Relações Internacionais do Mundo Atual - unicuritiba

**Submetido em:** 19/12/2023
**Aprovado em:** 03/03/2024
**Avaliação:** Double Blind Review
ISSN: **2316-2880**

# CHOOSING A MODEL FOR EFFECTIVE MANAGEMENT OF INDUSTRIAL ECOSYSTEMS IN RUSSIA: A NUMERICAL EXPERIMENT

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## ABSTRACT

**Objective:** This article introduces conceptual approaches to Russian industrial ecosystems in the context of reindustrialization and import substitution. It addresses the contemporary priority of achieving technological sovereignty in the Russian Federation through industrial policy. The paper's objective is to develop a comprehensive understanding of reindustrialization and import substitution by analyzing their conceptual aspects and their interplay within the context of industrial ecosystems. The study also involves exploring the selection of effective management models for industrial ecosystems. **Methods:** Comparative analysis is conducted between adaptive and proactive approaches, leading to the development of a generalized scheme for industrial ecosystems. Additionally, the article proposes a mathematical model for managing industrial ecosystems based on homogeneous differential equations. A numerical experiment is conducted to validate the feasibility of the proactive approach. **Results:** Definitions of reindustrialization and import substitution are provided, their relationships and synergies are elucidated, and a typology for managing industrial ecosystems is outlined. The article presents changes in quantitative and qualitative parameters that describe the dynamics of industrial development. **Conclusion:** It is concluded that despite proactive approach obvious advantages, its implementation will entail adaptation process, and resources redistribution will inevitably occur. In this regard, state strategically important assets and competencies holders additional monitoring is of key importance.

**Keywords:** Proactive approach; Industrial policy; Industrial ecosystems; Reindustrialization; Import lead; Economic and mathematical modeling.

Relações Internacionais do Mundo Atual - unicuritiba

**Submetido em:** 19/12/2023
**Aprovado em:** 03/03/2024
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# ESCOLHA DE UM MODELO PARA O GERENCIAMENTO EFICAZ DE ECOSSISTEMAS INDUSTRIAIS NA RÚSSIA: UM EXPERIMENTO NUMÉRICO

## RESUMO

**Objetivo:** Este artigo apresenta abordagens conceituais aos ecossistemas industriais russos no contexto da reindustrialização e substituição de importações. Aborda a prioridade contemporânea de alcançar a soberania tecnológica na Federação Russa através da política industrial. O objetivo do artigo é desenvolver uma compreensão abrangente da reindustrialização e da substituição de importações, analisando seus aspectos conceituais e sua interação no contexto dos ecossistemas industriais. O estudo também envolve explorar a seleção de modelos de gestão eficazes para ecossistemas industriais. **Métodos:** A análise comparativa é conduzida entre abordagens adaptativas e proativas, levando ao desenvolvimento de um esquema generalizado para ecossistemas industriais. Adicionalmente, o artigo propõe um modelo matemático para gestão de ecossistemas industriais baseado em equações diferenciais homogêneas. Um experimento numérico é conduzido para validar a viabilidade da abordagem proativa. **Resultados:** São fornecidas definições de reindustrialização e substituição de importações, suas relações e sinergias são elucidadas e é delineada uma tipologia para a gestão de ecossistemas industriais. O artigo apresenta mudanças nos parâmetros quantitativos e qualitativos que descrevem a dinâmica do desenvolvimento industrial. **Conclusão:** Conclui-se que apesar das vantagens óbvias da abordagem proactiva, a sua implementação implicará um processo de adaptação e a redistribuição de recursos ocorrerá inevitavelmente. Neste sentido, a monitorização adicional dos detentores de activos e competências estrategicamente importantes é de fundamental importância.

**Palavras-chave:** Abordagem proativa; política industrial; ecossistemas industriais; reindustrialização; liderança em importações; modelagem econômica e matemática.

## 1 INTRODUCTION

Modern economic and geopolitical realities force Russian Federation industrial policy development expediency. Taking into consideration current geopolitical situation, unprecedented sanctions, supply chains disruption and international cooperation, urgent measures are required to radically transform the country's economy in general, and its industrial complex in particular. At the same time, today we state industry development inertia, its significant spatial differentiation, as well as industrial ecosystems import dependence at economy’s macro-, meso- and micro levels. Russian Federation industrial policy key tasks is to achieve technological sovereignty. This requires competitive domestic products release, economic development growth rate acceleration, world market production Russian products share increase import dependence lowering and import advance leveling. The hypothesis of this study is that the named goals can be achieved only with industrial

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**Aprovado em:** 03/03/2024
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ecosystems development proactive model.

Reindustrialization and import outpacing are interrelated and can complement each other in country's economy development strategy. Both strategies are aimed at creating appropriate competitive advantages and sustainable economic growth of the economy in general and the industrial sector in particular. Reindustrialization can serve as a basis for achieving an import lead, since strong and competitive industrial sector development helps to increase exports and reduce dependence on imports. In turn, import outpacing can stimulate reindustrialization, cause competition in the world market can push domestic producers to innovate, improve quality and increase efficiency. Thus, we consider reindustrialization and import outpacing as industrial economy modern management model two interrelated elements. In order to enhance its management effect, it is necessary to consider them together, and currently, these processes should proceed in parallel, highly insensitive. In the economic literature, there are different approaches to reindustrialization processes describing.

