platform for interaction, increasing the efficiency of ecosystem initiatives (Janipour, Z., De Gooyert, V., Huijbregts, M., & De Coninck, H., 2022).

Legal mechanisms that facilitate cross-regional cooperation help optimize resource utilization and promote best practices exchange. This issue is particularly relevant in countries with significant disparities in regional economic development. A prominent example is China, where the Xinjiang region exhibits pronounced economic imbalances (Ju, X., Zhou, X., Zhang, L., & Zhang, Y., 2024). Regulatory mechanisms that enhance interregional coordination improve regional clusters efficiency, create conditions for balanced resource distribution, and ultimately contribute to reducing regional disparities.

Environmental regulations, though initially imposing restrictions on enterprises, in the long run, enhance technological and resource efficiency in industry (Li, P., & Shi, L., 2021). Stricter environmental standards compel businesses to modernize production processes, reducing their ecological footprint and improving overall resource efficiency. For nations committed to sustainable development, transparent and effective mechanisms are essential to balancing economic growth with environmental safety (Tanaka, K., 2011). These mechanisms should encompass both national and regional strategies, including legal frameworks that incentivize green technologies, efficient resource management, and adherence to environmental standards.

Industrial policy also involves economic measures aimed at improving production efficiency while mitigating environmental impact. For example, to enhance energy efficiency, ecosystem participants integrate cost-cutting tools and strategies to boost competitiveness. The adoption of energy-saving technologies lowers operational expenses, minimizes financial risks, and strengthens environmental sustainability. Industrial ecosystems that actively invest in innovative developments and low-energy-consumption technologies achieve synergetic effects, simultaneously enhancing economic and environmental performance (Dyrdonova, 2019; Violet et al., 2024; Kumar et al., 2024). Prioritizing energy efficiency not only promotes resource conservation but also enables enterprises to comply with environmental regulations, ultimately reducing environmental impact and increasing competitiveness (Nagesha & Balachandra, 2006; Kurniady et al., 2022; Htet et al., 2025; Nguyen et al., 2024; Shariati et al., 2013).

Another industrial policy essential component is organizational measures implementation aimed at strengthening cooperation among ecosystem participants and optimizing resource use. A key condition for achieving synergy in industrial ecosystems is collective interaction mechanisms development and joint efforts coordination. The economic and environmental efficiency of industrial ecosystems depends on social engagement degree and potential for creating closed-loop production cycles that facilitate resource redistribution and waste utilization within the ecosystem (Yoon, S., & Nadvi, K., 2018; Schmitz, H., 1995).

Such interactions enable ecosystem participants to achieve significant economic gains while simultaneously reducing environmental impact.

Building trust among industrial ecosystem participants is also crucial, as it enhances knowledge exchange and accelerates innovation. When participants trust one another, they are more willing to share expertise and insights, strengthening competitiveness and fostering successful development (Niu, K., 2010).

Encouraging innovation and knowledge exchange among ecosystem participants is a vital factor in successful industrial ecosystems. Despite innovation inherent risks, it significantly increases industrial ecosystems profitability of and their participants by developing intangible assets, including intellectual property. Industrial ecosystems that prioritize innovation establish lasting competitive advantages through enhanced collaboration and eficient knowledge management systems creation (Druzhinin & Alekseeva, 2020).

Another crucial aspect is financial and economic parameters analysis within cluster formations. Methodologies development and application to study interconnections and interdependencies among enterprises within ecosystems help optimize management and ensure long-term sustainable development (Pizengolts, Savelyeva & Korobeynikova, 2018; Ochilov, I., 2023). Effective cluster structures require collaborative mechanisms integration, innovation-driven growth strategies, and strategic resource management. Such approaches enhance cluster overall competitiveness and resilience.

Industrial ecosystem efficiency assessment must be comprehensive, encompassing both individual participant performance and ecosystem's overall results. It is essential that ecosystem activities align with macroeconomic objectives (Gusakov, E., 2021). One key factor for improving efficiency is knowledge integration among ecosystem participants, facilitating market adaptation and fostering innovation (Morosini, P., 2004). Moreover, interactions effectiveness within an ecosystem may depend on participants geographic proximity. The closer an entity is to the ecosystem's center (core), the more efficiently it can collaborate with other members, enhancing knowledge transfer and cooperation (Bagley, M., 2018). Typically, the core consists of key players—leading companies, research centers, educational institutions, or innovation hubs—that possess critical resources, expertise, and technologies, driving ecosystem growth and innovation.

