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Development of a Mechanism for Assessing Mutual Structural Relations for Import Substitution of High-Tech Transfer in Life Cycle Management of Fundamentally New Products

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Abstract: The emergence of fundamentally new products is conditioned both by the development of techniques and technologies and by the emerging new needs and conditions of economic and social life of society. In this case, the process of achieving product dominance in the market has a progressive cyclical character in the form of a spiral pattern, the movement along which occurs with acceleration. At the current stage of economic development, most states have problems expanding sales of products and capturing new markets. These problems today are described in the works of various scientists; the research of the authors touches upon the issues of economic development. Today's economic conditions, which are characterized by the application of sanctions pressure on a large scale, do not assess the opposite effect, when the countries that are subjected to this pressure, and the countries that organize this pressure, suffer economic damage. Some suffer damage in the form of reduced ability to produce knowledge-intensive products by providing them with imported materials and components, others who exert this pressure, by reducing the sales of their products, and in this case, it is relevant to build a mechanism for assessing mutual structural links for import substitution of high-tech transfer in the management of the life cycle of radical new products, which in our view is useful for those or other countries. The hypothesis is that the modeling of mutual structural relations of high-tech transfer in the management of the life cycle of radical new products will significantly improve the mechanisms of industrial policy management and national technological security and ensure sustainable economic development. The aim of the study is the task of developing a mechanism of mutual structural links and assessing the synergetic economic effect based on the approach of intersectoral links, interactions and interdependencies. In the course of the research, the following tasks are solved: the necessity to adequately replace high-tech imports within the framework of national technological security is substantiated, for this purpose it is necessary to create unique equipment for the system of RNP production; the assessment of the possibility of realization of such a task is carried out; the assessment of high-tech competencies of science and production, technical and resource readiness (configuration of the RNP system) is necessary, and a complex model for the assessment of structural and mutual linkages in the economy of innovation is developed. The modeling performed by the authors allowed us to assess the structure of domestic high-tech imports and the coefficients of mutual linkage of imports. The practical significance of the study lies in the fact that the conducted research makes it possible to significantly improve the efficiency of management of innovation processes of high-tech transfer to ensure the creation of a system of production of radically new products at the levels of organization, industry or national economy, which will ensure stable economic development. For this purpose, the structure and dynamics of high-tech imports of the Russian Federation have been analyzed and calculated, taking into account critical technologies and industries. The multiplier effects in high-tech industries of the Russian economy taking into account imports were analyzed on the basis of the latest actual detailed data of Rosstat. The estimation of the mutual relationship of imports and application of the developed toolkit for the example "Mechanical equipment, machine tools and other equipment for general or special purposes" is carried out.

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1. Introduction

The relevance of the research topic is determined by the need for accelerated modernization of the economy and intensification of high-tech transfer when managing the life cycle of fundamentally new products to ensure sustainable economic development of the country.

In today's world, where competition between countries and companies is increasingly fierce, and the creation of goods and services requires an accelerated increase in quality, productivity and knowledge intensity, the creation and implementation of fundamentally new products becomes one of the key factors of success of organizations, scientific and technological and inter-industry cooperation structures and national economy as a system.

Intersectoral linkages are the interaction and cooperation of different industries and sectors of the economy to develop and produce innovative products. Such linkages allow for combining the knowledge, technologies and resources of different stakeholders from different fields, which contributes to the creation of unique and breakthrough products (or quality competitive products with high added value).

The increasing role and understanding of the functioning of intersectoral structural and innovation links in the production of fundamentally new products is due to the need to improve the national innovation system, the development of intra- and inter-organizational innovation processes to improve the competitiveness of companies in the modern economy, and the formation of national technological security. The main problems identified by the authors in the reviewed sources [1–22] on science, technology and production technology policies of different countries (primarily the economies of the "G20"), as well as works devoted to the actual scientific and methodological apparatus, are expressed in the following: the theory of high-tech transfer has not been developed, models and a system for managing the life cycle of fundamentally new products have not been created, the problem has not been solved in analytical form and convenient tools have not been proposed.

The study of this topic will reveal the features and advantages of intersectoral links and innovative cooperation in the production of fundamentally new products to ensure sustainable economic development. Moreover, this study aims to develop effective strategies and mechanisms for cooperation between different industries and sectors of the economy, as well as to identify potential obstacles and challenges in this area.

The hypothesis considered by the authors is that the modeling of mutual structural relations of high-tech transfer in the management of the life cycle of fundamentally new products, provided that the theory and practice are created, and using modern models and tools in this area, will significantly improve the mechanisms of industrial policy management and national technological security. Since high rates of technological development and the possibility of creating fundamentally new products of high added value are provided by technological exports in developed countries, 50–55% of GDP (national exports) are knowledge-intensive products, and most of them are innovative products and services. In Russia, this figure is much lower.

The primary purpose of this study is to develop a mechanism that establishes mutual structural relations within the configuration of creating technological value for high-tech transfer in the management of the life cycle of fundamentally new products. The study also aims to assess the synergetic economic effect by employing an approach that considers intersectoral links, interactions and interdependencies, all with the ultimate goal of ensuring sustainable economic development.

