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Creating Industrial Ecosystems as a Tool for Anti-Crisis Management

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ABSTRACT

In the current economic climate, the Russian industrial sector needs significant structural reform to facilitate its transition to a new, more advanced technological level. To achieve this goal, it is recommended to introduce new management tools, one of which is the establishment of industrial ecosystems. **The purpose of the article** is to prove that industrial ecosystems have a positive effect on the sustainable development of the Russian economy, especially during economic crises. **The subject of the study** includes industrial ecosystems as a crucial tool for managing economic crises. It also explores the historical context of industrial collaboration and the formation of clusters during economic downturns. This paper explores two industries that have been significantly affected by recent economic crises: pharmaceutical and automobile manufacturing. It is shown that during times of crisis, some industries develop characteristics similar to ecosystems. The authors propose a method for analysing and evaluating the performance of industrial ecosystems. **The theoretical and practical significance of the study** of this study lies in identifying the key factors that contribute to the development of effective industrial ecosystems. Furthermore, it aims to develop a trustworthy tool for evaluating their influence on socio-economic processes. The establishment of industrial symbioses is seen not only as a way to overcome economic crises but also as the foundation for the strategic long-term development of the Russian economy.

Keywords: industrial economics; industrial cluster; industrial ecosystem; industrial symbiosis; economic crisis; crisis management

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INTRODUCTION

In the context of modern economic realities, the industrial sector in Russia requires a radical structural overhaul to ensure a transition to a qualitatively new technological level. To achieve this, it is advisable to seek new management tools, one of which is the formation of industrial ecosystems.

An industrial ecosystem is a system of interacting actors (including companies, government structures, research and educational institutions, as well as other stakeholders) who collectively contribute to innovation, economic development, and sustainable growth in the industrial sector. Such associations are created independently by their members, have a high level of independence from the governing bodies at various levels, and adopt a decentralized approach when making decisions [1]. The interaction of participants in industrial ecosystems is based on socio-economic and scientific-technological links that form sustainable cooperation even in the absence of legally binding relationships. The effect of participating in an ecosystem includes expanding the opportunities and competencies of participants through the joint use of resources.

Industrial ecosystems have emerged as a result of the evolution of industrial clusters, with a primary focus on symbiotic relationships between companies that not only coexist but actively exchange resources and waste, creating closed production cycles [2]. Industrial ecosystems and industrial clusters can be combined under the common term «industrial symbiosis,» which highlights the mutually beneficial relationships between different enterprises and organizations working together by exchanging resources and knowledge to achieve the common goal of sustainable development and increased efficiency.

World practice has shown that the ecosystem approach significantly contributes to the reindustrialization of the economy [3, 4]. On the international stage, there are several examples of successful industrial ecosystems that can serve as models for study (Silicon Valley in the USA, the Baden-Württemberg industrial cluster in Germany, etc.). Their effective functioning enables the achievement of a synergistic effect [5].

Particular attention is drawn to discussions about the development of the ecosystem business model, which, in its generalized form, represents "building a complex non-hierarchical cooperative chain of various business directions and individual companies, united by a set of common rules, methods, and technological tools, and functioning as a single entity in relation to the consumer." [6]

A modern industrial ecosystem is formed from several key elements [7], which interact and create common value (digital platforms, industry and cooperation chains, key actors, eco-resource potential, digitized business processes, etc.). This leads to an increase in the efficiency and transparency of collaboration between participants.

Despite numerous studies in the field of the ecosystem approach, the hypothesis that the creation of industrial ecosystems is an effective management tool in an unstable economy remains insufficiently substantiated. The study of existing ecosystems is complicated by the fact that existing economic indicators (sectoral, regional, and data on the economic performance of individual organizations) do not allow for a full analysis of this object of activity [8].

Thus, the aim of this article is to substantiate the hypothesis of the positive impact of industry ecosystems on the sustainable development of the economy, including in times of crisis.

INDUSTRIAL SYMBIOSIS AS A TOOL FOR OVERCOMING ECONOMIC CRISES: A HISTORICAL OVERVIEW

During times of economic crises, the industrial sector in many countries underwent sig-

nificant changes. Industrial associations were created to ensure coordination and interconnectedness between enterprises. For example, during the Great Depression in the United States, government intervention actively shaped economic processes, creating conditions for the formation of clusters. Industrial policy also took into account social and environmental effects, ensuring employment and social stability [9].

There is a study that analyzes how technological changes and crises lead to the formation of new organizational structures and interactions, including industrial clusters [10]. The authors explore how radically new technologies create advantages for new market participants. They ask questions such as: under what conditions does this occur? To what extent are the shortcomings of existing companies related to their inability to adapt to new opportunities and strategies in a timely manner? The concept of "value networks" is introduced in this context.

In recent history, Russia has also experienced significant government interventions and initiatives aimed at stabilizing and developing the economy during crises. For example, the financial crisis of 1998 caused deep economic and social shocks. The public administration sector was forced to actively search for ways to stabilize and restore the economy, including the use of cluster approaches [11]. Thus, in 1999, one of the first IT clusters was created in St. Petersburg, focusing on software development for IT systems management across various industries, as well as the installation and maintenance of information systems [12].

One study examines the concept of the virtual economy as a system of informal rent distribution that emerged in post-Soviet Russia in the 1990s [13]. The authors describe how unviable manufacturing sectors from the Soviet era sought to protect themselves from market discipline. Enterprise leadership and their allies in the economy, including officials, conspired to use non-market prices and various forms of non-monetary exchange, including barter, to transfer value from the raw materials sectors to manufacturing industries. According to the authors, these informal mechanisms helped preserve certain sectors of the economy during the crisis.

The global financial crisis of 2008–2009 caused significant changes in economic systems worldwide, prompting many countries to take measures to create and support industrial clusters and ecosystems. A study analyzes how cluster approaches can contribute to economic revival and sustainable development, emphasizing the importance of aligning state policy with new economic realities regarding competition [14]. It is believed that government support should focus on creating favorable conditions for the self-organization of cluster participants, rather than managing them entirely [15].

