European Proceedings of
Multidisciplinary Sciences
EpMS

www.europeanproceedings.com e-ISSN: 2421-826X

DOI: 10.15405/epms.2024.09.32

**MTMSD 2022**
**I International Conference «Modern Trends in Governance and Sustainable Development of Socio-economic Systems: from Regional Development to Global Economic Growth»**

# EVOLUTIONARY APPROACH TO REGIONAL FOREIGN ECONOMIC DEVELOPMENT RECOMMENDATIONS

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## Abstract

The article reflects some relevant aspects of the development of recommendation systems for the development of foreign trade activities of the regions. In the conditions of changing external conditions and evolutionary processes, it is necessary to adjust approaches to assessing the stability of systems. The paper proposes a methodology for the study of relations in regional foreign trade using graph theory. The analysis of the system indicators of foreign economic activity, namely the trade profile of the region based on the index of economic complexity. Variants of a scenario approach for the development of non-resource non-energy exports of regions are proposed. A prototype of software tools that can be used by government agencies to justify decisions on foreign economic activity in the region is described. This research article would be of interest to researchers, policymakers, and practitioners in the field of foreign trade, regional economic development and new IT technology.

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*Keywords:* Evolution, economic complexity, foreign economic activity, network graphs, recommendation system

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https://doi.org/10.15405/epms.2024.09.32
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eISSN: 2421-826X

## 1. Introduction

Structural and geopolitical changes in the modern world, the acceleration of the pace of innovation, the slowdown in economic growth lead to the need to change approaches to strategic planning for the development of industries and regions (Kadochnikov & Fedyunina, 2015). To implement this approach, especially in the context of adjusting the foreign trade balance, it is necessary to find new points of growth of regional export potential by increasing the volume of international and interregional trade flows of goods with high added value. To do this, it is necessary to assess the evolutionary variability of the structure of regional foreign economic relations (Bräuning & Koopman, 2020), which is based on a set of certain indicators. The complexity and sophistication of the model requires the construction of decision support systems involving mathematical and instrumental methods for studying trends in the variability of the world trade network.

The existing theory of economic complexity (Hidalgo & Hausmann, 2009) suggests that with limited resources, increasing the output of high-tech and high-margin goods is possible only by increasing the share of intellectual capital in value added. However, an assessment of the regional specifics of foreign economic activity showed that the export of high-margin non-primary products is concentrated in several large regions, as well as an imbalance in the development of intellectual capital and its concentration in large urban agglomerations. These features limit the use of aggregated indices of economic complexity, product complexity, the index of comparative competitive advantages, etc. (Harvard’s Growth Lab, 2018; Moiseev & Bondarenko, 2020) to assess the real level and potential of development of the territory, which requires the development of new approaches and indicators for analyzing the complexity and assessing the sustainability of economic ties at the subnational level (I. L. Lyubimov et al., 2017).

## 2. Problem Statement

Diversification of the region's production means the ability to produce as many technologically complex goods as possible. The limited capacity of the region in production can cause long-term economic backwardness. Choosing a new product for export, related to those that are already being produced, will lead to lower costs. It is possible to link production capabilities and export diversification directions, as well as eliminate the disadvantages of traditional methods of analysis and forecasting using indicators of economic complexity (Hausmann et al., 2014).

## 3. Research Questions

The issue described in this research paper prompts a number of research inquiries: What are the relevant aspects of developing recommendation systems for foreign trade activities of the regions? How can graph theory be used to study relations in regional foreign trade? What are the system indicators of foreign economic activity, and how can they be analyzed using the index of economic complexity? What variants of a scenario approach can be proposed for the development of non-resource non-energy exports

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of regions? What prototype software tools can be developed to assist government agencies in deciding on foreign economic activities in the region?

## 4. Purpose of the Study

The aim of the work is to build a recommendation system for the development of foreign economic activity of regions based on the study of evolutionary variability and assessment of the stability of foreign trade relations of the region (Evseeva & Ramenskaya, 2020; Kislyakov & Tikhonuyk, 2020). The term sustainability is proposed to be interpreted as the state of the foreign economic activity system of the region, which is aimed at resisting changes in the external environment under the influence of the external environment and stable fulfillment of contractual obligations.