Reindustrialization problems have been studied for several decades by scientists all around the world. The term "reindustrialization" is used in two main senses: as manufacturing industry reviving process and as a state policy. Firstly, the term reindustrialization is given in 1981 and is understood as a transition from traditional industry (capital, resource-intensive, energy- and labor-intensive) to industries based on advanced technologies and highly qualified personnel. Further, in 1984, the Americans Miller J., Walton T., Kovacic W. and Rabkin J. (1984) consider restructuring in connection with the transition to a centralized industrial policy as government coordinated strategy, business and national institutions. Tregenna F. defines reindustrialization as a steady increase in both production share in total employment and production share in GDP. But in transformation context, reindustrialization is a difficult task and requires great “effort” (Tregenna, 2011).

After 2008 crisis, high-tech and developed countries governments announced reindustrialization as manufacturing industry development driver. Modern researchers around the Globe understand reindustrialization as the need to reorganize industries in order to increase their competitiveness in comparison with foreign goods within the country and in international markets (Heymann & Vetter, 2013; Prisecaru, 2014; Zhao et al., 2014). Russian researchers also pay great attention to reindustrialization. Reindustrialization is seen as carrying out accelerated industrial development through a more complete use of one's own capabilities and resources (Bodrunov, 2019;

**Submetido em:** 19/12/2023
**Aprovado em:** 03/03/2024
**Avaliação:** *Double Blind Review*
*ISSN:* **2316-2880**

Bodrunov et al., 2018). At the same time, its main goal is to restore industry's role and place in the country's economy as its basic component based on a new, advanced technological order. A task of this magnitude is beyond private business power, its capabilities and motivation, so this problem should be solved at the national level (Sukharev, 2014). A.N. Zakharov (2017, 2018) believes that the reindustrialization program should affect industries that experience the strongest competition with imported goods, as well as new industries formation. Reindustrialization should be considered on the basis of scientific and technological progress as science, production and education unification into a single system (Bodrunov, 2015; Kondratiev, 2017).

Thus, at present, reindustrialization in developed countries is a strategy for economy's restarting, due advanced countries reaction to global transformation processes caused by existing post-industrial development model crisis. Consequently, reindustrialization, from developed countries viewpoint, is policy implementation aimed at economy's real sector overcoming decline and employment problem solving through production innovative modernization and supply chains optimization. In terms of fourth industrial revolution, reindustrialization is carried out by backbone industries new technological order creation and development. Among them are nanoindustry, bioeconomics and cognitive technologies, as well as by manufacturing industry.

Import substitution and importance have been studied by researchers since the 1960s. Import substitution supporters argued that developing countries should prevent manufactured goods import in order to promote domestic industry and reduce their dependence on foreign trade (Chenery, 1955; Winston, 1967, etc.). Modern economists prove that economy's active reindustrialization on new technological and human capital basis contributes to effective import substitution and import outpacing (Fonseca and Salomão, 2018; Khairov et al., 2017; Noskov & Ilyina, 2021; Soloviev, 2016; Tignor, 2006). Despite a plenty of publicationsrelated to this article issues, in general, we can state large-scale scientific research practical absence in terms of considering the industry from multi-level system standpoint, taking into account reindustrialization and import outpacing synergy. It is important to combine import substitutions with economy's modernization in order to overcome the backlog in scientific and technological development.

The purpose of this work is to develop reindustrialization and import advancement conceptual aspects, study its relationship and synergy and choose an effective model industrial ecosystems management. In order to formulate reindustrialization and import

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outpacing conceptual aspects taking into account their relationship and synergy we give theoretical basis, show its interconnection and develop industrial ecosystems management mathematical model. Numerical experiments confirmed hypothesis about proactive industry management model use expediency in order to reach technological sovereignty.

## 1.1 Industrial ecosystems reindustrialization and import outpacing: concepts definition, interconnection and synergy

Industrial ecosystems are sustainable socio-economic formations that organically combine clusters, holdings, financial and industrial groups, technology parks and business incubators features of (Kleiner, 2018). Ecosystem approach involves considering the industry in all the variety of its constituent elements, relationship between them and external environment, performed functions and ongoing processes. Let us present our vision of industrial ecosystems reindustrialization concepts and import outpacing. Reindustrialization is understood as a strategy for updating all technological structures, replacing obsolete technologies with modern ones, innovative production renewal and a qualitative transformation of the economy and the country as a whole. Thus, we can say that the ecosystem reindustrialization is country's industrial sphere revival process. Import substitution is a strategy based on domestic innovations and new technologies development and promotion, strengthening country's position as a world leader in high-tech industries. It involves active investment in new products and technologies research and development, as well as human resources. In many ways, reindustrialization and import outpace are achieved through modern production facilities creation for new, unparalleled products manufacturing using digital transformation tools (Albychev & Kudzh, 2023). That is, we are talking not just about import substitution, but about import outpacing, the creation of technologies, surpassing foreign models. The main difference between these terms is that the first one seeks imports volume reduction by stimulating domestic production, while the second is focused on innovations and new technologies development in order to achieve a leading position in the global economy.