The crisis related to the coronavirus pandemic in April 2020 led to a significant decline in most socio-economic development indicators in Russia. Subsequently, during 2020–2021, the government took vigorous measures to coordinate anti-pandemic and anti-crisis policies, including the development of an antivirus vaccine and vaccination of the population, which allowed, to some extent, to mitigate the most acute manifestations of the "corona-crisis" [16, p. 25]. At the beginning of the pandemic, many countries implemented restrictive measures, including border closures. In this context, the creation of clusters that utilized the advantages of sectoral and geographical proximity in forming new production chains, as well as the potential of small and medium-sized enterprises (SMEs), seemed preferable to relying solely on large businesses [17].

The 2022 crisis, associated with the beginning of the Special Military Operation (SMO) and unprecedented sanctions against Russia, led to the need for the introduction of a mobilization economy model [18]. The formation of

this model fully incorporated the experience of the anti-crisis and anti-pandemic policies of 2020–2021.

In all the economic crises discussed above, the role of the state can be highlighted, as it took an active stance in the management process by creating institutional conditions for the formation of clusters and ecosystems, including tax incentives, subsidies, investments in infrastructure, and educational programs. No less important was the self-organization of enterprises, and their active participation in the creation of effective industrial clusters and ecosystems ensured coordination and proper interaction among employees. Such industrial symbioses can be used not only as a tool for crisis management but also as a mechanism for long-term economic development.

Thus, it is proposed to use new structures, called metaverses, which represent the next stage in the development of industrial ecosystems and allow for the mobilization of resources in the relevant area without harming other sectors of the economy [19]. "An industrial metaverse is understood as a virtual space combined with real production processes, complementing them, and organized by leading technological companies based on network interaction principles to increase the efficiency of operations" [19, p. 379].

METHODOLOGY FOR ANALYZING AND EVALUATING THE EFFECTIVENESS OF INDUSTRIAL ECOSYSTEMS

Next, we will describe the author's methodology that we recommend for analyzing and evaluating the effectiveness of industrial ecosystems as a tool for crisis management. It includes several key stages.

1. **Problem Analysis**: The initial stage involves a detailed study of current and potential economic crises, their causes, and consequences. This is done to identify problem areas and needs that can be addressed and satisfied using the ecosystem approach.

2. **Development of an Indicator System**: The system includes three levels. First Level is *Leading Indicators*: These help determine the potential timeframes and scales of crisis phenomena. These indicators can include business confidence indices (BCI) in large sectors of the economy, measured in percentage terms and calculated based on surveys of industrial enterprise managers, as the difference between positive and negative responses. Additionally, stock market indicators, such as the monthly average index of the Russian Trading System (RTS), can be used. Leading indicators can signal the onset of an economic crisis in advance.

The Second Level is *Industry Indicators (Indices)*: These show how industrial ecosystems are created in some sectors during a crisis, which are essentially mechanisms of crisis management. The dynamics of such indicators allow for the assessment of the onset, depth, and end of crisis phenomena in each sector, as well as the potential for import substitution and economic growth.

The Third Level is *Performance Indicators*: These assess the impact of the created ecosystems on socio-economic processes. Such indicators can include the dynamics of GDP, adjusted for seasonality, GDP growth rates, real disposable income index, and others.

3. Dynamic Analysis of Three Groups of Indicators: This stage involves monitoring and evaluating leading and industry-specific indicators, as well as performance indicators. It examines the various effects related to the impact of crisis phenomena on industry-specific indicators (such as the onset of a downturn, depth of the decline, and the duration of the crisis until recovery). A conclusion is drawn about the signs of a crisis, the involvement of various sectors, and their impact on performance indicators.

4. Analysis of Fine Structure: Dynamics of Specific Industry Indicators: At this stage, a particular sector (or sub-sector) is selected for study, and the dynamics of industrial indi-

ces and specific types of products are analyzed in real terms.

5. Evaluation of the Effectiveness of Industrial Ecosystems: The final stage of the methodology includes a comprehensive assessment of the effectiveness of the functioning of industrial ecosystems within individual sectors. This evaluation is based on the analysis of results from previous stages of the methodology. The assessment determines how ecosystems impact production processes, the environment, and the social sphere, as well as how justified their use is as a tool for crisis management.

PRACTICAL EVALUATION OF THE METHODOLOGY

1. Problem Analysis: In our opinion, during crisis phenomena, certain sectors of industry acquire ecosystem traits for the following reasons:

- Companies begin to collaborate more closely to reduce costs and improve efficiency.
- Companies strive to diversify their services and products to be less dependent on a single market or direction, leading to the formation of ecosystems where different products and services complement each other.
- Crises accelerate digital transformation, and companies adopt new technologies to enhance the efficiency of their business activities.

For example, during economic crises, banks and financial companies often develop digital ecosystems, including online banking, mobile applications, and fintech services, to offer customers more convenient and diverse financial products [20].

2. **Development of an Indicator System**: *Table* 1 presents the system of indicators used by the authors.

3. Dynamic Analysis of Indicators. Let's consider the dynamics of the indicators in accordance with *Table* 1.

Leading Indicators (*Figures 1–2*).

Examples of Industry Indicators (*Figures 3–5*).

Performance Indicators (*Figures 6–7)*.

Table 2 contains the dynamic parameters of the response of the crises of 2020 and 2022 to the indicators presented in *Figures 1–7*.

From *Table 2*, it can be seen that among the leading indicators, the RTS index most adequately reflects the situation, with its decline typically being recorded a month before the onset of crisis events in the economy. The analysis of the dynamics of various sectors of the economy revealed the non-homogeneity of the time frames for entering crisis conditions, the depth of crisis manifestations, and the periods of post-crisis recovery. A differentiation in the indicators of economic performance is observed: during the first crisis, GDP fell within two months, whereas during the second crisis, it took five months. In contrast to GDP, disposable income showed a longer decline during the first crisis. This fact highlights the differences in the responses of various economic indicators to crisis phenomena.