1. Ensure National Technological Security:
    - Adequately replace high-tech imports within the framework of national technological security.

- Provide or create unique technological resources for the Research and New Product (RNP) production system, including equipment, competencies and other forms of integrated capital.

2. Assessment of Science and Production Competencies:
   - Conduct an assessment of high-tech science and production competencies within the RNP system.
   - Evaluate technical and resource readiness, considering the configuration of the RNP system.
3. Utilize Complex Models:
   - Employ complex models for assessing structural and mutual linkages in the economy of innovation.
   - Utilize these models to achieve the aforementioned objectives and enhance understanding of the intricate relationships involved.
4. Develop Modeling Tools:
   - Carry out the development of tools specifically designed for modeling the mutual structural links of high-tech transfer.
   - These tools will contribute to a comprehensive understanding of the structural relations and facilitate effective decision-making in the context of high-tech transfer.

By addressing these objectives, the study aims to contribute valuable insights and tools for managing the life cycle of new products, promoting national technological security, and fostering sustainable economic development through high-tech transfer.

To formalize the task of producing innovative products and the formation of the RNP production system, it is necessary to create unique equipment, train competent personnel and establish effective cooperative links, which requires the use of economic and mathematical models and methods of organizing the system of innovative production, equipment and technology, i.e., the design of innovation ecosystem and other structures of local and national innovation systems [22].

Radically new products are products that have technical characteristics superior to those of competitors, consumer properties focused on satisfying both current and future needs at a high level, a comfortable cost of acquisition and ownership for the consumer, and are able to dominate the market or create new markets.

The novelty of the study lies in eliminating the shortcomings of previous studies, namely the need for a comprehensive change in the mechanisms of modeling long-term economic development and accounting for complex structural links in the innovation economy, as well as the development of the theory and practice of modeling mutual structural links in the economy.

This study is organized as follows: Section 1 presents an introduction to the problem. Section 2 presents the works related to the estimation of reciprocal structural linkages for import substitution of high-tech transfer. Section 3 presents the methodology of the study. Section 4 presents the results. Section 5 provides a discussion of the results. Finally, Section 6 presents the main conclusions and limitations of this study.

2. Literature Review

Radical, i.e., fundamentally new, products (RNP) are products with the following characteristics: high level of scientific developments, significant R&D expenditures, products that have no analogs in the world and form a completely new market (or have a world analog, but are characterized by high indicators of competitiveness).

The organizational and economic system of fundamentally new products (OESP FNP) includes the organizational structure, processes and procedures, resource management, quality management system and risk management in the effective implementation of innovative products.

The following scientists have addressed the issues of innovation management, innovation processes and the life cycle of fundamentally new products at the present stage:

- Drucker P. (the importance of innovation for the successful development of organizations, a key component of competitiveness and growth) [23];
- Porter M. (competitive strategy and innovation) [24];
- Osterwalder A. (innovative business models) [25];
- Hippel E. (consumers and open innovation) [26];
- Christensen K. (the concept of disruptive innovation) [27];
- Glazyev S. (the role of the state in stimulating innovation, methods for assessing the effectiveness of innovation processes and the impact of innovation on economic growth) [28];
- Kuznetsov B. (model of innovation system) [29];
- Kleiner G. (innovation economy) [30];
- Fathudinov A. (models and methods for determining the life cycle of fundamentally new products, including the concept of "technological synergies" [31].

At that time, there was no question of a significant transition of the economy from the raw material model to the innovation model, and therefore, their works are not relevant to the current situation and require updating and expansion of the scientific and methodological apparatus [1–12].

The first line of research is the resource description of RNPs. The resource description of RNPs is aimed at identifying and analyzing the resources that are required for the successful development, production and distribution of fundamentally new products. A model is formed of the configuration of resources that are required for the successful commercialization of an innovative product and how these resources should be managed and optimized. Resources include financial resources, human capital, technology, infrastructure, materials and more [1,2].

The second direction of research is related to the modeling of structural relations in the framework of life cycle management of fundamentally new products. This direction includes analyzing the interaction of various structures and elements within a company, as well as between companies and their suppliers, distributors and consumers [4–6]. In this case, various methods are used, such as system dynamic models, network analysis and methods of modeling decision-making processes [5–7].

The third direction of research is related to the modeling of mutual structural links in the introduction of imported high-tech products (and their substitution) in the production of new products and the use (and substitution) of imported technologies at different stages of the product life cycle [5–7]. Such studies consider the selection of optimal suppliers and technological solutions, analyze the reasons for the success or failure of the introduction of imported technologies, as well as assess the impact of these links on the final product, the effectiveness of cooperation with foreign companies at the stages of development, design, production and marketing of a new product [5].

The fourth direction of study is related to the development of the mechanism of mutual structural relations in the entire organizational and economic system of fundamentally new products [7–12]. In this case, the analysis of the effectiveness of different organizational and economic aspects of the RNP system, which are associated with different groups of stakeholders, institutions and other structures [7–9], is used (Table 1).

