THEORETICAL AND METHODOLOGICAL ISSUES

DOI: 10.15838/esc.2024.6.96.3
UDC 332, LBC 65.9(2)

Interactions of Regional Economies and Multiplicative Effects (Using the Example of a Two-Zone Input-Output Model of Russia)

Victor I. SUSLOV
Institute of Economics and Industrial Engineering, Siberian Branch of the Russian Academy of Sciences
Novosibirsk, Russian Federation
e-mail: suslov@ieie.nsc.ru
ORCID: 0000-0001-7972-9811

Alexandr I. DUSHENIN
Novosibirsk State University
Institute of Economics and Industrial Engineering, Siberian Branch of the Russian Academy of Sciences
Novosibirsk, Russian Federation
e-mail: a.dushenin@g.nsu.ru
ORCID: 0009-0009-7988-6636

Yuri S. ERSHOV
Institute of Economics and Industrial Engineering, Siberian Branch of the Russian Academy of Sciences
Novosibirsk, Russian Federation
e-mail: eryus@mail.ru
ORCID: 0009-0003-8277-6645

Naimdzhon M. IBRAGIMOV
Institute of Economics and Industrial Engineering, Siberian Branch of the Russian Academy of Sciences
Novosibirsk State Technical University
Novosibirsk State University
Novosibirsk, Russian Federation
e-mail: naimdjon@ieie.nsc.ru
ORCID: 0000-0001-8540-5039

For citation: Suslov V.I., Dushenin A.I., Ershov Yu.S., Ibragimov N.M. (2024). Interactions of regional economies and multiplicative effects (using the example of a two-zone input-output model of Russia). *Economic and Social Changes: Facts, Trends, Forecast*, 17(6), 59–76. DOI: 10.15838/esc.2024.6.96.3

Abstract. Currently, the key areas of Siberian economics include analyzing the economy and assessing the prospects of the Asian part of Russia. To achieve the goal, it is necessary to determine the contribution of the Asian part of Russia to the economy of other regions and the country as a whole. The aim of this work is to study the interaction of Russia's European and Asian parts. The input-output tables built in the Institute of Economics and Industrial Engineering, Siberian Branch of the Russian Academy of Sciences for the European and Asian economic zones as of 2019 allow us to assess the effects of regional interaction at the industry level using multiplicative analysis tools. The paper presents calculated regional and interregional coefficients of direct and total costs, as well as balance sheets reflecting the creation and use of products for European and Asian regions. The results of the study indicate that in the structure of direct costs of the European part of Russia, the weight of the Asian part is significant for the production of coke and petroleum products (about 44%), ferrous and non-ferrous metallurgy (about 15%) and other industries. In the structure of the total costs of the European part of Russia, a high proportion of the Asian part is observed for extractive industries, ferrous and non-ferrous metallurgy and oil refining industry, which is partly due to the specifics of recording the results of foreign trade. If we consider the balance of use of products from the Asian part of Russia, we see that 7.5% of the produced product goes to intermediate consumption and 3.0% is sent to meet the final demand of European regions. The results of the work can be used to measure the effects of public financing at the regional and federal levels. Due to the fact that indirect and full costs account for only those product flows that relate to intermediate consumption, it seems advisable in the future to elaborate on the methodology so as to include accounting for investment goods.

Key words: interregional interactions, multi-regional input-output models, European part of Russia, Asian part of Russia, multiplicative effect, direct and indirect costs.

Acknowledgment

The article presents the results of project 5.6.3.2 (FWZF-2024-0001).

Introduction

The knowledge of industry indicators concerning the structure and directions of costs, and the proportions of the use of manufactured products are crucial for conducting any serious analysis of national economy and assessing its development prospects amid the changes in technology, final consumption and foreign economic relations. The most comprehensive picture of the situation regarding Russia's economy as a whole is provided by the input-output tables produced by Rosstat on a regular basis. Designing such tables in the context of territories (regionalization) is currently a task for research teams who use the entire available set of direct and indirect data to this end.