4. Analysis of fine structure: dynamics of sectoral indicators. This study examines two characteristic examples of empirical analysis of industries that were significantly impacted by the recent economic crises. The pharmaceutical sector effectively adapted to changing conditions, successfully implementing anti-crisis measures. In contrast, the automotive industry was less resilient in the face of severe economic turbulence.

Pharmaceutical sector analysis. The pharmaceutical sector became one of the key industries in the fight against the pandemic. Investments in the development of vaccines and medical drugs contributed to the growth of the healthcare sector, having a positive impact on the economy during the crisis. The increase in vaccine production and medical equipment positively influenced GDP dynamics. Empirical data illustrating the dynamics of this sector's indicators are presented in *Figures 8–10*.

According to *Figure 8*, at the beginning of 2020, the pharmaceutical production index showed a slight decline. However, in the fol-

Table 1

A system of indicators for assessing the effectiveness of industrial ecosystems as a tool for crisis management

Indicator	Calculation Method	Period	Source
Leading Indicators			
Business Confidence Index (BCI) in the extraction of minerals; manufacturing industries; electricity, gas, and steam supply; air conditioning, %	Calculated as the arithmetic average of the balance of demand levels (order portfolio), finished goods inventory (with the opposite sign), and expected production output (according to the Official Statistical Methodology approved by Rosstat Order No. 643, dated 14.09.2022). The balance is determined by the difference between the shares of respondents who reported "increase" and "decrease" in the respective parameters	Monthly	https://rosstat.gov.ru/leading_indicators
Russian Trading System (RTS) Index, USD	A price-weighted composite index of the Russian stock market, including the most liquid stocks of the largest and dynamically growing Russian issuers in sectors related to the main sectors of the economy represented on the Moscow Exchange	Daily, averaged monthly	https://www.moex.com/ru/index/RTSI
Industry Indicators			
Production indices for specific types of economic activities in Russia, %	The ratio of the current value of the parameter to its value in the corresponding month of the previous year * 100	Monthly	https://rosstat.gov.ru/enterprise_industrial
Production of key types of products in physical terms	Direct operational monthly data since 2017 according to OKPD 2	Monthly	https://rosstat.gov.ru/enterprise_industrial https://www.fedstat.ru/indicator/57783
Performance Indicators			
GDP at 2021 prices, billion rubles, excluding the seasonal factor.	The evaluation of GDP production data, excluding seasonal and calendar factors, is carried out using the software product "JDEMETRA +".	Quarterly	https://rosstat.gov.ru/statistics/accounts
Physical volume index of GDP, %.	The ratio of the current value of GDP to its value in the corresponding quarter of the previous year * 100	Quarterly	https://rosstat.gov.ru/statistics/accounts
Index of real disposable monetary income of the population, %.	The ratio of the current value of real disposable income to its value in the corresponding quarter of the previous year * 100	Quarterly	https://rosstat.gov.ru/folder/13397

Source: compiled by the authors.

lowing years, the sector significantly strengthened its position, as evidenced by the sharp growth in the production of pharmaceuticals from 2021 to 2023. An important factor contributing to this was the government preferences provided during the pandemic, as well as the import substitution strategy. In contrast to pharmaceutical production, the vaccine development process is characterized by greater stochasticity. A pronounced seasonal factor can be observed here, as well as the wave-like nature of the population's vaccination process.

Automobile production analysis. It turned out that the industry is highly influenced by economic conditions (*Figures 11–13*). This was especially evident at the beginning of 2022, when there was a sharp decline in production volumes. The greatest losses were recorded in the passenger car segment, indicating the high sensitivity of this sector to changes in economic conditions and structural crises.