Reindustrialization and import outpacing are connected with each other. The first helps to develop their own production capabilities, which in turn reduces imports and strengthens economic independence. Meanwhile, import outpacing is a tool for reindustrialization implementation, as it stimulates manufacturing sectors development

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*ISSN:* **2316-2880**

and increases their share in the domestic market. Both of these concepts are aimed at strengthening and developing the country's industrial sector, increasing its competitiveness and reducing dependence on foreign markets and suppliers. Reindustrialization and import outpacing synergistic effect is manifested in their complementary impact and mutual support in achieving economic development overall goals. These strategies combined use can lead to increased positive outcomes and more efficient industrial sector development. Reindustrialization and import outpacing theoretical and methodological basis should be built on a variety of proven theories, concepts and methods. The key theories underlying these two categories include competitiveness theory, innovations theory, industrial policy, etc. Reindustrialization and import outpacing objects include industrial enterprises, new technological sectors, research and development, domestic manufacturers that introduce new technologies and develop products that are technologically superior to imported analogues. Reindustrialization and import outpacing subjects include government bodies, the business community (industrial enterprises, entrepreneurs and investors), educational institutions, industrial associations, scientific institutes, etc.

## 1.2 Industrial ecosystems management approaches typology

Based on world experience studies, four different basic models for industrial ecosystems management can be distinguished: planned, market, adaptive and proactive. Let's consider them in detail.

*Planned approach.* This approach to industrial management implies proven methods and procedures usage in order to to achieve goals. It is focused on stability and predictability and includes a clear hierarchical management structure, a tasks and roles deterministic distribution and strict control. With this approach, the government forms an industrial policy and influences the national innovation system. Industrial and innovation activities are consistently implemented, starting with idea generation and ending with new product creation. In this case, changes in the internal environment are mainly taken into account, “closed innovations” model is used (Nizhegorodtsev, 2015), and monitoring and feedback are used to control decisions execution. This model was used in planned economy, where no significant control actions adjustment is required. The planned approach to industrial management has its advantages and disadvantages. The advantages of such an approach include:

- structured, clear management methodology;

**Submetido em:** 19/12/2023
**Aprovado em:** 03/03/2024
**Avaliação:** Double Blind Review
ISSN: **2316-2880**

- more predictable results;
- better manageability, it is easier to control resources distribution.

Planned approach disadvantages are:

- limited flexibility;
- focus on following established processes and standards;
- obsolescence risk and adaptation lack.

In general, a planned approach provides an advantages number, especially in areas with strict control, where the result is largely predictable. However, in practice, it, limits economic system flexibility and innovative potential.

*Market approach*. The transition from national economy management system, based on state planning and national economic relations strict regulation, to management using market mechanisms occurred without any adaptation of industrial enterprises to the new economic conditions. It was accompanied by an ill-conceived state policy in this area. The reasons for the sharp decline in production were prices liberalization, government orders reduction, demand limitation due to increased competition from foreign producers, etc. (Bodrova & Gusarova, 2013). This industrial development stage, which took place in the 90s, can be characterized by country's scientific and technological system survival and disintegration processes. In practice, the science sector served mainly to provide pay for research staff and create jobs. As a result, it almost completely lost his innovativeness.

*Adaptive approach.* As the world economy developed, global and country industrial systems expanded, due to innovative ideas new sources formation. In the global economy, innovative sources are not only ideas generated within the framework of innovative programs and projects that are carried out directly by scientific and educational institutions, industrial enterprises, but also ideas generated by the market. This leads to "open innovation subsystem" emergence in the macroeconomic innovation system (Chesbrough, 2003). Adaptive approach implies flexibility and willingness to change, based on agility and allows quick response to fluctuations in the external and internal environment.

In adaptive industry management, the emphasis is on resources efficient use, collaboration, and iterations, allowing desired outcome empirical testing. There are two adaptation aspects: passive and active. Passive adaptation includes assessing and planning the need for innovative development, providing opportunities to neutralize possible negative disturbances. Active adaptation includes innovative development

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results assessment and adjustment, ensuring managed indicator maximum possible compliance with the planned values. In addition, in adaptive management, development innovation most appropriate direction is determined regarding current situation.

Adaptive model in industrial ecosystems management makes it possible to adjust the national innovation system depending on changes in internal and external factors in order to ensure its stability. External factors carry both threats and opportunities. As a result, an industrial policy is formed, which is used by the government to improve innovation activity efficiency. Monitoring in this case plays a key role, and feedback involves adjusting the control action depending on changes in both the external and internal environment. An adaptive approach has its advantages and disadvantages. The advantages include:

– flexibility, the ability to rebuild in accordance with new conditions and requirements;
– early errors detection, which saves time and resources;
– innovations stimulation, innovative culture development, etc.

Adaptive approach disadvantages include:

– failure and new ideas and products rejection risks by the market;
– lack of stability, permanent changes in industrial ecosystems;
– long-term goals focus lack.

In general, an adaptive approach to industrial ecosystems management requires a careful balance between flexibility and stability, as well as a clear focus on long-term strategic goals. Industry's obligatory management component is organizational mechanisms presence for collecting and transmitting data on the controlled system and its external environment, as well as disturbing influences negative consequences leveling.