## 5. Research Methods

The most promising from the point of view of taking into account external conditions and internal opportunities for conducting foreign economic activity is the methodology of strategic planning based on the description of the trade and economic specialization of the subjects of the Russian Federation, including macro-regions (Hausmann & Hidalgo, 2011). The basic indexes forming an idea of the priority directions of the development of economic relations at the level of suppliers and consumers, as well as the increase in the production and export of high-margin non-primary products is the index of identified comparative advantages and the indexes of economic and product complexity calculated on its basis.

In practice, in order to describe the trends of evolutionary variability, as well as to manage the development of foreign economic activity in the region, it is necessary to additionally form ideas about the interrelationships of the identified promising types of products with the production capabilities of the region, taking into account the strategy of spatial development of the region and the assessment of the demand for goods both on world and domestic markets.

In this regard, a prospective analysis of the economic specialization of the regions allows the development of foreign economic activity in several directions

i. production of competitive products for the region;

ii. increasing the variety of the product range, taking into account the available production capacities and technological equipment;

iii. formation of technological clusters at the level of macro-regions, taking into account the strategy of spatial development of territories.

All these tasks require optimization of the development of foreign trade relations and trade value chains of goods in order to maximize the economic effect for each region of Russia. To do this, it is necessary to analyze the global trends in the evolution of goods markets, allowing to adjust the sectoral trade profile of the region and form an assessment of the possible directions of development of state policy in the field of foreign economic activity and innovative development.

One of the promising directions for the development of mathematical and instrumental methods for studying the evolutionary variability of complex socio-economic systems are the methods of graph

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theory, which are one of the most convenient and universal tools for identifying non-obvious stable dynamic relationships between objects (groups of goods, countries), as well as determining the optimal structure of regional foreign trade relations, taking into account the trends of evolutionary variability of indicators, including those aggregated by product groups and countries of interest (Durrett, 2007; Kislyakov et al., 2022).

To describe such network structures in graph format, the commodity nomenclature of Foreign Economic activity (FEA) is most often used to designate objects and form a hierarchy. At the same time, the vertices of the graph are commodity groups or countries, and the edges of the graph are quantitative indicators of foreign economic activity, for example, the number of transactions for a selected product between countries during the observation period, the volume of exports in value terms, the volume of imports in quantitative terms, etc.

The main problem of describing the space of interaction between subjects of foreign trade activity using graphs is a huge set of vertices in the study of a large number of groups of goods, as well as their consumers and suppliers. It should also be noted the problem of evaluating and filtering connections that do not have a significant impact on the overall picture of events and are quite rare. Thus, an increase in the number of vertices V of the graph, as well as edges E connecting them, leads to a significant complication of the analysis and perception of the network structure.

To generalize and analyze the mechanisms of graph formation, Filimonova et al. (2021) proposed a transition to the allocation of complete subgraphs (clicks) inside the graph G(V, E), which are formed by a set of vertices connected by edges in pairs with each other. The scale of such clicks can be different, and the maximum click cannot be expanded by including additional vertices in it. Hypothetically, this approach will allow us to identify stable interconnected groups of objects that have close relationships in their behavioral activity, characterizing foreign economic activity at the level of the subject. At the same time, this approach is easily scaled and can be focused on various types of objects.

The problem of removing relatively weak connections from the network structure in the most elementary representation can be solved by filtering weak interactions in accordance with a certain threshold value t of the Pearson correlation coefficient $r_{ij}$, which characterizes the closeness of the relationship between the time series of observed indicators for each pair of objects forming a connection, the expression for the filtering rule may look like this:

$$a_{ij} = \begin{cases} 1, \text{if edge } u_i \text{ adjacent to edge } u_j \text{ и } r_{ij} \geq t; \\ 0 - \text{in all other cases.} \end{cases} \quad (1)$$

Of course, this raises the problem of optimizing the structure of a graph consisting of N vertices in order to increase the informativeness of the description with its help of the structure of regional foreign economic relations. At the same time, the most valuable from the point of view of interaction analysis are the maximum click and 1-2 clicks close to it, characterized by the largest number of connections and forming an idea of the key vertices on which the evolutionary variability of the structure of the graph describing the regional trade profile depends. This task is also related to the task of selecting factors for forecasting quantitative indicators of foreign economic activity based on the analysis of the composition of the first clicks of the graph.