In conclusion, a differentiated approach to state support for industrial ecosystems, combining legal, economic, and organizational measures, enables sectoral and regional specificities consideration. This approach facilitates optimal resource allocation, enhances coordination, promotes collective action, and fosters innovation and knowledge exchange.

Materials and methods

The study utilized data from the State Industrial Information System (SIIS), including statistical indicators on industrial clusters in the Russian Federation for the period from 2020 to 2023. Key analyzed indicators included value added per employee and research and development (R&D) expenditures per employee. To assess cooperation level among cluster participants, a methodology was applied that calculated products volume ratio used by other cluster participants to the total volume of products produced.

The research also relied on academic literature review, including scientific articles, regulatory documents, and reports on industrial ecosystems and clusters. Industrial ecosystems classification by productivity and innovation levels was based on international approaches adapted to Russian conditions. When determining threshold values for productivity and innovation indicators, both leading global practices and the specific characteristics of the Russian economic environment were taken into account. For data visualization, phase portraits were constructed using dedicated library in Python, allowing for changes clear representation in cluster productivity and innovation activity over the study period.

A Differentiated Approach to State Support for Industrial Ecosystems

Modern industrial ecosystems represent complex, multi-level systems that encompass a wide range of participants—from traditional enterprises to innovative companies utilizing advanced technologies and digital solutions. Their development follows the structural dynamics and participants' internal co-evolution processes. Such ecosystems architecture includes technological maturity various levels, interdependencies between participants, and cooperation mechanisms (Benitez, Ayala & Frank, 2020). At lower development levels, ecosystems are characterized by stability and resilience but have limited potential for innovation. As their structure becomes more complex, they begin to integrate new technologies actively, creating conditions for industrial renewal and long-term growth (Sant'Ana et al., 2020).

Productivity and innovation are the two main factors shaping the dynamics of industrial ecosystem development. Productivity, which reflects the efficiency of resource utilization, is directly linked to the technological level and production organization (Andreoni, 2018). At the same time, innovation drives modernization and new technologies adoption, enhancing industrial ecosystems adaptability and competitiveness (Klimas & Czakon, 2021).

Industrial ecosystems boost productivity by integrating ideas, expertise, and resources from various economic actors, including government structures, thereby fostering the creation of new processes and business models (Erten, 2023). However, innovation of high level does not always lead to maximum productivity: enterprises actively implementing innovations may temporarily experience a decline in performance due to adaptation challenges. Conversely, ecosystems with high productivity but low innovation levels often face risks of technological lag and declining competitiveness in the long term (Greco et al., 2021).

A classification framework has been developed to evaluate industrial ecosystems based on two key criteria: innovation and productivity levels. (Table 2). This classification enables ecosystem types identification, ranging from traditional industries with low innovation activity to industry leaders leveraging cutting-edge technologies.

Table 1. Industrial ecosystems by innovation and productivity levels classification

	Productivity		
Innovations	**low level**	**medium level**	**high level**
low level	**Traditional production ecosystem** Conservative enterprises working with old technologies. Manual labor prevails, minor improvements in processes. Focus on stability, minimal changes and cost reduction.	**Adaptation ecosystem** Businesses that are beginning to adopt new technologies but are still heavily dependent on old ways of working. Automation tools partial adoption, but slow pace of change.	**Sustainability ecosystem** Traditional enterprises operating sustainably on old technologies, with innovations limited use. Stability of production activities prevails, but there is an active developmen lack.
medium level	**Improvement ecosystem** Companies that actively implement improvements in production processes, but do not focus on radical changes. Focus on optimization, quality improvement and small changes.	**Growth ecosystem** Companies that actively implement new technologies and production methods, increasing productivity. Medium speed of change prevails. Partial use of digital technologies and innovative solutions.	**Development Ecosystem** Companies that use new technologies and production methods on a regular basis to improve production efficiency. Continuous productivity growth through digitalization and innovation.
high level	**Experimentation Ecosystem** High-risk businesses that actively test new ideas and technologies. Frequently fail, but with potential for breakthroughs. Production process is unstable but innovative.	**New models transition ecosystem** Enterprises that are transitioning to innovative business models by actively implementing new production technologies. Implement digital solutions and new	**Leadership and Breakthrough Ecosystem** Industry-leading companies using advanced technologies to ensure high productivity. Automation and advanced technologies high usage, placing the company at industriy forefront.

		technologies to improve efficiency.	