From the mid-2000s to the present, an adaptive approach to industrial management has been predominantly used in Russia. There was country's partial integration into global production, technological chains, scientific and innovative space. This made it possible to prevent science and technology complete stagnation. However, at this stage there was no scientific and technological breakthrough in Russia. With this model, the country remained on the periphery of the global scientific and technological space. Economy's raw-material nature prevailed, high technologies imports were carried out in exchange for domestic raw materials. At the same time, big business

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remained immune to domestic innovations and preferred to purchase imported technologies instead of investing in Russian developments. As a result, science and production development processes took place in parallel and independently. The first process was aimed at scientific knowledge circulation expanding through research and development, and technological innovation was this process by-product. The second process related to the production system involved methods renewal, products and resource sharing in order to increase economic sustainability, value creation and organizations' capitalization.

*Proactive approach.* New threats and challenges in the economy entails a gradual change in state's industrial policy. This requires new approaches development to industrial ecosystems management. In our opinion, the proactive approach is an advanced one, where control actions initiator and executor is the ecosystem itself. Interacting with other stakeholders, it predicts expected changes in the markets in accordance with economy's real sector requirements, initiating necessary adjustments. In particular, an industrial organization can make a forecast of the innovations required for the new economy, taking into account the time lag.

A proactive approach to management aims to anticipate challenges, threats and opportunities. This approach is focused on planning for future events. In addition, it helps to identify and prevent potential hazards before they occur. Proactive management is a counter-adaptation that acts as an anti-trend regarding the economic system observed simplification and ensures it's less dependence on changes in external conditions (Drobyshevskaya & Isakov, 2022). In this case, the industrial policy is completely formed by the goverment and external factors are involved in the background. For example, after February 2022, external factors in relation to the national innovation system carry practically the same threats. Import deliveries are frozen. The country switched to import outpacing strategy and technological sovereignty. This enhances innovations role. Meanwhile, monitoring is still important, as some adaptation is necessary.

Proactive management approaches have their own advantages and disadvantages. The advantages include:

- innovations potential sources and opportunities early identification;
- problems and risks associated with innovation preventions;
- thorough planning, possible obstacles analysis and potential problem situations forecasting;

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– resources conscious and purposeful use.

The disadvantages are:

– limited flexibility,

– focus on pre-planned actions;

– high time and resource costs for research and development.

So, there is no universal management technique, yet the balance and overall deep and careful economy analysis, based on mathematical modeling and machine learning instruments, can significantly lower the uncertainty factor, leading to weighted managerial decisions.

## 1.3 Industrial ecosystems development parameters

Industrial ecosystems most important management tasks, such as its development forecasting, determining import outpacing and reindustrialization optimal trajectories, can be analyzed based on the scenario approach. Industrial ecosystems development scenarios are based on its parameters' estimates and can be considered in three versions: optimistic, pessimistic and averaged. The first two options represent the parameters in terms of their maximum and minimum, these are some borderline options. In real economic conditions, averaged parameters are used, while it is necessary to clearly define possible threats determine the degree of their influence on production development economic component. Table 1 presents some key parameters characterizing industrial ecosystems, factors influencing industrial production development and helps to identify its reasons.

**Table 1**. Industry's quantitative and qualitative parameters dynamics changes

| Parameter | Change Essence | Possible reason | Instruments / managing influence measures |
|---|---|---|---|
| Fixed assets | Increased performance and service life | Limited investment | Preferences for industrial investors, long-term loans market formation |
| | Structural changes in fixed assets | Limited ability to attract long-term credit funds | |
| Labor resource | Workforce aging and exodus | Low wages | Earnings average level and seniority pay increase |
| | There are changes in the structure of those employed in the economic sphere | Working profession prestige fall | Career guidance work by the enterprise, young employees financial and other resources provision |
| Technologies used | Technologies are designed to use enterprises' equipment with | Technologies and resources available to the enterprise aren't matching | Effective interaction in the chain of science-education-production formation. Additional funding for scientific |

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| | | | |
|---|---|---|---|
| | modernization emphasis | Technology lags behind modern requirements for product quality | research allocation |
| | | Required resources amount lack for technology implementation | Investment capital and more competent labor resources attraction |
| | Technological backlog | Modern domestic technologies application possibility absence | Business processes aimed at industrial production technological innovations introduction |
| External environment enterprises operation | External changes velocity | Industrial enterprises have no ability to quickly adapt to external changes | Flexible management structure formation, horizontal and vertical integration |
| Hi-tech | Technology lack | Patents obtain process is difficult | Preferences for enterprises, introducing domestic advanced technologies |
| | | | Bureaucratic barriers elimination when obtaining patents |
| | | | Science-education-production chain effective interaction formation |
| | | | Scientific researches additional funding allocation |
| | | Innovations limited financial resources | State's innovative projects financial support |
| | | New production technologies introduce high risk level | Venture funding, government programs, insurance systems |
| Investments | Limited investment flow | Profitability low rates | Industrial enterprise management efficiency improvement by investment projects package forming |
| | | Industry risk is high | Industry infrastructure capable of risk reduction development |
| Products | Industrial product market significant import share presence | Domestic products qualitative lag. | Improving product quality technologies use |
| | | Domestic products high price due production costs | Imported goods customs restrictions, modern production technologies use |
| | | Insufficient market's share | Domestic producers favorable conditions formation |

## 1.4 Industrial development management in Russia adaptive and proactive approaches comparison

At the moment, we can talk about Russian industry proactive stage formation development beginning. The challenges that the country has faced recently raised the necessity to scientific and technological development methodological approaches system changes. Within this stage, technological sovereignty is a priority. Table 2 presents industrial ecosystems management adaptive and proactive approaches comparative analysis.