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A set of click vertices $Q_1, Q_2, ..., Q_{N_q}$ allows you to identify groups of products that have time-stable relationships of variability in quantitative indicators, while where $N_q$ is the number of clicks in the graph. The criterion for determining the significance of a commodity group for describing the structure of a region's trade profile in the format of a network graph is the inclusion of some vertex $v_i, i = 1, 2, ..., N$ that characterizes, for example, a commodity group in one of the first maximum clicks. Mathematically, this criterion can be formulated as follows:

$$A: \left\{ v_i \in \left[ Q_1, Q_2, .., Q_j \right] \right\}, j = 1, 2, ..., N_q, N_q \leq 3 \tag{2}$$

Where $\left[ Q_1; Q_j \right]$ is a set of vertices that can be included in the first two or three maximal cliques. The task of determining the number of maximum clicks for analyzing the list of vertices is usually implemented on the basis of calculating the degree of vertices of the graph $\xi_1, \xi_2, ..., \xi_N$. Real network structures characterizing trade relations usually have a power law of distribution of the number of connections in the graph from the number of vertices:

$$P\left\{ \xi \leq k \right\} = k^{-\tau}, \tau \in \left( 1, 2 \right), \tag{2}$$

This indicator usually varies from 1 to 2. Such networks are called Internet-type network graphs and usually have quite a lot of subgraphs. As the indicator $\tau$ approaches one, the proportion of vertices that are included in the maximum click increases. When the value $\tau$ is close to 2, the proportion of vertices included in the maximum click increases to 50%. It is this parameter that is key for choosing the threshold value of the previously specified Pearson pair correlation coefficient, which determines the significance of connections in the graph during its optimization (Saramäki et al., 2007; Shitikov, 2020).

At the same time, the results obtained on the basis of studies on graph structure (Aiello et al., 2000) showed that any large-scale networks that have a sufficiently stable structure can be described based on the first few clicks, and the graph structure from the position of including new connections can be optimized based on the maximum of mutual information, introduced by new connections into the graph structure. When implementing practical calculations, no more than the first three clicks are usually used. In some cases, when there is a sharp change in the growth of mutual information, it is advisable to choose no more than the first five clicks, i.e. at $A: \left\{ v_i \in \left[ Q_1, Q_2, ...Q_5 \right] \right\}$.

However, the set of components that reflect the structure of the graph identified on the basis of click analysis also requires an analysis of comparative competitive advantages in the formation of new economic ties in relation to the production of a particular type of product and/or its purchase and delivery to certain countries.

The indicator of revealed comparative advantages (RCA) (Newman et al., 2001) is essentially defined as the proportional ratio of the share of exported goods p among the entire set of exported goods within the economy c of the territory (country, macroregion, region) to the share of the presence of this product in the volume of world exports, and can be defined as:

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$$RCA_{c,p} = \frac{\left( Ex_{pc} \Big/ \sum_{p} Ex_{pc} \right)}{\left( \sum_{c} Ex_{pc} \Big/ \sum_{p} \sum_{c} Ex_{pc} \right)} \tag{4}$$

at the same time, $Ex_{pc}$ is defined as the export in value terms of goods p by the economy of the territory c. An important distinguishing feature of the RCA indicator is its inertia to the factors on the basis of which comparative advantages are formed.

An increase in the quantitative value of the RCA indicator allows us to conclude that the economy of territory c has a comparative advantage in the production of goods (or product group) p. For formalization, approaching the use of the specified index in practice, they usually resort to restrictions on its value:

$$x_{pc} = \begin{cases} 1, if \ RCA_{cp} > 1 \\ 0, if \ RCA_{cp} \le 1 \end{cases} \tag{5}$$

The economy of a particular territory has a competitive advantage in the production of goods p in the event that the RCA value exceeds one, in all other cases there is no such advantage: This restriction allows you to ignore relatively small exports and allows for more adequate analysis (Roos, 2017).

Thus, the listed indicators and criteria make it possible to identify the vectors of the evolution of the development of foreign economic activity within a single economy of the territory and can be schematically visualized in matrix form (Figure 1).