The state must create conditions for industrial ecosystems effective functioning through financial support, tax incentives, infrastructure development, and regulatory frameworks establishment and enforcement. A key instrument in this process are development institutions, which facilitate coordination between businesses, the scientific community, and the government while also promoting international cooperation.

The authors argue that applying differentiated state support measures based on industrial ecosystems innovation and productivity levels is a reasonable approach. Given the complexity and diversity of these ecosystems, classifying them according to these criteria will help systematize management strategies and determine effective policy measures tailored to each ecosystem type (Table 2).

Table 2. Industrial ecosystems different types state support measures and instruments

Ecosystem type	**Measures and tools**			
	Legal	**Economic**	**Organizational**	**Cooperation stimulation**
Traditional production ecosystem	Equipment modernization stimulating (environmental standards, energy efficiency)	Subsidies provision, preferential loans, grants from the state	Enterprise modernization competence centers creation	Attracting technology partners, integrating into regional supply chains
Adaptation ecosystem	Technological modernization simplification (equipment accelerated registration)	Tax incentives for equipment imports introduction, grants for new digital solutions implementation provision	State platforms for technology transfer creation and development	Experience exchange programs with technology leaders, participation in national industrial clusters
Sustainability ecosystem	ESG standards implementation support, digital security regulation.	Preferential lending for improving energy efficiency and developing automated processes	Joint production centers creation and development	State support for entering international markets, subcontracting programs
Improvement ecosystem	Standardization initiatives development and certification mechanisms simplification.	Lean manufacturing technologies implementation grants provision, new digital solutions government subsidies.	Regional educational programs for advanced training development and implementation	Participation in industry consortia to share best practices
Growth ecosystem	Intellectual property and patent support protection conditions creation	State grants allocation for new products development and technologies implementation		Финансирование программ отраслевых альянсов и поддержка кооперации между предприятиями

Development ecosystem	Regulation that adapts labour laws to employment and digital business models flexible forms	Financial support for scalable R&D, support and high-tech product exports development	Industry innovation accelerators creation and development	international cooperation stimulation state programs development
Experimentation ecosystem	Experimental legal zones ("regulatory sandboxes") development	Venture financing and startups tax holidays	Experimental industrial sites creation and development	Strengthening ties with universities, supporting corporate partnerships with startups
New models transition ecosystem	Legal support for innovative business models	Digital transformation government subsidies allocation	Technology hubs creation and development	Industrial enterprises and IT companies unification programs
Leadership and Breakthrough Ecosystem	New technologies usage legal framework improvement (AI, quantum computing)	State mega-projects in high-tech industries implementation	International research centers creation and development	State and private partnerships development and high-tech export stimulation

A differentiated approach to state support for industrial ecosystems, based on their classification by innovation and productivity levels, offers several advantages:

- Ecosystem participants can assess their current position and identify optimal development trajectories.
- Classification enables most effective legal, economic, and organizational measures selection to stimulate innovation and enhance productivity for each ecosystem type.
- Industrial policy instruments can be tailored to different ecosystem types based on their maturity and potential.
- State support measures implementation adapted to specific ecosystem types will foster more effective collaboration among government institutions, businesses, research organizations, and other stakeholders, accelerating innovation and modernization processes.

Various types industrial Ecosystems policy measures analysis

1. **Traditional production ecosystems** typically require production assets modernization. State support measures should include subsidies and preferential loans for equipment upgrades, competency centers establishment and integration into regional supply chains.
2. **Adaptive ecosystems** often need new technologies rapid adoption. The state should facilitate equipment registration procedures, introduce tax incentives, fund digitalization projects, develop technology transfer platforms, and support knowledge exchange programs with industry leaders.
3. **Resilience ecosystems** focus on long-term sustainability in economic, social, and environmental dimensions, relying on established technologies with limited innovation adoption. Government support should include digital security standards, concessional loans for production automation, joint production centers creation with innovative enterprises and assistance in accessing international markets.
4. **Improvement ecosystems** are designed to drive innovation, enhance competitiveness, and accelerate economic growth. Support measures should involve standards development and certification simplification, technological grants, educational programs, and incentives for participation in industry consortia.
5. **Growth ecosystems** focus on developing new products and technologies. State support should ensure intellectual property protection, provide research and development grants, establish technology development centers and finance industry alliances for accelerated innovation deployment.