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**Table 2**. Adaptive and proactive approaches comparative analysis

| No. | Comparison criterion | Adaptive approach | Proactive approach |
|---|---|---|---|
| 1. | Goal | Economic sustainability increase | Technological sovereignty |
| 2. | Industry function | High technologies import in exchange for raw materials | High-tech products manufacturing |
| 3. | Business behavior | Weak receptivity to innovations | Innovative development attraction through impact of various forms combination |
| 4. | Science and production communication | Systemic connection lack between science and production | Research, educational, production and design organizations cooperation creation. |
| 5. | Participants cooperation mechanisms | Interaction between universities, scientific organizations and industry | Networking and integrated management forms |
| 6. | Government role | Track of changes and management adjustments | Priority goals and strategic plans set to achieve them |
| 7. | External environment role | Strong dependence on world markets parameters | Mutually beneficial cooperation while maintaining country's national priorities. |

## 2 METHODS

We present industrial ecosystems management approaches formalization. In order to analyze, predict and optimize industrial processes dynamics, including interactions between ecosystem components and external factors influence, we propose mathematical model based on linear homogeneous differential equations. Such a model allow to investigate various economic variables behavior over time.

The system for n variables can be represented as:

$$\dot{X}(t) = AX(t) \qquad (1)$$

where $X(t) = \begin{pmatrix} x_1(t) \\ x_2(t) \\ \dots \\ x_n(t) \end{pmatrix}$ – system's parameters vector function,

$A = \begin{pmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{pmatrix}$ is $n \times n$ matrix with constant coefficients, $t$ stands for time.

Relation (1) is linear differential equations normal system. The solution of such a system allows you determine how vector function components will change and interact with each other over time.

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Let $x_1$ is variable, characterizes public administration; $x_2$ and $x_3$ stand for industrial policy and industrial development respectively; $x_4$ represents external environment impact; $t$ stands for time. Then, the system (1) will take the following form:

$$\begin{aligned}
\frac{d\,x_1}{dt} &= a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + a_{14}x_4 \\
\frac{d\,x_2}{dt} &= a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + a_{24}x_4 \\
\frac{d\,x_3}{dt} &= a_{31}x_1 + a_{32}x_2 + a_{33}x_3 + a_{34}x_4 \\
\frac{d\,x_4}{dt} &= a_{41}x_1 + a_{42}x_2 + a_{43}x_3 + a_{44}x_4
\end{aligned} \qquad (2)$$

Figure 1 presents generalized model graphical form, including management, control and feedback connections.

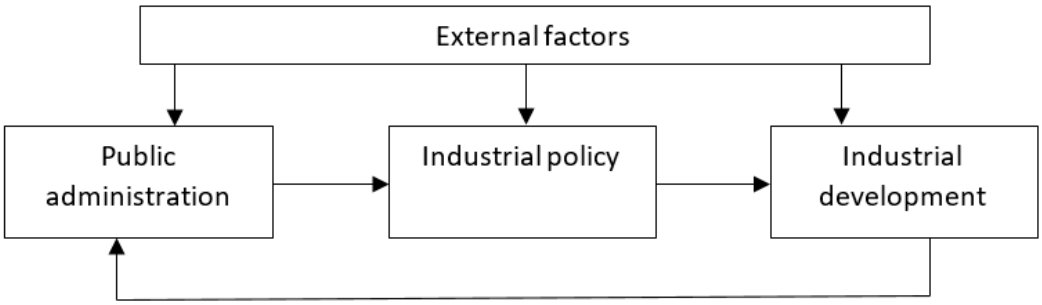


**Figure 1**. Generalized industrial ecosystem management scheme

In our case, equation system's diagonal coefficients are close to 1 (the system reproduces itself). At the same time, the first three coefficients ($a_{11}, a_{22}, a_{33}$) can be set equal to 0.95, which means a transition to stagnation without an active policy. Let's set external environment reproduction coefficient $a_{44}$ equal to 1.01, which means exogenous factor weak growth. As can be seen from Figure 1, coefficients $a_{12} = a_{23} = a_{31} = a_{41} = a_{42} = a_{43} = 0$ by default. Coefficient $a_{13}$ shows state's industrial development monitoring reaction to the data. Let's set its value to 0.02 for all models, since this reaction cannot be very strong. The remaining coefficients differ depending on industrial policy model choice.

## 3 RESULTS

### 3.1 Numerical experiment

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As for studies results, we present a numerical experiment to solve system (2) for various industrial policy models. In order to achieve better visualization and joint dynamics demonstration, the same values ($x_{i0}$ = 0.5) were chosen as initial conditions for the model variables. As numerical experiments results, we are more interested in parameters dynamics than variables exact values over time. Therefore, numerical integration was carried out using the simplest Euler method.

### 3.2 Linear (planned) model

The state has a certain influence on industrial policy, and industrial policy influences the development. This influence is very insignificant, since it is primitive and comes down to directive planning. We consider $a_{21} = a_{32} = 0.1$. During the planned economy, public administration and industrial policy are practically independent of the external environment influence, that is, $a_{14} = a_{24} = 0$. At the same time, external environment influence on country's industrial development is generally negative, so $a_{34} = -0.1$. Linear model numerical solution is shown in Figure 2.