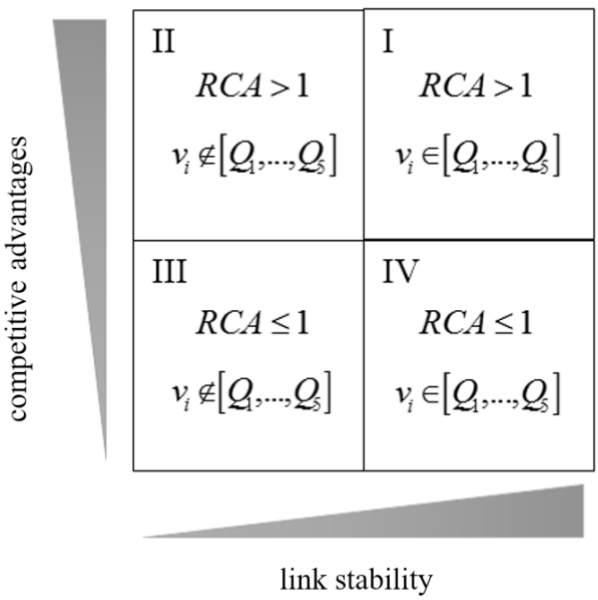


**Figure 1.** Matrix for identifying stable relationships between the vertices of the graph of foreign trade relations

Interpretation of the results of the analysis of the results of the calculation of these indicators allows you to rank products in the following four groups:

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Group 1 (I-th quadrant) is characterized by highly promising goods, among other things, determining variability and allowing to form vectors of evolution of the structure of regional foreign economic relations. The production of such goods usually requires the development of individual technologies, the development of new competencies, the creation of technological clusters. This will really increase the variety of manufactured goods and gain a confident competitive advantage in the global market.

Group 2 (II-th quadrant) defines groups of goods that have comparative advantages in a narrow corridor of technological capabilities for their production and may require the expansion of existing production and increase the diversity of the product range.

Group 3 (III-th quadrant) characterizes goods that have no prospects of development for production in the territory of the selected economic region.

Group 4 (IV-th quadrant) defines groups of goods that have stable links with other goods, but at the same time do not have identified comparative advantages. Such products most likely require a conversion of production to produce these new types of products and ultimately gain a competitive advantage. The question of the economic feasibility and timing of the implementation of these procedures remains open.

Based on the proposed methodological developments, a prototype of the recommendation system of the decision support system for the development of export directions and visualization of the rating of promising product groups and the formation of a trade profile for a given economic region was built. The block diagram of the recommendation block, taking into account the RCA index, is shown in Figure 2.

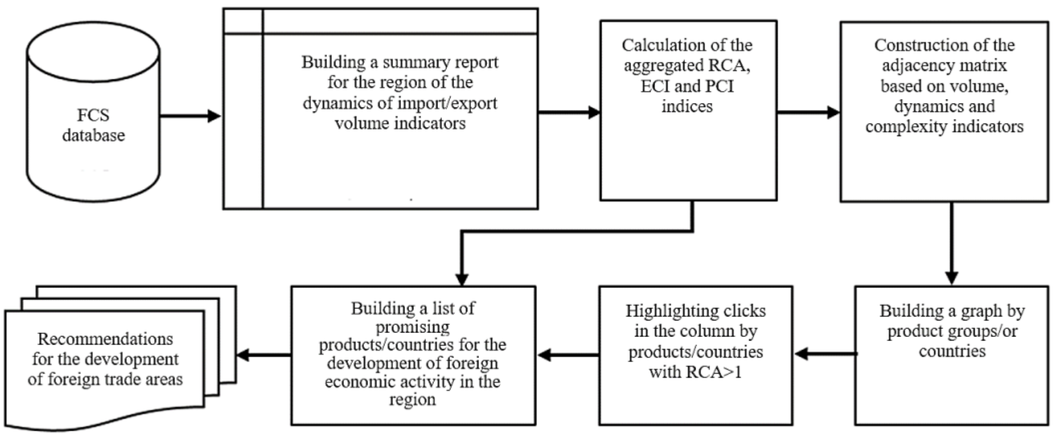


**Figure 2.** Block diagram of the recommendation block

An important advantage of the described methodological approach and the implemented prototype is the possibility of ranking goods based on the comparison of the listed indicators in accordance with the given matrix. In addition, the task can be sЫcaled up in relation to the comparison of the macro-regions of Russia and the entire Russian Federation with other countries of the world in the search for promising goods for the formation of an export basket.