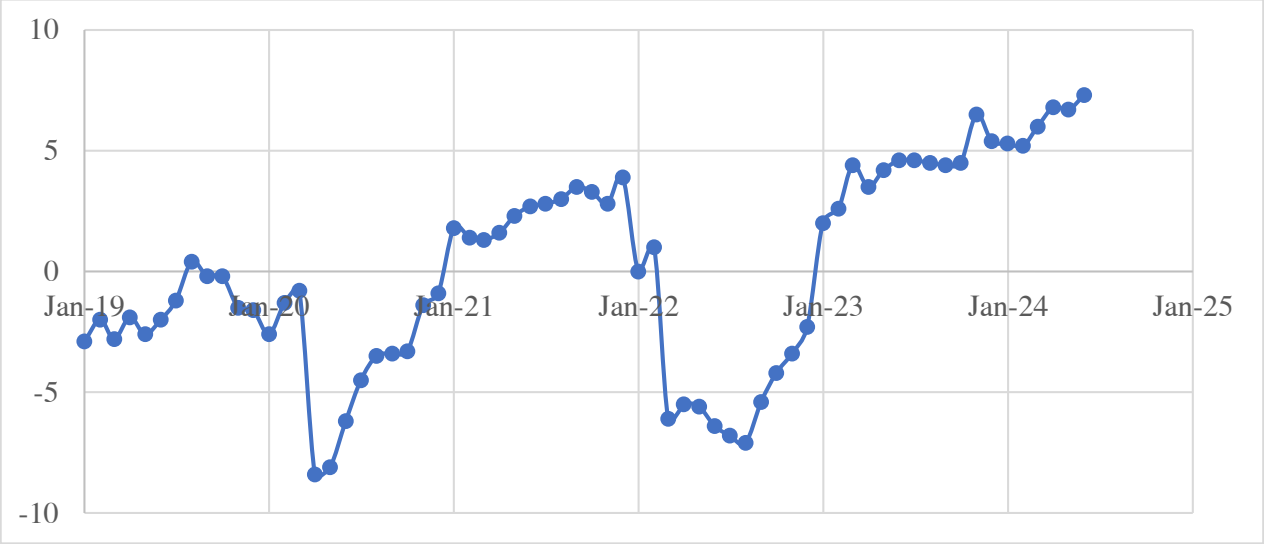

Fig. 1. **Dynamics of business confidence index in manufacturing, %**

Source: URL: https://rosstat.gov.ru/leading_indicators

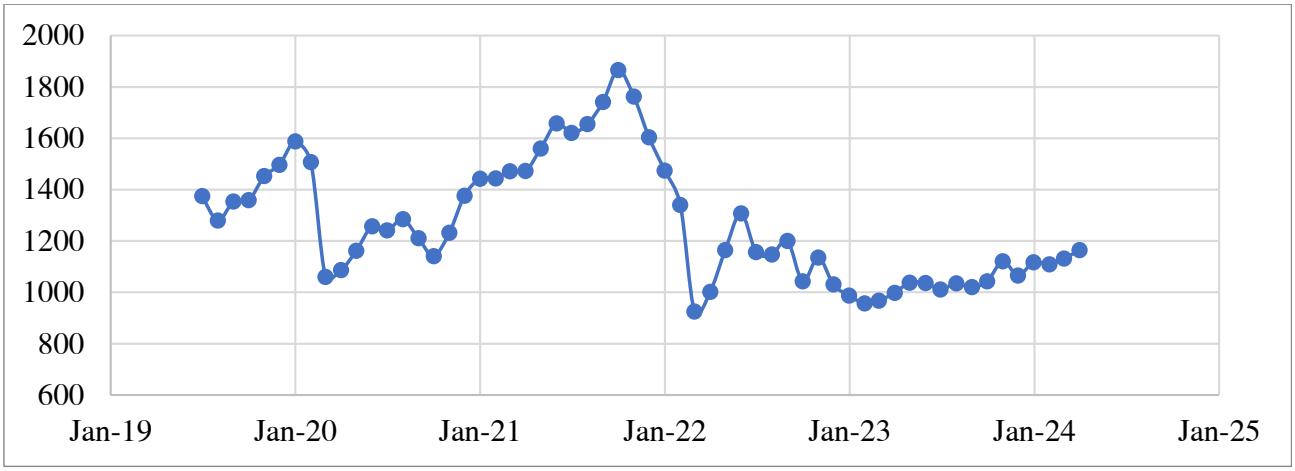

Fig. 2. **Dynamics of RTS index, USD**

Source: URL: https://www.moex.com/ru/index/RTSI

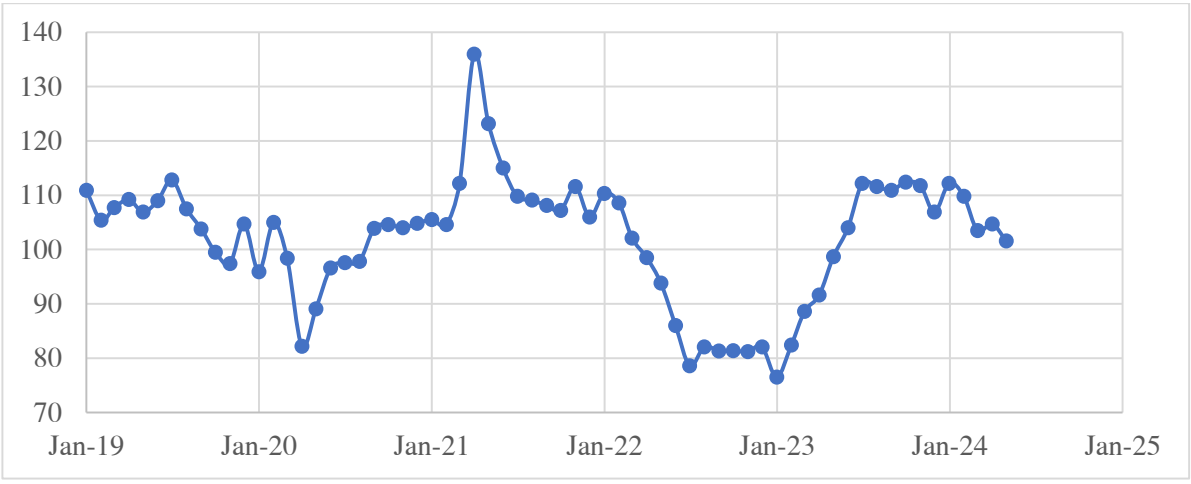

Fig. 3. **Dynamics of timber production index, %**

Source: URL: https://rosstat.gov.ru/enterprise_industrial

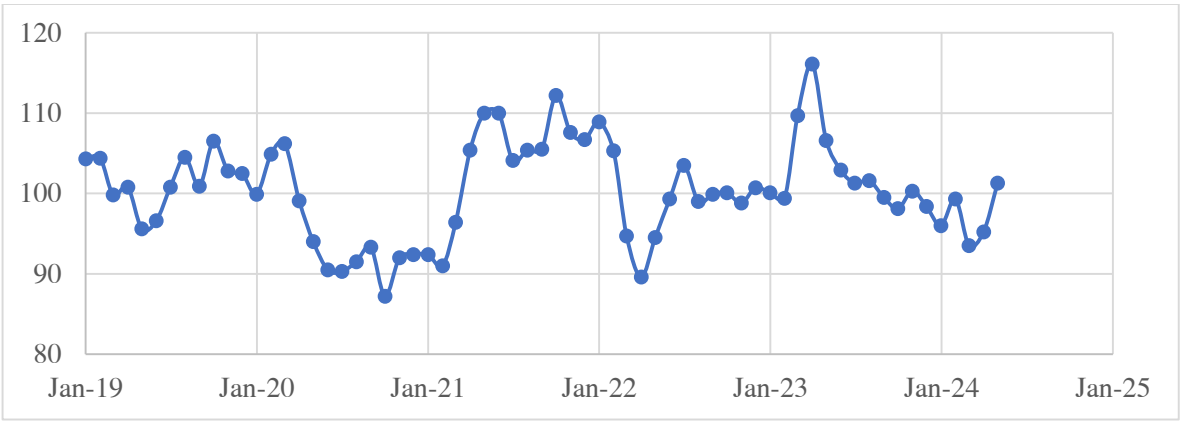

Fig. 4. **Dynamics of petroleum products production index, %**

Source: URL: https://rosstat.gov.ru/enterprise_industrial

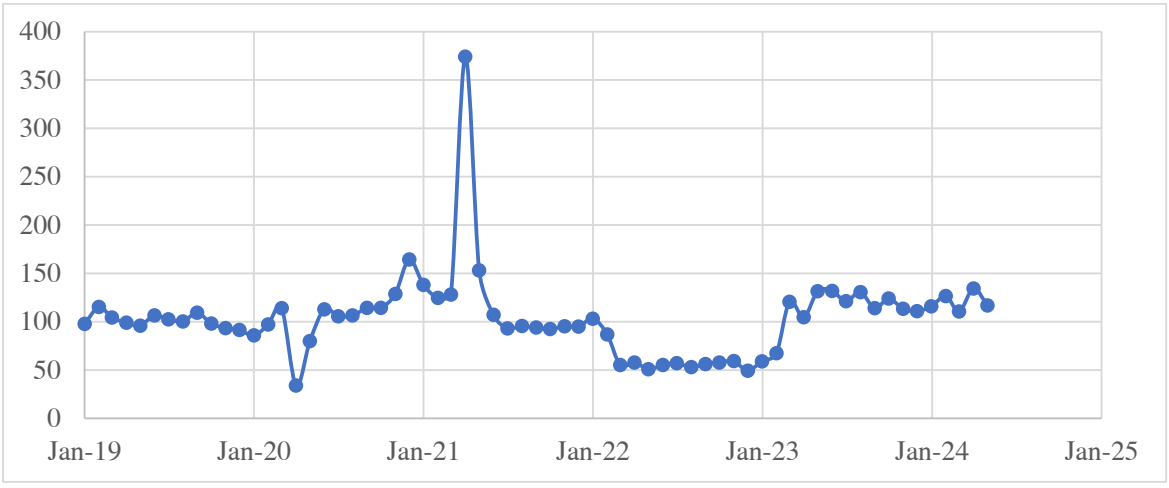

Fig. 5. **Dynamics of the household appliance production index, %**