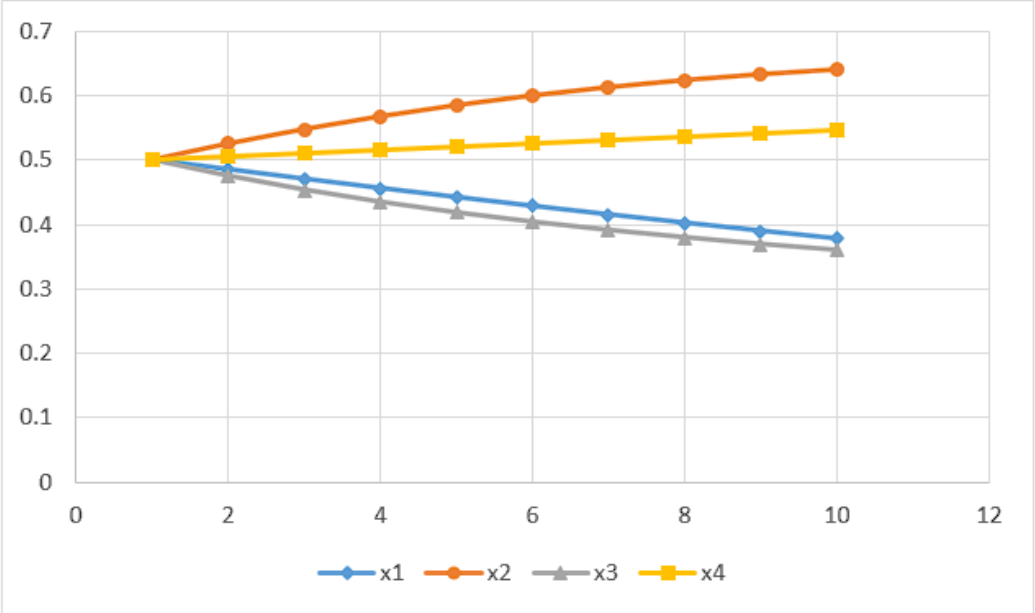


**Figure 2**. Linear model numerical solution

In our studies, the key parameter is $x_3$, which reflects industrial development level. Over the evaluation period, this parameter slowly decreases, which indicates linear market model weak efficiency. The state does not influence industrial policy, and industrial policy does not influence industrial development. Therefore, $a_{21} = a_{32} = 0$.

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In market economy period, public administration is positively dependent on the external environment. These are agreements with potential adversaries that seem positive for the authorities. Consider $a_{14} = 0.1$. External environment influence on industrial policy, and, moreover, on industrial development, is negative. In this regard, $a_{24} = -0.05, a_{34} = -0.07$. Relation (2) numerical solution for the market model is shown in Figure 3.

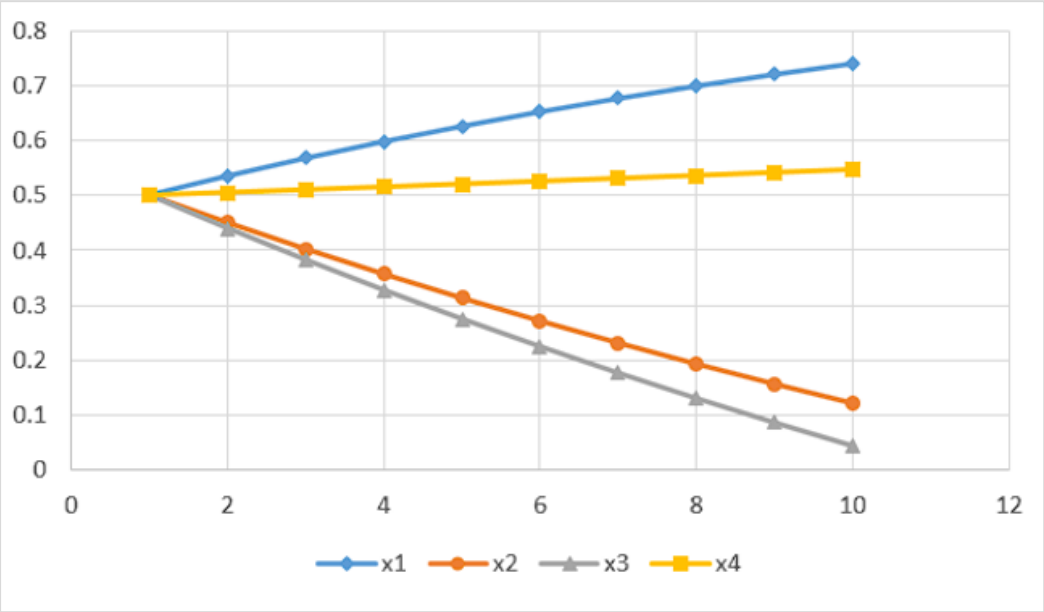


**Figure 3**. Market model numerical solution

It can be seen from the figure that, for given coefficients, industrial development level falls catastrophically.

3.3 Adaptive model

The state has a strong influence on industrial policy, and industrial policy on industrial development. Therefore $a_{21} = a_{32} = 0.3$. External environment, industrial policy and industrial development have negative influence. Consider $a_{14} = a_{24} = a_{34} = -0.1$. Relation (2) numerical solution for the adaptive model is shown in Figure 4.