The Institute of Economics and Industrial Engineering, Siberian Branch of the Russian Academy of Sciences (IEIE SB RAS) carries out this work so as to further use the tool of optimization multi-regional input-output models (OMRIOTs), which is actively applied in long-term forecasting of the development of national economy in spatial and sectoral aspects. Currently, the Institute's staff, using this tool, are pursuing the following goals: building long-term macroeconomic forecasts and their sectoral and spatial sections (Ershov, 2012); analyzing and forecasting the development of the fuel and energy complex of the Russian Federation (Suslov, Buzulutskov, 2018); analyzing and forecasting the development of the

Russian forest complex (Blam, Mashkina, 2019); analysing and forecasting the development of the Russian transport complex (Malov, Melentyev, 2022); coalition analysis, search for the core and equilibrium state of the spatial economy of the Russian Federation (Suslov et al., 2021); agent-based modeling (Tsyplakov, 2022); assessment of investment projects (Novikova et al., 2021).

Currently, a set of interrelated models is used to achieve these goals, which primarily includes static and semi-dynamic formulations of OMRIOT. The main purpose of the static model is to estimate exogenous parameters of the base year for subsequent use in the semi-dynamic model, which is the main tool for addressing the tasks listed above.

A static OMRIOT is constructed by spatial expansion of the all-Russian tables of resources and the use of goods and services using direct and indirect regional statistical indicators available in Russian statistics (Ershov et al., 2021). Thus, a static OMRIOT reflects the condition of the country's economic space in the base year. This allows us to explore the possibility of using static OMRIOTs not only to build the foundation of a semi-dynamic model, but also to measure the structure of production and the proportions of distribution of goods and services between industries and regions.

One of the goals of the calculations performed is to assess the effects of interactions between the economies of the European and Asian parts of Russia as of 2019. The relevance of the work is explained by the fact that the development specifics of the Asian part of Russia are among the most important components determining the development of Siberian economics. It is worth noting that the current version of OMRIOT fully corresponds to the research direction. This is reflected by the spatial context of the economy at the model level, namely: federal districts with the division of the Ural Federal District into two components – the Tyumen Region and the rest of the territory. We define the Tyumen Region, the Siberian and Far Eastern federal districts as the Asian part of the country (Asia), and all other regions as the European part (Europe).

The results of the work allow us to obtain quantitative estimates of the features of economic interaction between these two macro zones, and the degree of their interdependence. In the future, it is planned to conduct a retrospective analysis of the interaction of the regions, which will allow us to identify and explain the changes that have taken place.

Literature review

Foreign experience

An important step toward measuring the effects of interregional interactions is to assess input-output tables for regions. When solving this problem, economists tend to think within the framework of two paradigms (Oosterhaven, Hewings, 2014). The first paradigm is based on the construction of a single input-output table for all regions, which comprehensively reflects the interregional flows of intermediate products. In this case, an interregional input-output model is obtained, in which the balance of production and distribution of products in region *r* looks as follows:

$$X^r = \sum_{s=1}^{R} A^{rs} X^s + Y^r, r = \overline{1,m},$$

where A^{rs} – interregional direct cost coefficients, X^r, Y^r – regional output and end-use volumes, respectively (in a broad sense, including the balance of exports and imports, gross fixed capital formation, and reserves growth).

With this formulation of the model, it becomes necessary to estimate regional and interregional input coefficients. The most preferred approaches are based on the adjustment of national coefficients using regional indicators that are able to reflect information about the regions' "demand" for goods and services. To understand the general logic, let us consider location quotients, reflecting the specialization of a region in relation to the country.

If the value of the location quotient for region *r* is greater than one, then region *r* is more specialized than the country and can meet its own demand at its own expense. Otherwise, region *r* needs supplies from other regions. Therefore, the proportions of the spatial distribution of production in the region can be described as follows

$$a_{ij}^{rr} = \begin{cases} LQ_i^r a_{ij}^n, & if \quad LQ_i^r < 1 \\ a_{ij}^n, & if \quad LQ_i^r > 1 \end{cases}$$

$$a_{ij}^{sr} = \begin{cases} (1 - LQ_i^r) a_{ij}^n, & if \quad LQ_i^r < 1 \\ 0, & if \quad LQ_i^r > 1, \end{cases}$$

where a_{ij}^n – direct input coefficients in the country as a whole.