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## 6. Findings

An example of the implementation of the developed methodological approach and the formation of recommendations was implemented on the basis of a data set for various levels of detail of commodity groups and goods by codes in accordance with the commodity nomenclature of foreign economic activity FEACN (analogous to the international harmonized system of customs codes HS-code). The data set reflects transactions by goods and countries in quantitative and monetary terms. The structure of data sources is shown in Figure 3.

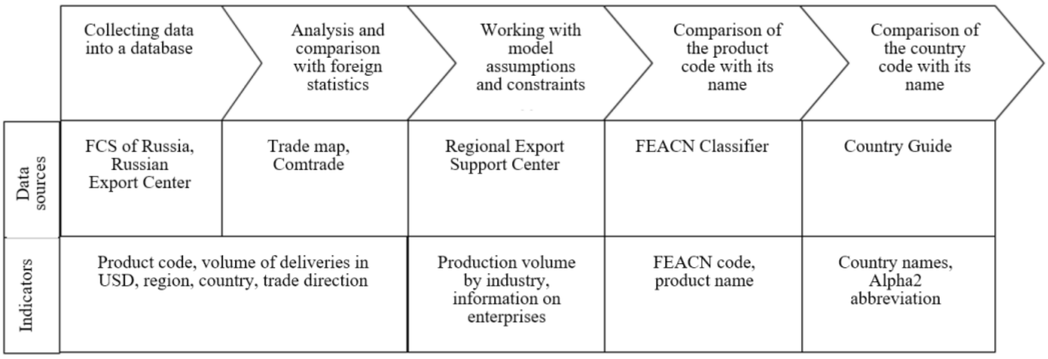


**Figure 3.** Recommendation system data sources

Also, one of the data sources is the official portal of the World Trade Organization and the TradeMap service, as well as the UN Comtrade database. Therefore, the main database is compiled based on the integration of domestic and foreign data sources.

The first stage of creating a BI-system for forecasting the export potential of the Vladimir region is the preparation of initial data on foreign trade indicators. This process includes the calculation of indicators of the economic complexity of the export basket of the region: RCA, ubiquity, PCI, density, COG. Then a list of related products by proximity is formed and brought into the required format for further work. Here, the seasonality index is calculated, which shows how the volume of sales falls or increases in a certain period.

In order to identify the directions and trends of the evolutionary variability of foreign trade relations in the context of commodity groups, it is necessary to conduct studies of the relationships between groups of goods for sustainability. For this purpose, a graph with structure optimization was formed, shown in Figure 4, in which a cosine similarity measure was used as distance metrics (Kislyakov, 2020). In the column, commodity groups are represented in two-digit FEACN codes.

Graph structure optimization was performed based on the Pearson correlation coefficient, taking into account the maximization of mutual information introduced by each vertex into the graph, taking into account the value restriction $\tau$ within 2. This approach allows us to obtain the graph structure that is most informative from the point of view of analysis, close to the structure of an Internet-type network and discard less significant connections from the point of view of the problem being solved (Mastitsky, 2020).

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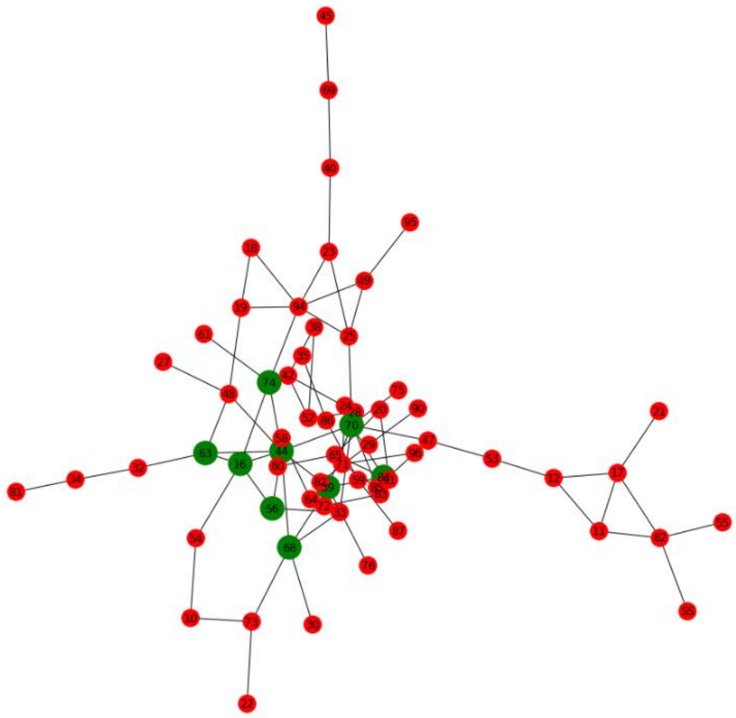