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6. **Development ecosystems** support industries experiencing rapid expansion. Policy measures should address labor law adaptation for digital business models, funding for scalable R&D, export incentives for high-tech products, and the expansion of international cooperation programs.

7. **Experimental ecosystems** require an enabling environment for testing new ideas and technologies. State support should include venture financing incentives, tax benefits for startups, industrial testbeds development and stronger university-business partnerships.

8. **Transition ecosystems** require support for digital transformation. The state should develop legal frameworks to protect innovative business strategies, allocate subsidies for digitalization, and promote industrial-IT sector integration.

9. **Leadership and breakthrough ecosystems** are focused on advancing high-tech industries. Government support should enhance AI regulation, establish international research centers, and promote high-tech products export.

It is essential to emphasize that these measures are conceptual and may vary in composition and priority depending on industry-specific characteristics, economic conditions, technological development levels and national contexts. A comprehensive approach to supporting innovation ecosystems is necessary, considering their development stage. Beyond financing and regulation, organizational mechanisms should be strengthened to foster collaboration, while support measures must align with ecosystem participants current state.

Russia's industrial ecosystem development dynamics analysis

Currently, Russia does not maintain separate statistical records for industrial ecosystems. Instead, statistical data is collected on industrial clusters within the State Information System for Industry (GISP), which features an Industrial Atlas covering for 151 clusters. However, not all clusters qualify as ecosystems, and for many, complete statistical data is unavailable.

Industrial ecosystem development dynamics assessment requires economic activity indicators set, reflecting economic entities (participants) specific characteristics involved. In addition to innovation and productivity metrics, a comprehensive evaluation of industrial ecosystems must consider the level of participant cooperation. Several tools exist to quantitatively assess interaction degree within a cluster. For instance, the methodological guidelines developed for cooperation monitoring within GISP propose several ratios calculation, including:

1. Goods, works, and services volume, produced and supplied by an enterprise, that are used by other industrial cluster participants (in million rubles).

2. Goods, works, and services total volume produced and supplied by the enterprise (in million rubles).

This allows for a quantitative assessment of how extensively participants engage in joint activities based on their output within the ecosystem demand.

Statistical data processing revealed that the highest levels of cooperation were observed in the following industrial ecosystems: Pskov Region Industrial Electrical Engineering Cluster – 80.4%, Industrial Cluster for Specialized Equipment – 73.66%, Transport and Specialized Machinery & Instrumentation Cluster – 66.71%.

The nature of the products manufactured within these clusters suggests a specific organizational production structure. A closed or near-closed production cycle appears to be in place, enabling these ecosystems to achieve high cooperation levels among participants. High Cooperation has significant positive effects, thus strong integration within supply chains enhances collaboration and efficiency, meanwhile there are potential barriers to innovation diffusion: a highly closed system may be less open to external innovation and new technologies developed outside the cluster.

Table 3 presents two key indicators for Russian industrial clusters with cooperation levels above 30% from 2020 to 2023: R&D expenditure per cluster employee (in million rubles) and Value added per cluster employee (in million rubles). Clusters were selected based on both a cooperation level above 30% and data availability for two key metrics: innovation and productivity.

These indicators combined evaluation provides insight into Russia's industrial sector technological development and competitiveness. However, it does not fully capture ecosystem's performance all aspects, such as:

1. Organizational and institutional factors specific to different industries.
2. External influences, including economic conditions and international competition.

Thus, while cooperation, innovation, and productivity serve as essential benchmarks, a broader framework is needed to assess industrial ecosystem dynamics at full complexity.