There are many variations of location quotients, but one of the most popular is an indicator proposed by A. Flegg (Flegg, Webber, 2000):

$$FLQ_{ij}^r = \lambda^r \left(\frac{x_i^r / x_i^n}{x_j^r / x_j^n} \right)$$

$$\lambda^r = \left(\log_2 \left[\left(1 + \frac{\sum_i x_i^r}{\sum_i x_i^n} \right) \right] \right)^{\delta}, \delta \in [0; 1],$$

where x_i^r – regional output in *i*-industry,

x_i^n – corresponding indicator for the country as a whole.

His methodology is often used in the development of regional tables and models in countries such as South Korea (Flegg, Tohmo, 2013), Spain (Azorín et al., 2022), Sweden (Kronenberg, Fuchs, 2021), Japan (Fujimoto, 2018), Finland (Flegg, Tohmo, 2013), Ireland (Morrissey, 2016) and others. The relevance of this approach is characterized by the activity of research on its modification (Pereira-López et al., 2020; Pereira-López et al., 2021), including works that use machine learning and deep learning algorithms (Fukui, 2023).

In addition to location quotients, there is a group of methods that similarly determine spatial contributions by adjusting national coefficients. These include Regional Purchase Coefficients (Lahr et al., 2020), Regional Supply Percentages (Jackson, Járosi, 2020), and Commodity Balance (Round, 1972). The presented methods are actively used in many countries, such as the UK, Finland, USA, Indonesia, etc.

A limitation of the presented approaches lies in the possibility of using them only for the economy represented in the context of two regions. In the case of a multi-regional economy, these methods are able to quantify how much a region produces independently (a_{ij}^{rr}) and how much other regions produce for it (a_{ij}^{sr}). The influence of one region on other regions (a_{ij}^{rs}) cannot be determined by the presented approaches.

The second paradigm is to create separate tables for each region, after which it becomes necessary to calculate trade flows between regions. In this case, a multiregional input-output model is obtained, the balance of production and distribution of which is as follows[1]:

$$X^r = A^r X^r + Y^r + \sum_{s \neq r} (X^{rs} - X^{sr}), r = \overline{1, m},$$

where X^{rs}, X^{sr} – regional export and import volumes.

When applying this approach, an important step is to evaluate the "aggregate" coefficients of direct costs of the regions (technical coefficients). The difference between the coefficients of A^{rr} and A^r matrices is that the former characterizes the direct costs of this particular region, excluding products from other regions (interregional direct cost coefficients) and imported products (import coefficients), i.e.:

$$A^r = A^{rr} + \sum_{s \neq r} A^{sr} + A^{rIm}.$$

The simplest way to assess these indicators is to equate them with national direct cost coefficients. For example, this approach was used in the USA (Isard, Keunne, 1953). However, many authors identify the need to adjust national coefficients for interregional price differences (Richardson, 1972) and industry aggregation (Shen, 1960).

[1] OMRIOT is a multiregional model.

If the total values of intermediate consumption by rows and columns are known, it is possible to use the RAS method (Stone, 1961), which is an iterative procedure for bi-proportional fitting of quadrants by rows and columns. For each product, the relative disparities by rows are calculated as follows:

$$r_i = \frac{x_{ij}^r}{\sum_j x_{ij}^r},$$

after which the values of change proportionally along the rows. Next, a similar procedure is performed for the columns:

$$c_j = \frac{x_{ij}^r}{\sum_i x_{ij}^r}.$$

As a result of several iterations, the values of regional intermediate consumption and, consequently, the values of regional technological coefficients a_{ij}^r are estimated. Moreover, there are several RAS modifications (for example, CRAS, GRAS) that are used to regionalize input-output tables in the Czech Republic (Holý, Šafr, 2023), the Netherlands (Junius, Oosterhaven, 2003; Mínguez, 2009), Taiwan (Liu et al., 2013), the United Kingdom (Wiedmann et. al., 2011), Japan (Gabela, 2020) and many other countries. It is worth noting that the RAS method can also be used to update the first quadrant of input-output tables, both national and regional (Oosterhaven, 1980).