Source: URL: https://rosstat.gov.ru/enterprise_industrial

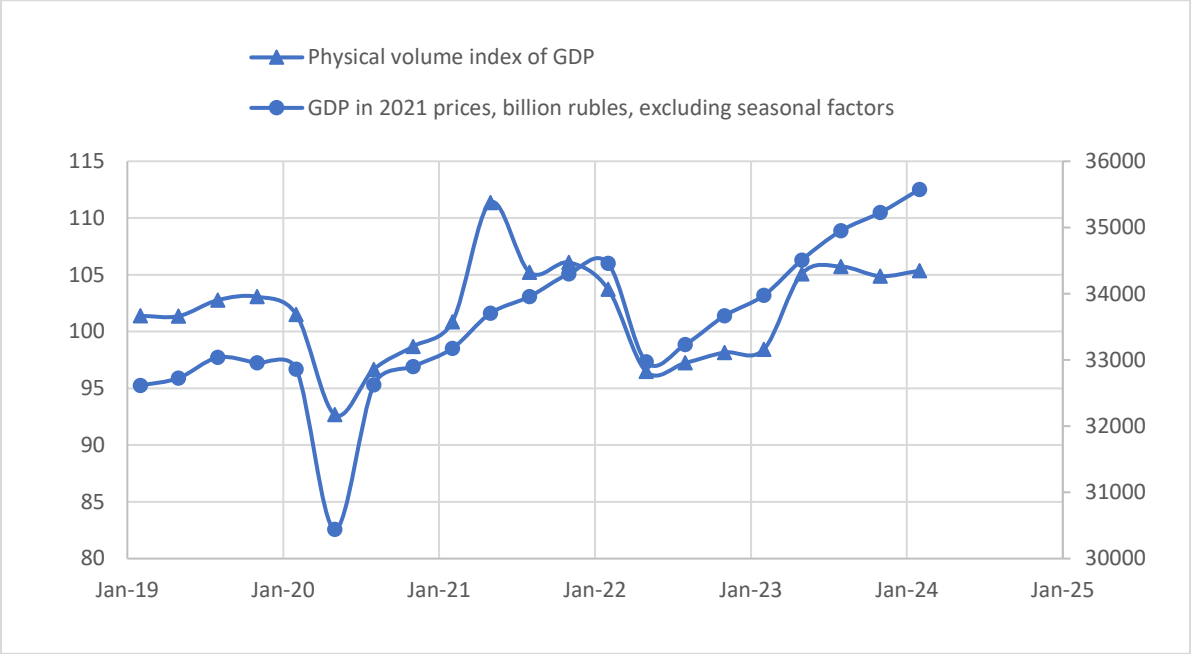

Fig. 6. **Dynamics of physical volume index of GDP,% (left axis) and GDP in 2021 prices, billion rubles (right axis)**

Source: URL: https://rosstat.gov.ru/statistics/accounts

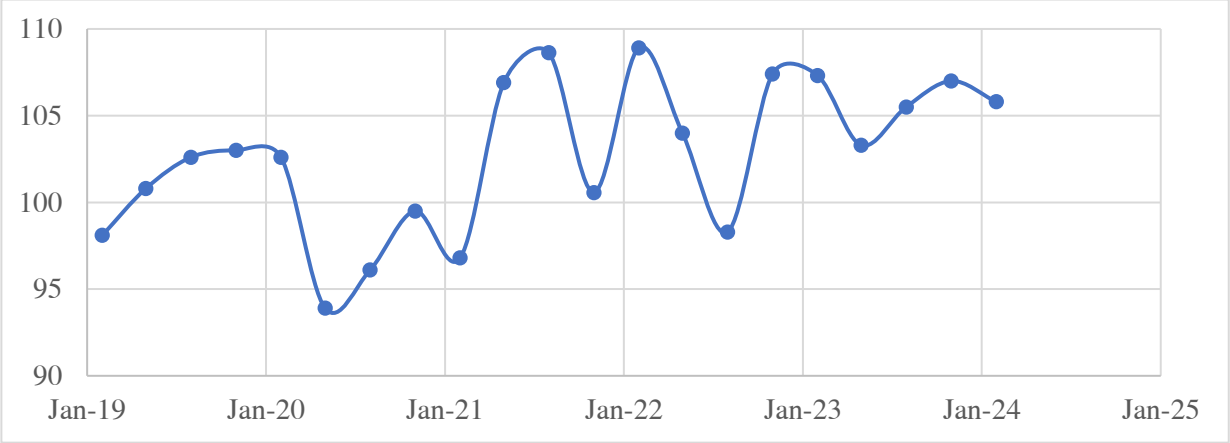

Fig. 7. **Dynamics of index of real disposable income, %**

Source: https://rosstat.gov.ru/statistics/accounts

5. Evaluation of Industrial Ecosystems Effectiveness. In conclusion, we present an analysis of several sectors of the economy in terms of the creation of industrial ecosystems and their potential as an effective tool for crisis management.