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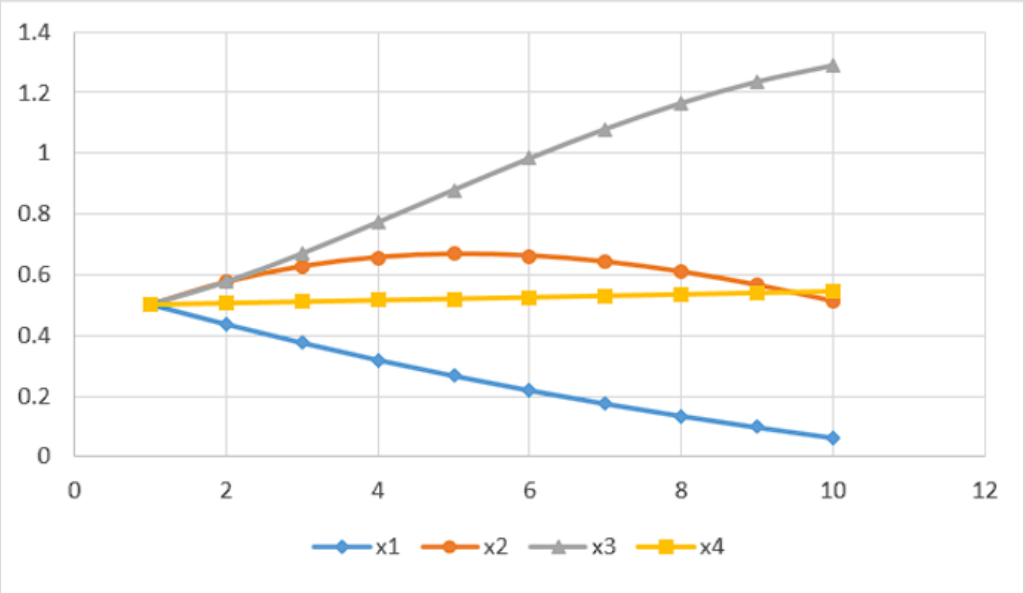


**Figure 4**. Adaptive model numerical solution

It can be seen from the figure that for given coefficients, industrial development level increases, but over time it becomes saturated.

3.4 Proactive model

The state has a strong influence on industrial policy, and industrial policy on industrial development. Therefore $a_{21} = a_{32} = 0.3$. External environment influence on the state and industrial policy is equal to zero, and on industrial development is negative. Consider $a_{14} = a_{24} = 0, a_{34} = -0.1$. Relation (2) numerical solution for the proactive model is shown in Figure 5.

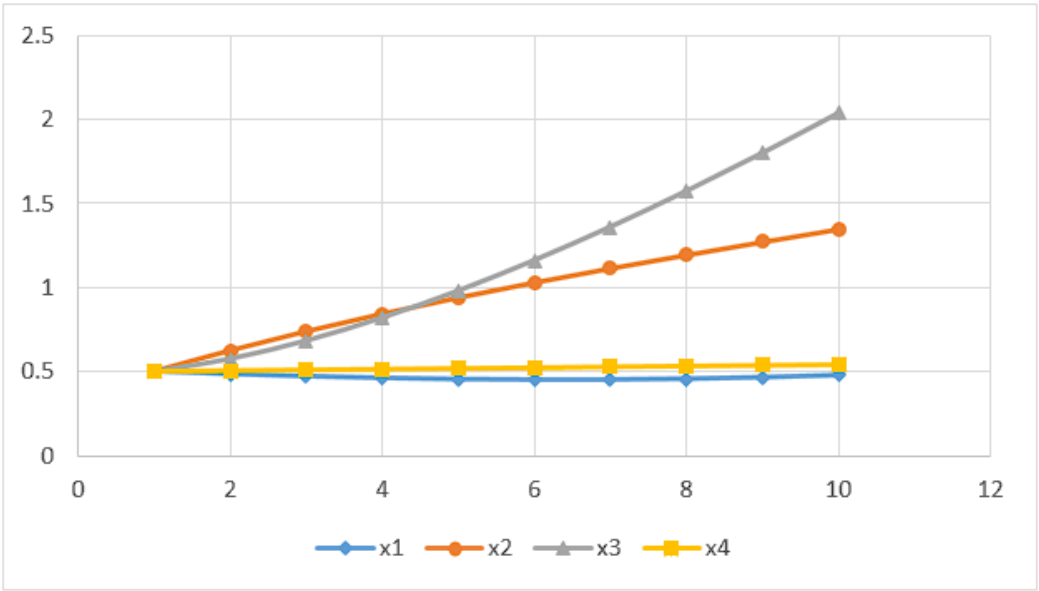


**Figure 5**. Proactive model numerical solution

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The figure shows that industrial development level is increasing, solving technological sovereignty achievement problem. Assuming that Russia's proactive industrial policy has a negative impact on competing countries' economies (counter-sanctions, restrictions on the import or export of, etc.), we can set the coefficient $a_{43} = -0.03$. Then equation systems numerical solution for the proactive approach will take the form shown in Figure 6.