Table 3. Industrial ecosystem development indicators dynamics

Cluster (industrial ecosystem)	Participants and cluster infrastructure expenses volume on scientific research and development, million rubles, per one cluster employee				Added value created by industrial cluster participants, million rubles, per cluster employee			
	2020	**2020**	**2020**	**2020**	**2020**	**2021**	**2022**	**2023**
Voronezh Region oil, gas and chemical equipment manufacturers cluster	0,263	0,266	0,228	0,198	1,173	1,256	1,244	0,374
Pskov Region industrial electrical engineering cluster	0,042	0,075	0,056	0,020	0,737	0,938	0,000	0,000
"TRANSMASH" industrial cluster	0,006	0,004	0,004	0,013	0,385	0,470	0,782	0,982
Pipeline fittings production cluster	0,001	0,001	0,000	0,001	0,949	1,006	1,056	1,109
"ABAT" industrial cluster	0,074	0,029	0,013	0,010	1,136	0,829	1,215	1,418
Volga Federal District furniture cluster	0,000	0,002	0,003	0,011	0,000	0,061	0,096	1,194
"Transport and special mechanical engineering and instrument making" cluster	0,033	0,034	0,072	0,060	2,179	1,648	2,330	3,305
"Kalashnikov industrial cluster "	0,101	0,122	0,121	0,148	0,400	0,432	0,441	0,058
Khabarovsk Territory industrial and construction cluster	0,001	0,002	0,006	0,005	0,520	0,661	0,739	0,903

Defining threshold values in economic system analysis constitutes a key scientific and practical issue, remaining a debated question within the international academic community. Contemporary methodological approaches to establishing these ranges include socio-economic system parameters statistical analysis, cross-national comparative studies, econometric modeling methods and others. However, despite methodological pluralism, no consensus exists on a universal calibration methodology for threshold values. This fact appears to be determined by economic system structures heterogeneity, institutional specificity and functional characteristics polymorphism. Specifically, attempts to synchronize comparisons of heterogeneous sectors (e.g., the information and communication technology segment and heavy engineering) or clusters with fundamentally different production functions (e.g., extractive industries and research institutes) appear methodologically unjustified.

Regarding applied research perspective, this necessitates limiting the methodology's scope to homogeneous or coherent industry clusters. Nevertheless, to verify proposed methodological toolkit operational potential, the study empirically determines reference indicator ranges, whose visualization enables dynamic explication patterns in analyzed clusters. The following boundaries are established for indicators reflecting industrial ecosystem development dynamics:
for the indicator "Participants and cluster infrastructure expenses volume on scientific research and development, million rubles, per one cluster employee".

- Low innovativeness – less than 0.1 million rubles per worker;
- Medium innovativeness – from 0.1 to 0.3 million rubles per worker;
- High innovativeness – more than 0.3 million rubles per worker.

For the indicator “Added value created by industrial cluster participants, million rubles, per cluster employee”:

- Low productivity – less than 2 million rubles per worker
- Medium productivity – from 2 to 4 million rubles per worker
- High productivity – more than 4 million rubles per worker

To assess innovativeness and productivity, a three-tier indicator stratification scale is proposed, tested in international and Russian studies (see, e.g., Morris, D. 2018; Crépon, B., Duguet, E., & Mairesse, J. 1998). However, absolute threshold values require adaptation to national economic conditions, technological development levels and methodological standards. The rationale for these ranges is outlined below.

Established R&D expenditure gradations rely on the "critical investment mass" principle necessary for innovation generation. The threshold of 0.1 million rubles per worker reflects the minimum level at which cluster participants can sustain basic research processes corresponding to “incremental innovations”. Exceeding 0.3 million rubles per worker is of high-tech sectors characteristic where R&D expenditures correlate with patent activity and entry into global markets. For the Russian economy, thresholds are adjusted based on two following factors. The first one is that economy has structural imbalances – imported equipment in R&D infrastructure high share increases nominal costs but does not always ensure proportional quality growth. The second is that R&D, commonly has state funding, thus, subsidies may artificially inflate indicators, masking low private investment efficiency.