**Figure 4.** Graph of exports of the Vladimir region for 2021 by product groups with optimization of communication based on the correlation coefficient

The first five maximal clicks of the resulting graph shown in Figure 4 have the following vertices in their composition (44, 48, 63, 70, 39, 68, 16, 56, 74). The specified list represents the goods forming the basis of the trade profile of the region.

It should be noted that the time series of variability of quantitative values of indicators for export volumes in value terms of each of the selected groups of goods, for the most part, do not have high values of the pair correlation coefficient (>0.9 on the Cheddock scale) as shown in Figure 5.

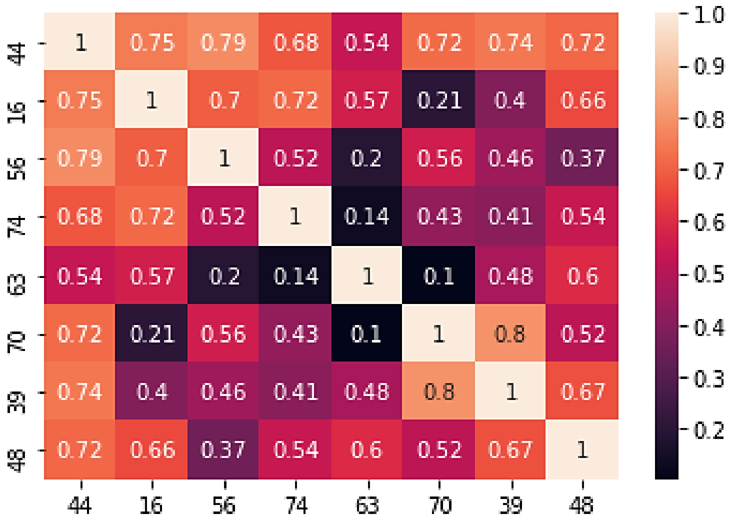


**Figure 5.** Heat map of paired Pearson correlation coefficients for various product groups

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As a result, a graph of the product space was constructed, which allows us to visualize the structure of relationships between market entities. A fragment of the graph is shown in Figure 6. The specified graph is formed based on the calculation of the density index (Lyubimov & Yakubovsky, 2019) for the product space calculated on the basis of the comparative advantage indicator.

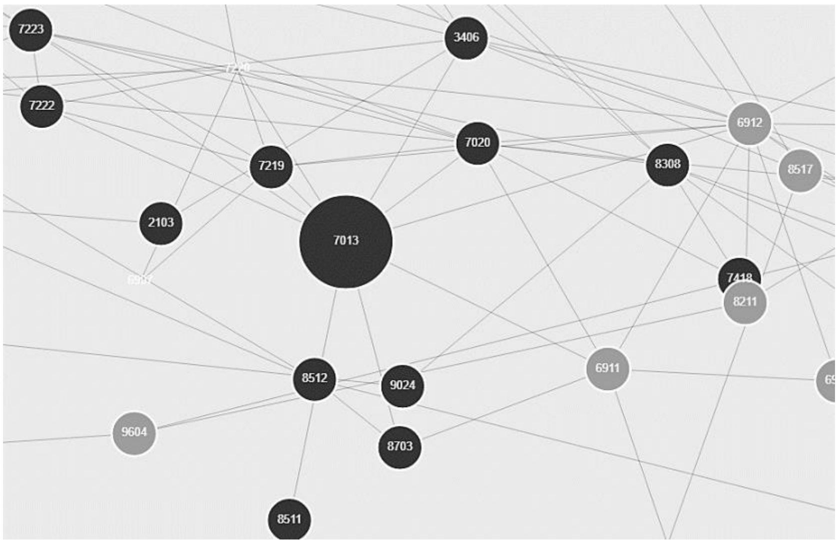


**Figure 6.** A fragment of the product space at the level of Russian regions (on the example of the Vladimir region)

The fragment of the graph (Figure 6) shows a group that is formed around the vertex "Glassware" (FEACN 7013). This subgroup of goods is included in the group of 70 included in the list based on the analysis of clicks in the column of commodity exports (Figure 4).