Among the scientific and technical backgrounds of the authors, it is worth highlighting the studies in the field of advanced development [23], increasing the competitiveness of high-tech organizations [22] and the effectiveness of organizational and economic system management [8,13] through the modeling of innovation processes [30,31] and innovation management. The presented theoretical studies do not provide practical tools for solving the problem of modeling mutual structural relations of high-tech transfer in life cycle management in order to ensure sustainable economic development.

Table 1. The degree of study of the problem of developing a mechanism of mutual structural relations of high-tech transfer.

Direction	Models
RNP resources	Resource-Based View Of The Firm—RBV, Intellectual Capital Model, Five Ms Model, Porter's Five Forces Model, SWOT Model, Brand Building Model, Innovation Capital, Triple Bottom Line Model, Balanced Scorecard Model, Integrated Reporting <Ir> Framework, Competitive Advantages
RNP life cycle	Technology Readiness Levels Model, Technology Readiness for Scaling Model, Technology Maturity Model, Technology Adoption Model, Technology Legal Readiness Model, Integrated Readiness Model, Innovation Readiness Model
Management of technological changes in RNPs	Technology Roadmaps, Forecasting, Technological Treasure, Trend Management, Technology Transfer Model, Franchising Model, Innovation Net Transfer Model
Organizational and economic system of RNPs	Stakeholder Model, National Innovation System, Cluster Innovation System, Open Innovation System, Innovation Ecosystem Approach, Triple and Multiple Helix Model of Innovation, Integrated Management Systems Model, Ecocentric Model, Circular Economy Model

Source: authors' calculations on the basis of [1–12].

3. Methodology of the Study

The research methodology is based on well-known principles of economic and mathematical modeling:

- Input–output approach;
- Product availability level approach;
- Product life cycle approach.

However, the authors propose to combine these approaches into one tool and introduce mechanisms for accounting for structural economic relations based on the apparatus of models of intersectoral balances, integrated readiness and the life cycle of high-tech products.

The model of intersectoral balances describes intersectoral and mutual relations in the economic system, and therefore this model can be used to describe the innovation ecosystem project. This model will identify the relationship between the output of a particular sector and the costs of production using a reciprocal linkage matrix.

The input–output matrix is the main tool of Leontief's model. Let us make an addition that takes into account the need for unique equipment and competencies (integrated capital), as well as to introduce restrictions: we will not consider specific industries, but a set of knowledge-intensive industries, where the output of the industries is denoted as X.

The output of industries X over a given time period can be represented as the sum of all inter-industry supplies Xi and the value of final demand for the products Y of a given industry in matrix form [22–31]:

$$X = Xi + Y \tag{1}$$

To satisfy final Y and inter-industry demand Xi, the industry pays for supplies from other industries, thus generating intermediate demand $X^T i$, and also pays for integrative inputs (labor, capital and payments to the budget (especially taxes)), which are included in value-added V:

$$X^T i + V = X \tag{2}$$

It is possible to determine the volume of full costs (direct and indirect) for the production of a product on the basis of the inverse cost matrix (Leontief) A, as a matrix of coefficients of direct costs of product i for the production of product j:

$$A = \frac{Xi}{X} \tag{3}$$

Thus, the basic equation will take the form:

$$X = (E - A)^{-1}Y \tag{4}$$

The model can also be used to assess the economic impact of changes in specific sectors or to analyze the impact of indirect costs on the economy as a whole.

4. Results

Modeling of mutual structural relations using the developed model of inter-industry balance between knowledge-intensive industries allows to model complex innovation relations in the economy. If we present the contribution to the national economy (GDP) in the understanding of the terms of inter-industry balances (sum of final demand, consumption index—*c*, sum of value added, benefits index—*b*), we can obtain the expression:

$$\begin{gathered} Y = Society_c + Government_c + Business_c + (Export- \\ Import\ Balance) = Society_b + Government_b + Business_b \end{gathered} \tag{5}$$

where Society—consumption and accumulation of households (citizens); Government—consumption and accumulation of public institutions (budget); Business—consumption and accumulation of business institutions (investment);

$(Export - Import\ Balance)$—trade balance of exports and imports of the national economy.

Using these principles of national accounts formation [15–17], GDP, inter-industry balances methodology [16], the final demand Y for knowledge-intensive products includes [18]:

1. Government—economic interest of the state (budget);
2. University—economic interest of the academic environment;
3. Industry—economic interest of the industrial environment;
4. Business—economic interest of the business environment;
5. Society—economic interest of the social environment (in general, in the form of wages of employees and households);
6. Environment—economic interest of the environment (as a fictitious stakeholder, to express its interests).

Thus, we obtain extended models of consumption and accumulation of stakeholders of the knowledge and innovation economy:

$$Y = Government + University + Industry + Business + Society + Environment \tag{6}$$

Optimizing the individual components leads us to the mathematical problem of interest harmonization:

$$\begin{gathered} Y = w_g * Government + w_u * University + w_i * Industry + w_b * Business + \\ w_s * Society + w_e * Environment = \sum w_i y_i \ \rightarrow max \end{gathered} \tag{7}$$

where $w_g, w_u, w_i, w_b, w_s, w_e$—weighting coefficients.