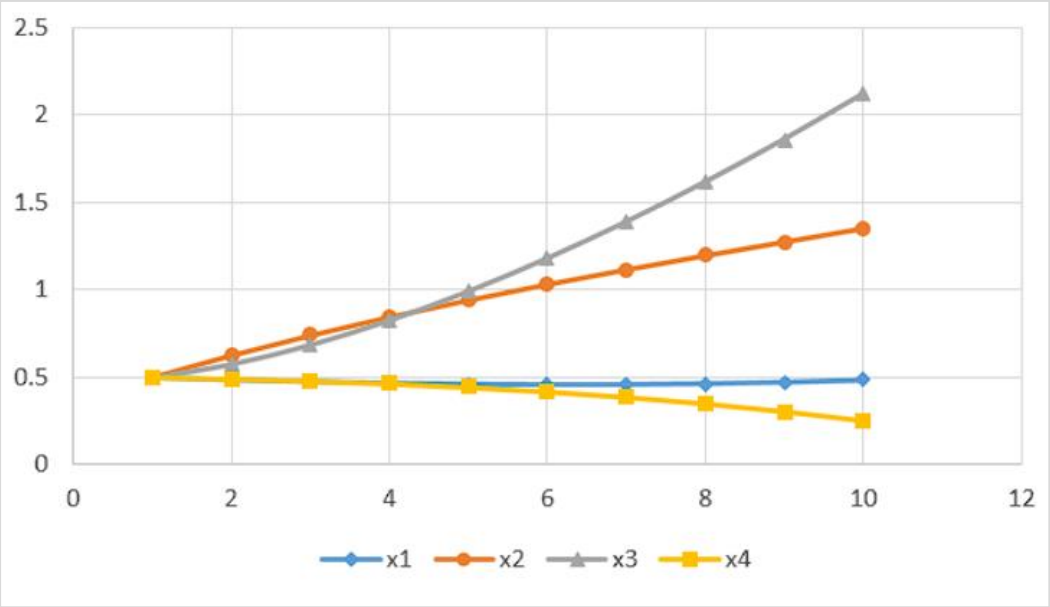


**Figure 6**. Proactive model numerical solution with $d_3 = -0.03$

The figure shows that $x_4$ parameter dynamics, which characterizes the external environment, acquires a negative trend.

## 3.5 Incentive measures accounting

Thus, linear homogeneous differential equations system determines industrial ecosystems parameters change rate without taking into account additional incentive measures. In order to correct this fact, we introduce a vector of functions:

$$B\big(t, X(t)\big) = \begin{pmatrix} b_1(t, X(t)) \\ \vdots \\ b_n(t, X(t)) \end{pmatrix}$$

And the original matrix equation takes the form listed below (3).

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$$\dot{X}(t) == AX(t) + B(t, X(t)) \quad (3)$$

New economic conditions and a change in the economic situation which force to analyze economic situations wide class and obtain non-trivial schemes for industrial ecosystems parameters changes. Functions $b_i(t, X(t))$ describe measures impact aimed at industrial ecosystems development improvement. These functions specific form may correspond to various economic situations: permanent incentive measures, point impacts, periodic impacts, etc. Such quantities introduction into original equations system has an external influence reflection meaning.

Reindustrialization and import outpacing strategies correspond to modern economic trends adopted in the most developed countries. For Russia, reindustrialization and subsequent import outpacing are urgent tasks due to deep economy deindustrialization occurred in the 90s and the consequences of which were not overcome by now. It is important to note that industry share reduction was not based on labor productivity increase (bringing displaced jobs to the service sector) and was not associated with industrial production transfer abroad. On the contrary, there was industries' technological and personnel degradation, accompanied by its significant destruction. This seriously complicates industrial production restoration and provides technological sovereign on a modern basis and, at the same time, makes this task even more urgent. This paper hypothesizes that technological sovereignty is possible only with proactive model formation and industrial ecosystems development using reindustrialization and import outpacing strategies.

Despite proactive approach obvious advantages, its implementation will entail adaptation process, bringing resources reallocation and sources of income. In addition, consumption culture transformation and interaction with customers will create turbulence periodic waves, even for the most proactive ecosystems. In this regard, state's strategically important assets additional monitoring is of key importance.

Industrial ecosystem management mathematical modeling with proposed model allowed to confirm this study hypothesis numerically. Nevertheless, we recognize that conceptual aspects outlined in the article require further improvement. Firstly, reindustrialization and import outpacing full synergy effect become tangible only after presented theoretical assumptions practical confirmation. Second, real systems more accurate behavior description requires more complex and non-linear models than homogeneous differential equations.

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## 4 CONCLUSIONS

We state that in order to achieve Russian Federation technological sovereignty, ensure reindustrialization and import outpacing in the country, it is necessary to form industrial ecosystems development proactive model. In this regard, the paper proposes reindustrialization and import outpacing concepts definitions, shows their relationship and synergy, and also presents approaches typology to industrial ecosystems management. Quantitative and qualitative parameters describing industry's functioning and development dynamics is presented. The study also carried out various approaches comparative analysis and Russian industrial ecosystems management generalized scheme. Based on this scheme, industrial ecosystems management mathematical model proposed, using homogeneous differential equations apparatus. Numerical modeling confirmed authors' assumption about proactive approach expediency in industrial ecosystems management. In presented model development, its modification with incentive measures is given. However, despite proactive approach advantages, its implementation will require an adaptation process, which in turn will lead to resources and income sources reallocation. Therefore, strategically important assets and competencies holders additional state monitoring becomes important.

## ACKNOWLEDGMENTS

The research was funded by the Russian Science Foundation (project No. 23-78-10009).

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