The dark gray color highlights the commodity groups in which there are goods that the Vladimir region exports at the level of comparative advantage, light gray - the Vladimir region exports these goods, but does not specialize in them. In addition, there are connection points on the graph without marked vertices – this means that this product is associated with the export of the Vladimir region, but the region itself does not export these goods. The volume of deliveries on the graph reflects the size of the marker. Glassware (FEACN 7013) is often found in exports together with porcelain tableware (FEACN 6911) and ceramic tableware (FEACN 6912). Despite the general market trends, the Vladimir region does not specialize in the export of these goods as shown in Figure 4. Group 68 is missing.

From the data on co-exported goods, a density indicator is calculated, which reflects the probability of specialization of a region or country on the export of this product in the next period. The density distribution for the goods of the Vladimir region is shown in Figure 7.

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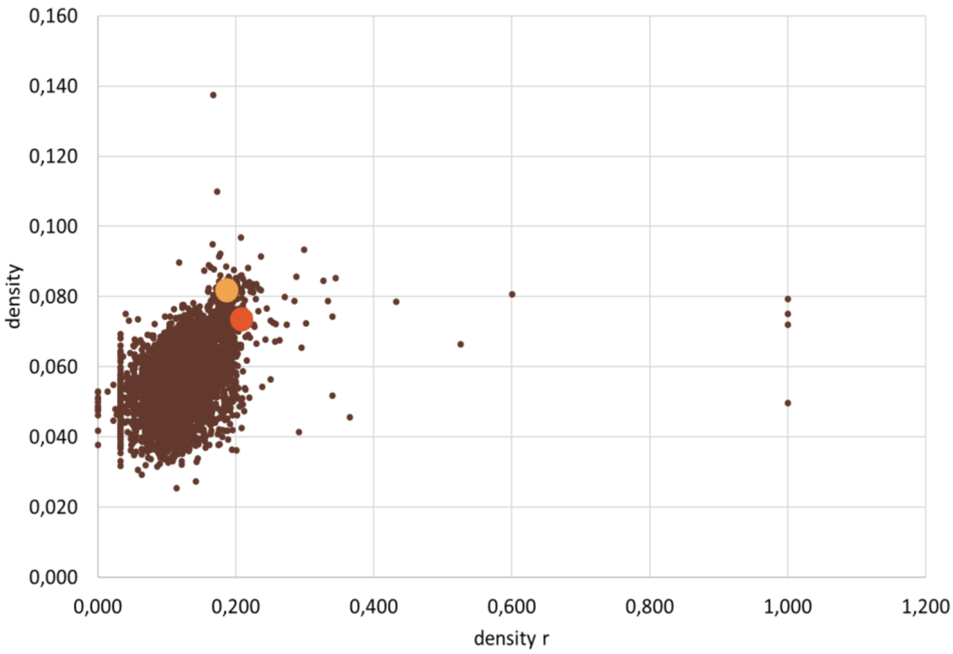


**Figure 7.** Distribution of the values of the indicator of the density of goods (density) of the Vladimir region at the regional and global levels

A small level of diversification limits the links of the export basket of the Vladimir region with other high-tech goods in the grocery space, which is due to the low value of the export complication potential relative to other indicators. Figure 8 below shows the distribution of the strategic importance of the goods of the Vladimir region at the regional and global levels.