According to Russian Government Resolution No. 779 (31.07.2015) "On Industrial Clusters and Industrial Clusters Specialized Organizations" and for applying activity stimulation measures, labor productivity in an industrial cluster must exceed the average labor productivity in the corresponding region’s manufacturing industry. Differentiation by value-added per worker level aims to identify resource-oriented economies “productivity trap”. The 2-million-ruble-per-worker threshold generally corresponds to manufacturing industries minimum profitability dominated by manual labor and low automation (OECD, 2020). The 4-million-ruble-per-worker mark signals the transition to an "intelligent manufacturing" model based on digital technologies synergy, skilled labor, and value chain optimization. In Russian conditions, a key adjustment parameter is sanction pressure: import restrictions on technologies reduce productivity in high-tech clusters, temporarily justifying lower thresholds.

The three-tier scale provides not only cluster state diagnostics but also identifies "development dysfunctions". For instance, high innovativeness combined with low productivity signals technology commercialization issues, while the opposite suggests resource-extensive growth model exhaustion. Additionally, proposed ranges enable tracking dynamics within industrial cycles: transitioning to "high" values in both indicators signifies cluster maturity, requiring a shift from state support to market self-sufficiency.

Thus, the developed thresholds integrate international methodologies and national specifics, forming a foundation for targeted state support and strategic planning. Notably, the proposed boundaries adequately reflect differences between traditional and high-tech economic sectors. In highly industrialized countries, productivity per worker is often significantly higher, but for developing economies, including Russia, these thresholds are quite realistic.

None of the studied ecosystems reach both innovation development and high productivity high levels. Phase portraits (Fig. 1), presented for some industrial ecosystems in Table 2, illustrate development dynamics.

In terms of innovativeness, most clusters exhibit low R&D expenditure. The exception is the "Kalashnikov" industrial cluster, whose innovativeness level approaches medium. Industrial clusters "Transport and Special Engineering and Instrumentation," "TRANSMASH", and the Pipeline Fittings Production Cluster show stable productivity growth. Meanwhile, productivity indicators decline for the Oil & Gas and Chemical Equipment Manufacturers Cluster in Voronezh Region and the "Kalashnikov" industrial cluster. In 2023, the Furniture Cluster of the Volga Federal District shows a significant increase in value added, which may indicate production expansion or a strategic course change.