The idea of harmonization of interests is that a comprehensive program with localization of knowledge-intensive industries and a vertically integrated form of organization of the national economy will increase the economic interests of the state budget, reduce the costs of intermediate stages of production and achieve high results in high-tech progress and capital efficiency.

As a result, the basic equation of the intersectoral balance takes the form (and allows us to solve the problem of harmonization of interests) [2]:

$$\begin{gathered} AX + (w_g * Government_{max} + w_u * University_{min} + w_i * Industry_{max} + w_b * \\ Business_{min} + w_s * Society_{max} + w_e * Environment_{min}) \ = \ X \end{gathered} \tag{8}$$

The algorithm for calculating the cost–output matrices, taking into account the basis of Leontief's model of inter-industry balances and the peculiarities identified by the authors, can be presented as follows:

1. First, you need to identify all the resources X needed to produce the output.
2. Create a cost matrix A that shows how many resources each sector uses to produce its output.
3. Create an output matrix AX that shows what goods and services each sector produces.
4. Calculate the vector of final demand Y, which represents the total demand for each of the goods produced in the economy.
5. Calculate the inverse structural linkage matrix (A^{-1}) using the formula $A^{-1} = (E - A)^{-1}$, where A is the cost matrix, and E is the unit matrix (a matrix with all elements equal to 0 except the diagonal—there, all elements are equal to 1).
6. Calculate the vector of total costs (T) using the formula:

$$T = A^{-1} * Y \quad (9)$$

where Y is the vector of final demand.

7. Calculate the RNP production vector (X) using the formula:

$$X = Y + T \quad (10)$$

To calculate integrated production resources to ensure the creation of RNPs and the formation of advanced development of the organization, we take: output of goods X1; final demand Y1; number of employees L1; labor remuneration fund W1 = (L1 ∗ average annual salary in the industry).

Algorithm for calculating the multiplier effect in the production of RNPs:

1. An increase in demand leads to a direct increase in industry sales (Direct Effect X2 − X1).

2. But it also leads to an increase in sales in all related industries (Indirect effect).

3. This leads to a multiplicative increase in employment, which can also be calculated from the reciprocal linkage matrices (Jobs Effect L/X1 ∗ (X2 − X1)).

4. This, in turn, increases wage funds in the economy (Wage effect = (L ∗ average annual industry wage)/X1 ∗ (X2 − X1)).

5. And it is possible to calculate the increase in the number of employees by category.

For quantitative assessments, it is optimal to use the approach of intersectoral balances and links. For this purpose, the authors have proposed their own complex modified model of mutual structural links of high-technology transfer when managing the life cycle of fundamentally new products.

Let us present the scientific and methodological apparatus for the development of the toolkit. The model of efficiency indicators of the organizational and economic system of RNP production $Q(t)$ includes, in addition to the direct efficiency of the innovation ecosystem, the influence of external and internal factors on the dynamics of efficiency $G(t, Q(t))$ in the form of quantitative influence $B_k(t)$ of competitive advantages $G_k(t)$: assessment of human–competence potential, production–technological level of enterprises, assessment of the terms of creation and production of unique equipment, as well as construction and organization of production and its infrastructure:

$$\frac{dQ(t)}{dt} = A(t)Q(t) + G(t, Q(t)) = A(t)Q(t) + \sum_{k=1}^{M} B_k(t)G_k(t) \quad (11)$$

where $A(t)$ is the economic diffusion matrix of performance indicators.

1. Organizational performance measures have inertia due to the indirect influence of product attributes.

2. Manufacturers engaged in the realization of a small range of products under the service model cannot achieve a large increase in economic efficiency.

3. Transition to business models of RNP realization can be effective with a clear transition algorithm and allows to create a growth point by creating new consumer and operational properties of products.

The life cycle of fundamentally new products includes all stages of RNP creation, starting from science, production and market realization, taking into account education at each stage and infrastructural development. In the form of economic growth results, where the function $R(A(T))$ describes the sufficient level of economic results when analyzing the RNP production and its efficiency:

$$R(A(T)) = \gamma(t)c(t)\left(\frac{T(t) - A(t)}{T(t)}\right) \quad (12)$$

where $c(t)$ is a function depending on the level of development of competencies of specialists in the field of information use for managing economic processes of RNP.

$T(t)$—theoretically possible level of satisfaction of needs, which would take place if all necessary technologies were developed and brought to the consumer in real time (i.e., in the absence of time lag between the industrial development of technology and its use by the consumer for his own purposes).

$\gamma(t)$—is an indicator of infrastructure development;

$A(t) = \frac{\gamma(t)c(t)}{\gamma(t)c(t)+\lambda(H)} T_0 e^{\lambda(H)t}$—marketing component of scientific and technological potential;

$\lambda(H)$—growth rate.