There is a group of entropy methods that represent a mathematical programming problem, where weighted cross-entropy acts as the target functional (Lamonica et al., 2020):

$$\begin{cases} H = \sum_i \frac{x_j^r}{\sum_j x_j^r} \sum_j a_{ij}^r log_2(\frac{a_{ij}^r}{a_{ij}^n}) \rightarrow min_{a_{ij}^r} \\ \sum_j a_{ij}^r x_j^r = x_i^r \\ \sum_i a_{ij}^r = \gamma_j, \end{cases}$$

where a_{ij}^r, a_{ij}^n – direct cost coefficients of region *r* and country, respectively;

x_i^r – output of industry *i* of region *r*;

γ_j – proportion of intermediate consumption in the output of industry *j*.

The essence of entropy methods is similar to the RAS procedure, which consists in the adjustment to known total values in rows and columns with minimal changes in the table structure.

The method of gravity models is quite popular for estimating regional export/import values. In the framework of this approach, the degree of interregional interactions can be characterized by the distance between regions (the smaller the distance, the stronger the interaction). This methodology is used in China (Mi et al., 2018), Brazil (Siroen et al., 2014), Iran (Tarahomi, Bazzazan, 2021), Japan (Greaney, Kiyota, 2020) and other countries.

If in interregional models the proportions of the regional product distribution are set exogenously (coefficients a_{ij}^{rr} and a_{ij}^{sr}), then in the case of multiregional models the corresponding indicators must be measured using calculated values of technological coefficients and interregional trade. The Moses – Chenery approach (Zhuoying, 2002) can be applied to this end. This method is used in this article; thus, its detailed description is given in the next section.

Russian experience

Russian practice has an experience of compiling regional tables, but their development was carried out in a different economic system and based on the methodology of the balance of national economy (BNE). So, for 1959, 1966, 1972, 1977, 1982 and 1987, input-output tables were constructed for all the union republics of the USSR. However, after the transition to the SNA, statistics authorities no longer assess regional tables.

After the collapse of the USSR, work on the creation of regional input-output tables intensified in the 2000s. Thus, regional balances were

constructed for the republics of Bashkortostan (Sayapova, 2004) and Buryatia (Dondokov et al., 2014), for the Far Eastern Federal District (Mikheeva, 2005), and for the system of federal districts of the Russian Federation as a whole (Zaitseva, 2002; Ershov et al., 2021).

If we talk about the key parameters of the regional tables, then to calculate the values of intermediate consumption, the structure of the all-Russian table was used as an initial approximation, after which the RAS procedure for balancing was performed. The import-export values were determined both by collecting information on interregional flows from enterprises, and by applying the basic equation of input-output balance and further correcting inconsistencies.

Research methodology

To achieve the set goal, it is proposed to modify the basic formulation of the Moses – Chenery model by considering "economic" industries (matrix K) and highlighting imports (column vector M). Mathematically, this can be described by the following matrix equation:

$$KX + M = GAX + GY,$$

where X and Y – column vectors (compositions of vectors X^r, Y^r respectively) of dimension $(m \times n)$; A – quasi-diagonal matrix of dimension $(m \times n) \times (m \times n)$, the diagonal blocks of which are regional matrices of direct cost coefficients A^r; G – trading coefficients matrix of dimension $(m \times n) \times (m \times n)$, consisting of m^2 diagonal blocks (Dushenin et al., 2023).

Trading coefficient g_i^{rs} determines the share of region r in the internal use of the products of the i-th industry of region s. The internal use of region s is understood as the use (output plus import) minus the export-import balance of a given region S_i^s:

$$g_i^{rs} = \frac{x_i^{rs}}{x_i^s + m_i^s - S_i^s}.$$

For the economies of two regions (Europe and Asia), the block matrix model looks like this:

$$\begin{pmatrix} K^{\mathrm{E}} & 0 \\ 0 & K^{\mathrm{A}} \end{pmatrix} \begin{pmatrix} X^{\mathrm{E}} \\ X^{A} \end{pmatrix} + \begin{pmatrix} M^{\mathrm{E}} \\ M^{A} \end{pmatrix} =$$