The defense-industrial complex (DIC) played a significant role in maintaining economic stability during the 2022 crisis. The increase in government orders for defense and related sector products contributed to the preservation of economic activity in the country. Despite the limited availability of empirical data, indirect evidence points to a growth in DIC product volumes over the last two years. DIC enterprises act as a driving force for domestic

Table 2

Dynamic Parameters of the Response of the Crises of 2020 and 2022 to the Indicators

No	Indicator	Crises 2020			Crises 2022		
		Start Date	Decline Depth	Recovery Period	Start Date	Decline Depth	Recovery Period
1	Business Confidence Index (BCI) in Manufacturing	04.20	10%	7 months	04.22	2%	8 months
2	RTS Index	03.20	30%	11 months	03.22	27%	7 months
3	Timber Production Index	04.20	20%	6 months	05.22	20%	6 months
4	Refined Petroleum Products Production Index	04.20	10%	12 months	04.22	8%	13 months
5	Household Appliances Production Index	04.20	20%	9 months	03.22	20%	8 months
6	GDP	05.20	8%	2 months	05.22	5%	5 months
7	Real Disposable Income Index	05.20	9%	5 months	08.22	10%	3 months

Source: compiled by the authors.

industry, stimulating reindustrialization and import substitution processes in the context of a mobilization economy.

After February 2022, DIC enterprises began to integrate more closely with various sectors of the economy to ensure a stable supply of necessary materials and components [21]. One study suggests using entrepreneurial ecosystems as a new form of interaction between DIC enterprises, SMEs, and other participants under changed conditions [22]. In another study, the authors justify the need for interaction between DIC enterprises and SMEs but highlight the emerging issue of technology transfer from small businesses to large ones [23]. The paper proposes a model for technology transfer, describing the interaction mechanism between small innovative enterprises and large regional businesses to create new innovative products. Another article presents a technology for managing the development of an enterprise's innovation ecosystem and demonstrates its testing at a large DIC enterprise. The research confirmed the methodological and practical value of the considered ecosystem technology [24].

Thus, it can be concluded that the hypothesis regarding the effectiveness of crisis management at defense-industrial complex (DIC) enterprises using the ecosystem methodology is well-founded.

A completely different situation is observed in the *automotive industry*. The empirical data presented in *Figures 11–13* show that in early 2022, when most foreign car manufacturers left the Russian market, it collapsed, particularly in the passenger car segment. The low level of production localization and slow import