Thus, it is possible to analyze the economic growth as well as the increase in intellectual and productive capital along the entire RNP chain.

The RNP life cycle can be divided into 9 stages: basic scientific research, applied scientific and technological research, design and technical and technological R&D, commercial research and development, production and application, consumption and exploitation, support and improvement, replacement, modification and renewal.

Let us consider the following steps in developing a model of mutual structural relations of high-tech transfer. The first step is to build an integrated model of system resources. Let us form an integrated model taking into account the presence of an integrated structure of certain types of resources and competencies, as well as the need for different resources to integrate all management processes in the organization. New business models are effective if they bring income to the enterprise higher than in the model of traditional sales and allow, at the expense of additional income, to carry out innovative development of this enterprise, which is focused on the production of new competitive products, superior in performance characteristics to the existing one [22]. Let us express it through the indicator of product competitiveness IQ:

$$IQ = \left(\frac{QS_F}{\frac{S_0}{N} + S_1}\right)(1 - R)(1 + F) \to max \quad (13)$$

where Q—technical and economic indicators of products that form their competitiveness (vector of indicators);

I—technical and economic indicators of market leaders (or indicators achievable at the current level of scientific and technological development) (vector of indicators);

S_0—cost of incurred resource costs to create the product and start production for its output;

S_1—cost of a unit of production;

S_F—price of similar products on the market (if there are no analogs, then $S_F = S_1$);

N—forecasted number of units of products to be sold on the market;

R—internal factors arising in the process of creating new products;

F—external factors accompanying product sales on the market [31].

If we refer to RNP production, the following production resources are required, taking into account the product life cycle:

1. Investment resources (financial and economic);

2. Design and technological resources and resources of means of production (production and technological);

3. Material and energy resources (material–technical and fuel–energy);

4. Production resources (infrastructural, transportation and sales resources);

5. Human resources, management resources, competencies (human–competence and intellectual and information resources).

Thus, the matrix of resource support of the organizational and economic system of fundamentally new products is formed:

$$MR = \sum_{j=1}^{J} wlc_i MR_j \rightarrow max \tag{14}$$

wlc_i—is the weighting factor of the life cycle stage;

MR_j—is the local type of production resource;

$J = size(MR)$.

For the second stage of development of the conceptual model of the integrative readiness matrix, we propose to develop the methodology of matrix readiness levels of technological projects and results of the RNP production system.

Thus, we form a complex model in the form of a matrix of global integrative readiness of the organizational and economic system of fundamentally new products.

$$IRL = \sum_{i=1}^{I} w_{rl} irl_i \rightarrow max \tag{15}$$

where w_{rl}—a weighting coefficient of readiness level from 1 to 9;

irl_i—local indicator of integrative readiness (separate type of readiness),

$$I = size(IRL).$$

Each readiness level model has specific criteria for each level and is used in different areas of technology, manufacturing and systems. In general, such models help manufacturers and developers to understand how ready new technologies, systems or equipment are for real-world use. For the production of fundamentally new products, it is proposed to introduce the concepts of competence readiness levels.

The third step in the development of the toolkit of the matrix of mutual structural relations will be the comparison of the matrix of system resources with the matrix of system readiness for planning and forecasting the results of development of the organizational–economic system of fundamentally new products. For this purpose, we will use the well-known input–output model [14–17] and significantly modify it.

$$Y = w_g * Government + w_u * University + w_i * Industry + w_b * Business + w_s * Society + w_e * Environment = \sum w_i y_i \rightarrow max$$

$$R = \sum wlc_i MR_j \rightarrow max$$

$$RL = \sum_{l=1}^{L} w_{rl} irl_i \rightarrow max \tag{16}$$

where $Y \equiv MR$, $wlc_i \equiv IRL$, $L = size(RL)$.

Thus:

$$w_g * Government + w_u * University + w_i * Industry + w_b * Business + w_s * Society + w_e * Environment = \sum_{l=1}^{L} \sum_{i=1}^{I} \sum_{j=1}^{J} w_{rl} irl_i MR_j \rightarrow max \tag{17}$$

Thus, if we present the results of achieving local levels of readiness as output, and the necessary local elements of integral resources, form a matrix of mutual relations from them, and take as a basis the innovation patterns of knowledge-intensive sectors of the economy, it is possible to obtain a matrix of mutual relations for predicting the life cycle of the organizational–economic system of fundamentally new products.

As a result, we obtain an integral indicator of global competitiveness of the entire organizational–economic system of RNP production IQ_j:

$$IQO = \omega_0 \sum_{j=1}^{N} \omega_j IQ_j + \omega_* IQ + \sum_{i=1}^{M} \omega_i K_i \rightarrow max$$

where ω_i—weight coefficients of business competitiveness factors;

K_i—integral indicators of organizational and economic system efficiency.