$$= \begin{pmatrix} G^{\mathrm{EE}} & G^{\mathrm{EA}} \\ G^{\mathrm{AE}} & G^{\mathrm{AA}} \end{pmatrix} \begin{pmatrix} A^{\mathrm{E}} & 0 \\ 0 & A^{\mathrm{A}} \end{pmatrix} \begin{pmatrix} X^{\mathrm{E}} \\ X^{A} \end{pmatrix} + \begin{pmatrix} G^{\mathrm{EE}} & G^{\mathrm{EA}} \\ G^{\mathrm{AE}} & G^{\mathrm{AA}} \end{pmatrix} \begin{pmatrix} Y^{\mathrm{E}} \\ Y^{A} \end{pmatrix}.$$

From the constructed Moses – Chenery model, it is easy to distinguish the matrices of spatial multipliers of direct and total costs Q and B, respectively, each of which includes four blocks:

$$Q = \begin{pmatrix} Q^{\mathrm{EE}} & Q^{\mathrm{EA}} \\ Q^{\mathrm{AE}} & Q^{\mathrm{AA}} \end{pmatrix} = GA,$$

$$B = \begin{pmatrix} B^{\mathrm{EE}} & B^{\mathrm{EA}} \\ B^{\mathrm{AE}} & B^{\mathrm{AA}} \end{pmatrix} = (K - Q)^{-1} G.$$

The degree of interdependence and complementarity of the regions can be viewed from several angles. First, by the balance of use of products:

$$K^{\mathrm{E}} X^{\mathrm{E}} + M^{\mathrm{E}} = Q^{\mathrm{EE}} X^{\mathrm{E}} + Q^{\mathrm{EA}} X^{\mathrm{A}} + G^{\mathrm{EE}} Y^{\mathrm{E}} + G^{\mathrm{EA}} Y^{\mathrm{A}},$$
$$K^{\mathrm{A}} X^{\mathrm{A}} + M^{\mathrm{A}} = Q^{\mathrm{AE}} X^{\mathrm{E}} + Q^{\mathrm{AA}} X^{\mathrm{A}} + G^{\mathrm{AE}} Y^{\mathrm{E}} + G^{\mathrm{AA}} Y^{\mathrm{A}}.$$

In fact, this means that each region allocates its resources to its own intermediate and final consumption, as well as to the intermediate and final consumption of another region. This allows determining the "generosity" of the European and Asian parts of the Russian Federation.

Second, through the balance of product creation[2]:

$$X^{\mathrm{E}} + M^{\mathrm{E}} = Q^{\mathrm{EE}} X^{\mathrm{E}} + Q^{\mathrm{AE}} X^{\mathrm{E}} + GVA^{\mathrm{E}} + M^{\mathrm{E}},$$
$$X^{\mathrm{A}} + M^{\mathrm{A}} = Q^{\mathrm{EA}} X^{\mathrm{A}} + Q^{\mathrm{AA}} X^{\mathrm{A}} + GVA^{\mathrm{A}} + M^{\mathrm{A}}.$$

In fact, this means that the resources of each region include production costs of all regions, production activities income (GVA), and imports. This will determine the "importance" of the European and Asian parts of the Russian Federation.

[2] *GVA* – gross value added.

Table 1. Trading coefficients as of 2019

Industry	Europe (*r*)		Asia (*r*)	
	Europe (*s*) G^{EE}	Asia (*s*) G^{EA}	Europe (*s*) G^{AE}	Asia (*s*) G^{AA}
Agricultural industry	0.994	0.000	0.006	1.000
Forestry and logging	0.812	0.000	0.188	1.000
Fish farming and fishing	0.520	0.000	0.480	1.000
Coal mining	0.116	0.000	0.884	1.000
Oil production	0.594	0.000	0.406	1.000
Gas production	0.265	0.000	0.735	1.000
Extraction of ferrous metal ores	1.000	0.322	0.000	0.678
Extraction of non-ferrous metal ores	0.557	0.000	0.443	1.000
Extraction of other minerals	0.772	0.000	0.228	1.000
Food industry	1.000	0.304	0.000	0.696
Light industry	1.000	0.253	0.000	0.747
Woodworking	0.999	0.000	0.001	1.000
Pulp and paper industry	1.000	0.221	0.000	0.779
Printing and copying	1.000	0.548	0.000	0.452
Coke production	0.936	0.000	0.064	1.000
Production of petroleum products	0.992	0.000	0.008	1.000
Chemical industry	1.000	0.237	0.000	0.763
Other non-metallic mineral products	1.000	0.468	0.000	0.532
Ferrous metals	1.000	0.435	0.000	0.565
Non-ferrous metals	0.728	0.000	0.272	1.000
Production of finished metal products	1.000	0.580	0.000	0.420
Mechanical engineering	1.000	0.277	0.000	0.723
Other productions	1.000	0.018	0.000	0.982
Electricity generation and distribution	0.852	0.000	0.148	1.000
Source: own calculations.				