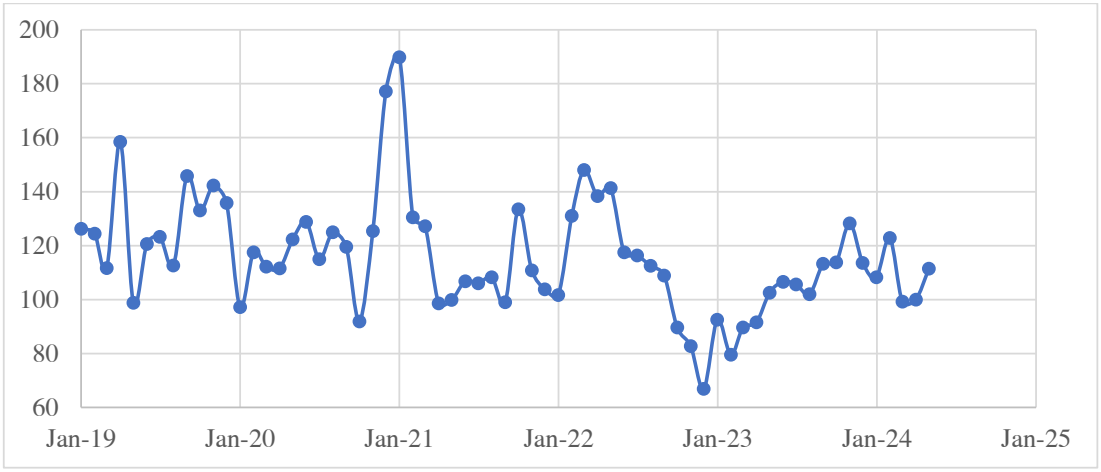

Fig. 8. **Dynamics of industrial production of medicines, %**

Source: URL: https://rosstat.gov.ru/enterprise_industrial

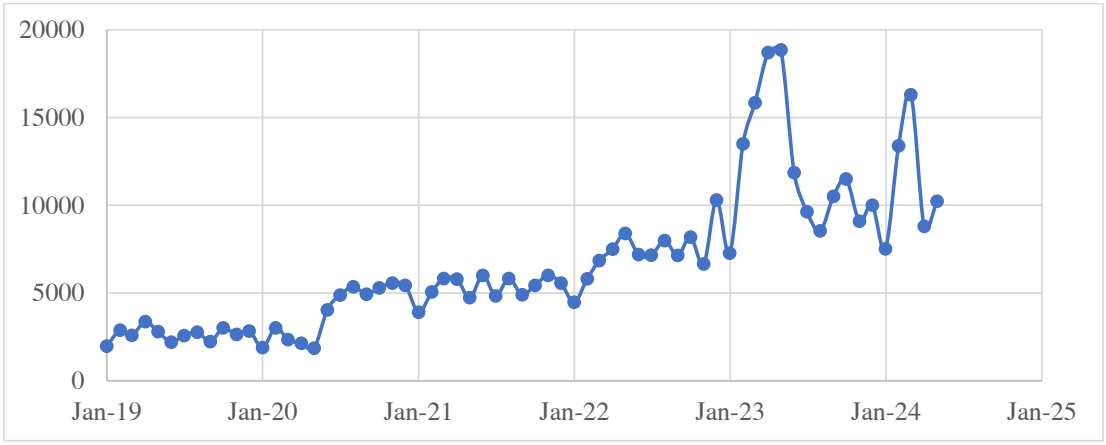

Fig. 9. **Dynamics of pharmaceutical production, thousand packages**

Source: URL: https://www.fedstat.ru/indicator/57783

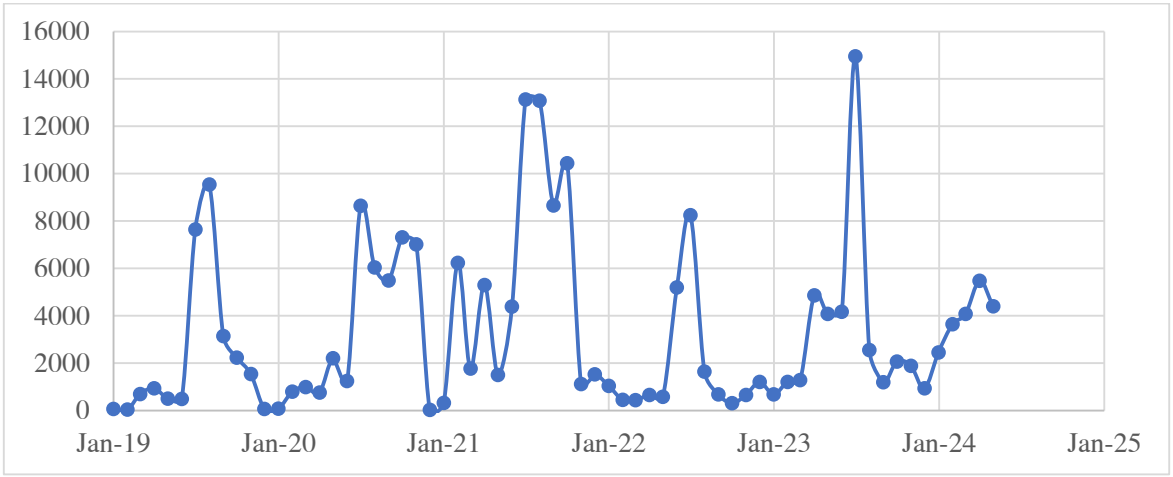

Fig. 10. **Dynamics of vaccine production, thousand doses**

Source: URL: https://www.fedstat.ru/indicator/57783

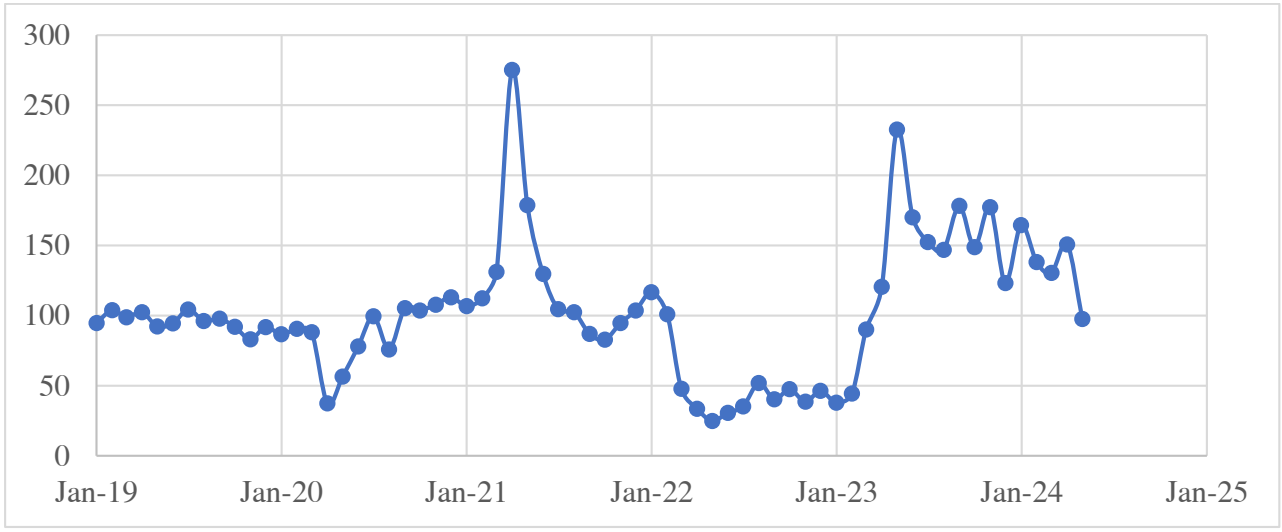

Fig. 11. **Dynamics of the motor vehicle production index, %**

Source: URL: https://rosstat.gov.ru/enterprise_industrial

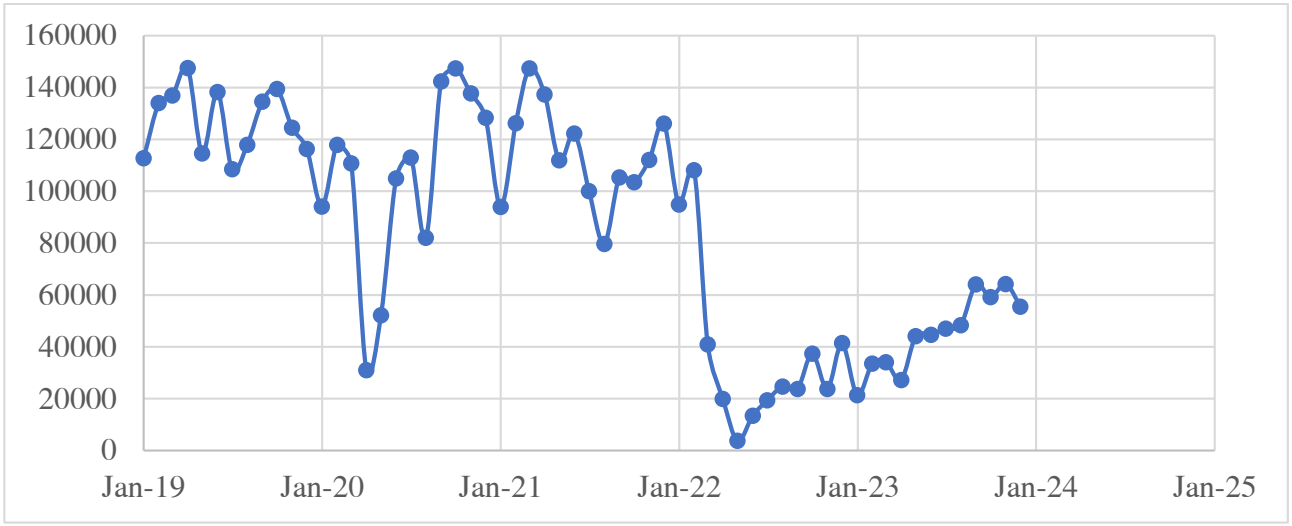

Fig. 12. **Dynamics of the passenger car production index, pcs.**

Source: URL: https://www.fedstat.ru/indicator/57783

substitution rates are, among other things, due to domestic manufacturers' reluctance to switch to network interaction.

A model of the automotive sector's innovative ecosystem, covering various technological innovations, is presented in a paper by Brazilian scientists [25]. The authors link the level of integration of ecosystem participants to car manufacturers' responsiveness to open innovations (OI). They believe that adapting participants to a platform ecosystem requires the implementation of digitalization and the shift toward OI practices. Furthermore, to create an effective ecosystem, a new level of cooperation and an "eco-friendly" type of competition between players is necessary. Interaction between the government and business is required to develop policies for integrating enterprises into the ecosystem.

Such systems are functioning in leading car-producing countries. In contrast, the domestic automotive industry is currently facing difficult

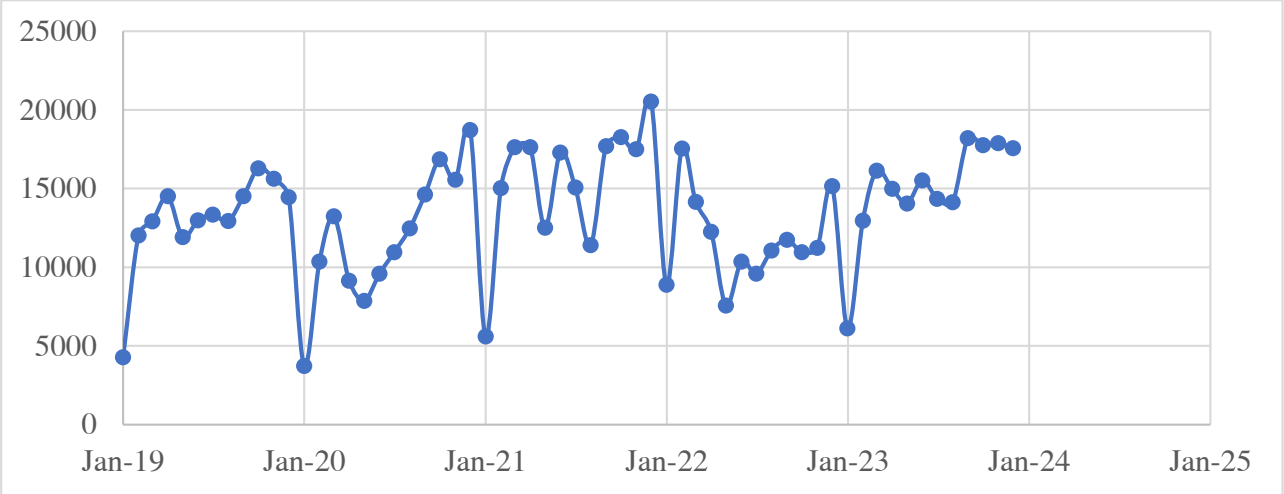

Fig. 13. **Dynamics of the truck production index, pcs.**

Source: URL: https://www.fedstat.ru/indicator/57783

times. The main barrier to ecosystem creation is the insufficient innovation culture among participants. To improve the situation, models of integration within automotive clusters and ecosystems developed by leading scientists can be applied.