The developed system of models of mutual structural relations of high-tech transfer in the management of the life cycle of fundamentally new products on the basis of the above approach provides the possibility of scientific and practical significance, as it allows for solving the problems of complex assessment for adequate substitution of high-tech imports within the framework of national technological security and the formation of the system of RNP production. Thus, in the field of economic theory, the practice of economic decision-making is improved, and on the basis of the created models, it is possible to form the basis of the concept of technological security of an organization, cooperation or industry.

This model is unique for Russia due to the fact that Russia has been, and is, mainly engaged in resource exports. In the structure of Russia's imports in 2023, the category "machinery, equipment and vehicles" has the largest specific weight (49.3%). Russia's dependence on imports of high-tech goods from countries that have imposed sanctions against it is assessed as high.

However, in our opinion, the mechanism of assessing mutual structural relations for import substitution of high-tech transfer when managing the life cycle of fundamentally new products can be adapted for application in other countries, taking into account the peculiarities of their development and the impact of both internal and external factors.

5. Discussion of Results

Let us explain the use of the developed toolkit by the example of assessing the mutual linkage of high-tech imports.

The mechanism of using the coefficients of mutual linkage of high-tech imports for import substitution of technological transfer includes several stages.

1. Analyze the science intensity of imported technologies. At this stage, the science intensity of imported technologies is assessed. For this purpose, these technologies are researched and analyzed to determine the scientific knowledge and competencies that are necessary for their creation and use.

2. Determination of the coefficients of reciprocity. Based on the analysis of the science intensity of imported technologies, the coefficients of reciprocal linkage are determined. These coefficients show how dependent the possibility of import substitution of technological transfer is on the availability of certain competencies and scientific knowledge within the country.

3. Assessing the availability of competencies, scientific knowledge and other scientific and productive forces. This step assesses the availability of competencies and scientific knowledge within the country necessary for the realization of import substitution of technological transfer. This assessment identifies areas where there are deficiencies in competencies and knowledge, as well as areas where the country has strong competencies and knowledge.

4. Development of import substitution strategy. Based on the data obtained, an import substitution strategy is developed, which determines what steps should be taken to increase

competencies and scientific knowledge in areas where there is a shortage. This may include developing scientific research, creating educational programs and supporting innovation and technological development.

5. Strategy implementation and monitoring. Once the import substitution strategy is developed, it is implemented through specific activities to improve competencies and scientific knowledge. At the same time, it is necessary to continuously monitor and evaluate the results in order to adapt the strategy if necessary.

Let us take the average value of the dollar exchange rate for 2022, $1 = 73 rubles (https://cbr.ru/currency_base/daily/ (accessed on 20 November 2023)). Then, for example, there were about 20 trillion rubles ($280 billion) of goods imports to the Russian Federation for 2022; for the Russian Federation GDP at PPP, which for 2022 was estimated at 330 trillion rubles ($4.494 trillion (according to the IMF)). Accordingly, the share of high-tech imports from the GDP of the Russian Federation is more than 6%, which proves the globality of this task. Let us summarize the results in Table 2.

Table 2. Structure of high-tech imports of goods in the Russian Federation for 2022.

No.	Category	Import Trade Flow (Rubs)	Share in Total Imports, %
1	Nuclear reactors, boilers, equipment and mechanical devices; parts thereof	3,969,811,746,517	19.45
2	Electrical machinery and equipment, parts thereof; sound recording and sound reproduction equipment, equipment for recording and reproduction of television images	2,689,645,828,273	13.18
3	Means of land transportation, other than railway or streetcar rolling stock, and their parts and accessories	1,955,574,176,039	9.58
4	Pharmaceutical products	1,005,883,804,089	4.93
5	Plastics and plastics products	921,625,055,553	4.51
6	Optical, photographic, cinematographic, measuring, inspection, precision, medical or surgical instruments and apparatus; parts and accessories thereof	633,500,251,282	3.10
7	Ferrous metal products	470,809,396,743	2.31

Source: authors' calculations.

The structure and volumes of high-tech imports (2017–2022) are almost unchanged, and the average value is 10 trillion rubles per year.

Thus, it is possible to obtain initial data on the demand for high-tech imported products. The result is Table 3.

Table 3. Structure of integrated production costs for the creation of RNPs to replace high-tech imports of goods in the Russian Federation.

Type of Resource	Total Demand (Mln. Rub.)	Import Reciprocity Coefficient
Financial and economic resources	32,031	4.0
Production and technological resources	412,229	51.5
Infrastructure resources	187,744	23.5
Transportation and sales resources	27,649	3.5
Material and technical resources	97,155	12.1
Fuel and energy resources	53,598	6.7
Personnel and competence	10,386	1.3
Intellectual and informational	8562	1.1
Social and reputational	3838	0.5
Natural and environmental	33,873	4.2

Source: authors' calculations.

The algorithm of using the coefficients of reciprocal relationship of knowledge-intensive imports for import substitution of technology transfer includes the following steps:

1. Data collection. Collect data on knowledge-intensive imported technologies, competencies and scientific knowledge within the country.

2. Analyze the data. Analyze the data to determine the knowledge-intensive imported technologies and the availability of competencies and knowledge within the country.