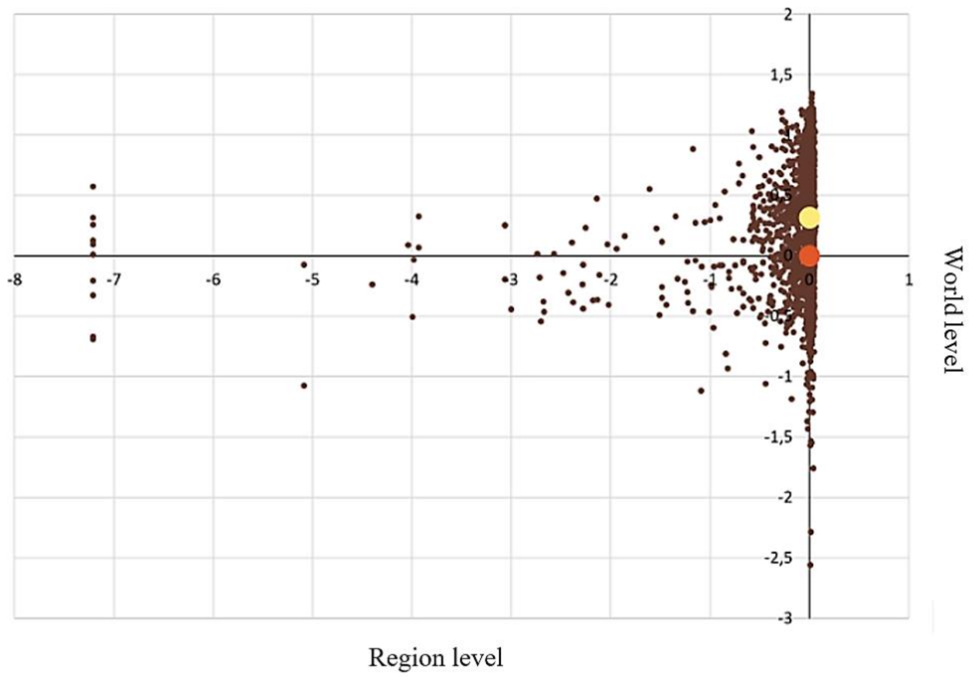


**Figure 8.** Distribution of strategic importance of goods of the Vladimir region at the regional and global levels

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The differences in the distribution of strategic importance at the level of regions (on the X axis) and at the level of countries of the world (on the Y axis) are due to the difference in the structure of the product space at different levels. At the regional level, goods are connected with each other by a large number of connections, since the export baskets of different regions of the Russian Federation are more similar than the export baskets of different countries of the world. At the regional level, the Vladimir region's export basket is associated with many undeveloped technological goods, while there are fewer technological goods available for development in the global product space.

The model of the foreign trade profile obtained in the work nevertheless has some limitations. The study uses import and export statistics of the Federal Customs Service of the Russian Federation. These statistics are based on data from customs declarations, therefore, information about the regions participating in trade is filled in based on the legal address of the companies of the senders and recipients, which may differ from their actual location. Accordingly, the goods exported by the region are not always produced on the territory of this region. However, this limitation is not related to the problems of applicability of the developed methodology, but to the objectivity of the primary data.

## 7. Conclusion

As a result of the work carried out, trends in the development of exports and imports of the Vladimir region were identified, the analysis of groups of sustainable exports and sustainable imports in the context of conditional industries and partner countries was carried out. An assessment of the structure of the trade profile of the region is given, a list of high-tech and high-margin goods with stable competitive advantages relative to other regions and countries is revealed. The calculation of the strategic importance of goods was also carried out, which allows us to form the specifics of the trade profile of the region.

The paper tested the methodology for assessing the trade profile of the region using automation tools and the Python programming language. The results are presented in the form of an analytical dashboard with the formation of a system of "hints" on the directions of strategic planning of the foreign economic activity of the region.

The direction of development of tools for foreign policy analysis is recognized as one of the priorities in Russia, therefore, the development of tools for automated analysis and forecast of exports, which are presented in this study, is supported by a grant from the Center for Management Decision-making. Within the framework of this topic, a computer program "Software for creating a rating of promising export goods of the region" has also been developed and registered.

The approach considered in this paper can also be used to build interpreted predictive models of foreign economic activity indicators for data aggregation, as well as as one of the ways to reduce the dimension of the model feature space.

Further development of the work consists in the study of trends in the stability / variability of time series of indicators of export /import of goods. Modeling the dependence of foreign economic activity on various external parameters is also a task for continuing work.

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https://doi.org/10.15405/epms.2024.09.32
Corresponding Author: Said-Magomed Islamovich Musaev
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2421-826X

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