As for the *pharmaceutical sector*, cooperation between enterprises within the ecosystem approach is not only possible but also entirely feasible. The COVID-19 pandemic became a vivid example when medical companies actively collaborated, creating ecosystems for the development, production, and distribution of vaccines. Additionally, telemedicine and digital platforms for remote medical services were developed [26].

In Moscow, an ecosystem has been formed for the rapid conduct of clinical trials of pharmaceutical products, aimed at improving the performance of the pharmaceutical industry under the pressure of sanctions, with the active implementation of import substitution mechanisms. One of the prominent examples of its effective functioning was the clinical trial of the COVID-19 vaccine «Sputnik V.» Thanks to the creation of this ecosystem, a significant increase in pharmaceutical production was achieved in 2023 (see *Fig. 9*).

Therefore, the ecosystem approach is beginning to be implemented in the pharmaceutical sector, leading to improved crisis management efficiency.

CONCLUSION

The empirical analysis of the crises of 2020 and 2022 demonstrated that industrial ecosystems play an important role in crisis management and economic recovery. Based on both crises, timely government support measures, investments in key sectors, and adaptation of production processes help accelerate economic recovery and mitigate the negative effects of crises.

The study results showed significant industry differentiation, with varying elasticity of sectors to crisis phenomena. This is confirmed by the parameters of the start, depth, and duration of the crises of 2020 and 2022 for different sectors of the economy.

At the same time, the high degree of integration of participants in the production process, characteristic of industrial ecosystems, is not supported by all sectors of the economy. This is due to their competitiveness level, the impact of sanctions, and historical development features that have influenced

the acceptance or rejection of the open innovation ideology.

Overall, it can be stated that the author's hypothesis about the possibility (and, in some cases, the advisability) of applying the ecosystem approach as a mechanism for crisis management in certain sectors of the national economy has been fully confirmed.

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