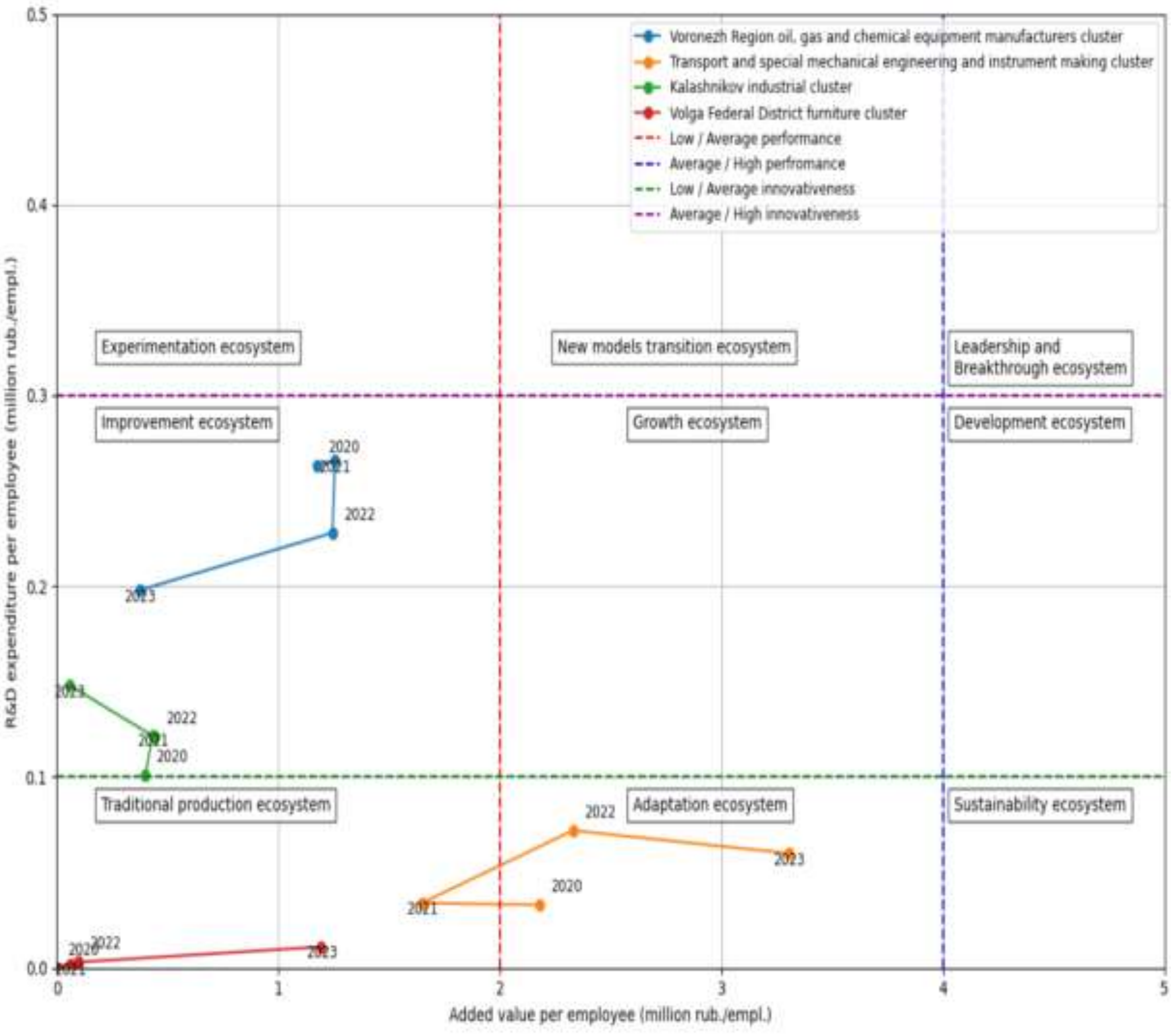

Fig. 1. Industrial ecosystem dynamics phase portraits

Figure 1 illustrates that over time, clusters can transition between different ecosystem types, reflecting their development dynamism. For example, the "Transport and special mechanical engineering and instrument making" industrial cluster belonged to the traditional production ecosystem in 2020 and 2021, shifting to the adaptation ecosystem in 2022 and 2023. Such transitions – from traditional production and adaptation to growth and leadership ecosystems –may result from changing internal and external conditions. These changes can be driven by various factors, including internal organizational transformations, fluctuations in R&D investment volumes, economic cycles, and shifts in demand for products and services.

Given that industrial ecosystems evolve over time, differentiated state support is required, involving state support measures implementation and tools adapted to industrial ecosystems specific types.

Discussion

Research on industrial ecosystems demonstrates that their development is shaped by numerous factors. Beyond innovativeness and productivity, additional criteria include:

1. Participant cooperation level.
2. National and global supply chains integration degree.
3. Digital transformation level.
4. Environmental sustainability.
5. Market adaptability.

These factors comprehensive consideration would enable a more complete assessment of different ecosystem types and facilitate even more effective state support measures development.

The hypothesis regarding differentiated approach necessity to state support, based on classifying industrial ecosystems by innovativeness and productivity levels, is partially confirmed. Different types of industrial ecosystems indeed require specific state support measures and tools. However, this hypothesis full verification requires more detailed statistical data. Specifically, it is necessary to analyze: Which state support measures were applied to different industrial ecosystems regarding time periods during which these measures were implemented and their impact on ecosystem development. Systematized data lack on state measures concerning industrial ecosystems complicates their effectiveness assessment. Future research should focus on establishing a database tracking state support measures application across various ecosystems and their outcomes.

Conclusions

The study demonstrates that an industrial ecosystem is a complex and dynamic structure, which development depends on multiple factors. A differentiated approach indeed enables the adaptation of state support measures and tools to different industrial ecosystems specifics based on their innovativeness and productivity. Based on the conducted analysis, several key directions for improving industrial policy can be identified:

1. Expanding the statistical database for industrial ecosystems comprehensive assessment, including applied state support measures and their effectiveness analysis.
2. "Industrial ecosystem" concept legislative formalization in regulatory documents, enabling more targeted state support measures.
3. State support measures and tools flexible adaptation depending on the industrial ecosystem's development stage and specifics.

Thus, the approach proposed in this study can serve as a foundation for further research and effective industrial ecosystem management strategies forming, promoting their sustainable development and enhancing Russian industry competitiveness.

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