3. Calculate reciprocal linkage coefficients. Based on data analysis, calculate reciprocal linkage coefficients that show the dependence of import substitution capability on the availability of certain competencies and scientific knowledge.

4. Strategy development. Develop an import substitution strategy, taking into account the obtained coefficients of mutual relationship and assessment of the availability of competencies and knowledge.

5. Implementation and monitoring. Implement the strategy, monitor progress and adapt the strategy if necessary.

Thus, the use of coefficients of reciprocal relationship of knowledge-intensive imports helps to determine the presence and lack of competencies, scientific knowledge and other scientific and production forces, and on their basis to develop a strategy for import substitution of technological transfer.

As a result, the developed models and tools can be applied in the creation of an intelligent system to decide, plan and manage the production of fundamentally new products. These models and tools can be applied as the foundation of the innovation management system and production management of innovative products to ensure sustainable economic development.

6. Conclusions

The input–output model in the economy, combined with modern digital technologies, allows you to analyze the dependencies between different sectors of the economy, which helps to make more informed economic decisions at the level of the state, region or enterprise in the formation of a comprehensive program to ensure national technological security.

The model is a system of algorithms that effectively link the tasks of end users with the capabilities (material, labor and financial) of producers of all forms of ownership. Based on the model, the effective distribution of public production investments is determined. By implementing the model, the leadership of a country or enterprise gains the opportunity to adjust development goals in real time, depending on the specified production capabilities of residents and the dynamics of end-user demand.

In conclusion, it can be noted that:

1. National technological security requires the development of scientific, technological and production potential.

2. Competitiveness depends on the development of workers' competencies and creation of high-tech products.

3. Successful technology transfer requires a digital technology platform.

4. The strategy of advanced technological development is important to ensure technological sovereignty and the creation of national high-tech companies, as well as to ensure sustainable economic development.

5. Expansion of high-tech production policy and scientific and technological cooperation contribute to the creation of knowledge-intensive products.

Thus, it is necessary to carry out works related to state regulation and subsidization; to achieve the goals, it is necessary to create a digital mechanism of state planning of scientific-technological and economic development (analog of digital state planning of the economy) and the infrastructure of the intersectoral system of high-technology production.

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References

1. Gorlacheva, E.N.; Omelchenko, I.N.; Drogovoz, P.A.; Yusufova, O.M.; Shiboldenkov, V.A. Cognitive factors of production's utility assessment of knowledge-intensive organizations. *Nucleation Atmos. Aerosols* **2019**, *2171*, 090005. [CrossRef]
2. Balzat; Hanusch, H. Recent trends in the research on national innovation systems. *J. Evol. Econ.* **2004**, *14*, 197–210. [CrossRef]
3. Cobos, M.P.; Quezada, V.F.; Morloy, L.I.Z.; Alvarez, P.V.; González, S.P. A model based on the Technology Readiness Level (TRL) scale to measure the maturity level of research projects that can become spinoffs in Higher Education Institutions. In Proceedings of the 2021 Congreso Internacional de Innovación y Tendencias en Ingeniería (CONIITI), Bogotá, Colombia, 29 September–1 October 2021; pp. 1–6. [CrossRef]
4. Blut, M.; Wang, C. Technology readiness: A meta-analysis of conceptualizations of the construct and its impact on technology usage. *J. Acad. Mark. Sci.* **2019**, *48*, 649–669. [CrossRef]
5. Sharma, A.; Gaikwad, A.; Singh, D.P.; Kalra, R.; Keerthi, S.S.; Raj, V.H.; Shaghnab, M.L. Reshaping Industry: Adoption of Sustainable Techniques providing Remanufacturing Solutions in High-Tech industries. *E3S Web Conf.* **2023**, *453*, 01028. [CrossRef]
6. Bacon, E.; Williams, M.D.; Davies, G.H. Recipes for success: Conditions for knowledge transfer across open innovation ecosystems. *Int. J. Inf. Manag.* **2019**, *49*, 377–387. [CrossRef]
7. Hekkert, M.P.; Janssen; M.J.; Wesseling; J.H.; Negro, S.O. Mission-oriented innovation systems. *Environ. Innov. Soc. Transit.* **2020**, *34*, 76–79. [CrossRef]
8. Granstrand, O.; Holgersson, M. Innovation ecosystems: A conceptual review and a new definition. *Technovation* **2020**, *90*, 102098. [CrossRef]
9. Cai, Y.; Lattu, A. Triple Helix or Quadruple Helix: Which Model of Innovation to Choose for Empirical Studies? *Minerva* **2022**, *60*, 257–280. [CrossRef]
10. Kumar, S.; Lim, W.M.; Sureka, R.; Jabbour, C.J.C.; Bamel, U. Balanced scorecard: Trends, developments, and future directions. *Rev. Manag. Sci.* **2023**, *77*. [CrossRef]
11. Pan, J.; Guo, J. Innovative Collaboration and Acceleration: An Integrated Framework Based on Knowledge Transfer and Triple Helix. *J. Knowl. Econ.* **2022**, *13*, 3223–3247. [CrossRef]
12. Drogovoz, P.A.; Kashevarova, N.A.; Dadonov, V.A.; Sadovskaya, T.G.; Trusevich, M.K. *Industry 4.0 in Russia: Digital Transformation of Economic Sectors*; CRC Press: Boca Raton, FL, USA, 2021; pp. 191–207. [CrossRef]
13. Usmanov, M.R.; Garina, E.P.; Romanovskaya, E.V.; Andryashina, N.S.; Vatletsov, D.P. *Evaluation of Management Effectiveness of the System Based on the Use of Management Indicators*; Springer: Berlin/Heidelberg, Germany, 2021; pp. 77–85. [CrossRef]
14. Bouncken, R.B.; Kraus, S. Entrepreneurial ecosystems in an interconnected world: Emergence, governance and digitalization. *Rev. Manag. Sci.* **2022**, *16*, 1–14. [CrossRef]
15. Gil'mundinov, V.M. Interindustry Competition in Russia's Economy. *Stud. Russ. Econ. Dev.* **2020**, *31*, 505–513. [CrossRef]
16. Baranov, A.O.; Pavlov, V.N.; Slepenkova, I.M.; Tagaeva, T.O. Dynamic Input-Output Model with a Human Capital Block Applied to Forecasting of the Russian Economy. *Stud. Russ. Econ. Dev.* **2018**, *29*, 654–664. [CrossRef]
17. Moskovtceva, L.V.; Pilipchuk, N.V.; Khashir, B.O.; Popova, Y.N.; Aksenova, Z.A. Development of Digital Regional Ecosystems: Russian Specifics and Risk Leveling. In *AgroTech*; Popkova, E.G., Sozinova, A.A., Eds.; Springer: Singapore, 2022. [CrossRef]
18. Den Hertog, P.; Bilderbeek, R. The new knowledge infrastructure: The role of technology-based knowledge-intensive business services in national innovation systems. In *Services and the Knowledge-Based Economy*; Routledge: London, UK, 2019; pp. 222–246. [CrossRef]
19. Kivimaa, P.; Brisbois, M.C.; Jayaram, D.; Hakala, E.; Siddi, M. A socio-technical lens on security in sustainability transitions: Future expectations for positive and negative security. University of Sussex. *Futures* **2022**, *141*, 102971. Available online: https://hdl.handle.net/10779/uos.23492045.v1 (accessed on 20 November 2023). [CrossRef]
20. Tyulin, A.; Chursin, A. *The New Economy of the Product Life Cycle*; Springer: Berlin/Heidelberg, Germany, 2020.

21. Frenning, G. On the thermodynamic consistency of the Drucker–Prager Cap model: Modification of the plastic potential and analysis of unloading. *Powder Technol.* **2023**, *423*, 118503. [CrossRef]
22. Yarlychenko, A.A. Application of the modified model of M. Porter as a tool for the realization of innovation strategies of enterprises. *Sci. Forum Econ. Manag.* **2020**, *11*, 53–57.
23. Litvinova, A.G. Development of idea management system in the company "Innovative Management Systems". *Vestn. Altai Acad. Econ. Law* **2020**, *7*, 68–72. [CrossRef]
24. Ponkin, I.V.; Kupriyanovsky, V.; Moreva, S.; Ponkin, D. Subversive technological innovations: Concept, meaning and ontology. *Int. J. Open Inf. Technol.* **2020**, *8*, 60–68.
25. Glazyev, S.Y. Regulation of innovation processes in the new technological and global economic patterns. *Econ. Revival Russ.* **2022**, *2*, 24–27. [CrossRef]
26. Alieva, E.A. Essence of innovation: Analyzing theoretical approaches. *Vestn. Plekhanov Russ. Univ. Econ.* **2019**, *6*, 21–31. [CrossRef]
27. Vittori, D.; Natalicchio, A.; Panniello, U.; Petruzzelli, A.M.; Albino, V.; Cupertino, F. Failure is an option: How failure can lead to disruptive innovations. *Technovation* **2024**, *129*, 102897. [CrossRef]
28. Anastassiadou, K.; Hindersmann, I.; Staub, S. Integration of resilience assessment aspects in life cycle management. *Transp. Res. Procedia* **2023**, *72*, 1343–1348. [CrossRef]
29. Zhang, T.; Bai, Y.; Zhou, X.; Li, Z.; Cheng, Z.; Hong, J. Towards sustainability: An integrated life cycle environmental-economic insight into cow manure management. *Waste Manag.* **2023**, *172*, 256–266. [CrossRef] [PubMed]
30. Ali, Q.S.A.; Hanafiah, M.H.; Mogindol, S.H. Systematic literature review of Business Continuity Management (BCM) practices: Integrating organisational resilience and performance in Small and medium enterprises (SMEs) BCM framework. *Int. J. Disaster Risk Reduct.* **2023**, *99*, 104135. [CrossRef]
31. Hayakawa, K. Recent development of covariance structure analysis in economics. *Econom. Stat.* **2021**. [CrossRef]