Calculation results

Table 1 shows the values of trading coefficients for the European and Asian parts of the Russian Federation. As we see, the Asian part of Russia supplies itself with almost all types of minerals, which is confirmed by the single values of g^{AA} coefficients and zero values of g^{EA} coefficients for the respective industries. In addition, for many types of extractive products, the contributions of this region to the European part of Russia are so significant that they approach unity (values of coefficients g^{AE}). In fact, this situation means that the Asian part of Russia is characterized by excessive output of raw materials and Asia is the only supplier of raw materials.

Essentially, the reason for such resource dependence lies in regional specialization due to geographical location. However, it is important to consider the directions of using the resources of the East. For example, Asia's high contributions of oil and gas products to Europe are related to the specifics of registering the results of foreign trade activities (the main part of oil and gas exports belongs to the Central Federal District – Moscow). In addition, it is necessary to point out the refining and petrochemical specialization of the European part of Russia.

Table 2. Spatial multipliers of direct costs as of 2019

Industry	Europe (*s*)		Asia (*s*)	
	Europe (*r*) Q^{EE}	Asia (*r*) Q^{EA}	Europe (*r*) Q^{AE}	Asia (*r*) Q^{AA}
Agricultural industry	0.484	0.004	0.041	0.444
Forestry and logging	0.479	0.022	0.026	0.502
Fish farming and fishing	0.388	0.013	0.029	0.376
Coal mining	0.474	0.077	0.025	0.515
Oil production	0.107	0.013	0.004	0.103
Gas production	0.166	0.008	0.003	0.081
Extraction of ferrous metal ores	0.322	0.054	0.017	0.366
Extraction of non-ferrous metal ores	0.402	0.068	0.022	0.445
Extraction of other minerals	0.282	0.047	0.015	0.319
Food industry	0.708	0.010	0.071	0.657
Light industry	0.633	0.003	0.097	0.574
Woodworking	0.593	0.035	0.038	0.650
Pulp and paper industry	0.596	0.015	0.067	0.589
Printing and copying	0.665	0.003	0.138	0.569
Coke production	0.543	0.238	0.010	0.788
Production of petroleum products	0.493	0.215	0.009	0.709
Chemical industry	0.646	0.012	0.089	0.582
Other non-metallic mineral products	0.621	0.044	0.117	0.534
Ferrous metals	0.635	0.094	0.092	0.643
Non-ferrous metals	0.449	0.067	0.066	0.459
Production of finished metal products	0.647	0.032	0.151	0.561
Mechanical engineering	0.701	0.013	0.157	0.569
Other productions	0.595	0.017	0.101	0.535
Electricity generation and distribution	0.629	0.085	0.011	0.655
Gas production and distribution	0.569	0.078	0.010	0.596
Production and distribution of thermal energy	0.648	0.088	0.011	0.685
Water supply, waste collection and disposal	0.589	0.030	0.062	0.560
Construction	0.551	0.014	0.115	0.455
Trade and repair of ATSiM	0.412	0.007	0.011	0.423
Land transport	0.472	0.009	0.015	0.468
Pipeline transport	0.580	0.012	0.019	0.555
Other transport	0.586	0.003	0.015	0.528
Hotels and catering	0.557	0.007	0.066	0.494
Information and communication	0.488	0.001	0.019	0.474
Financial and insurance activities	0.308	0.000	0.004	0.306
Real estate transactions	0.233	0.003	0.010	0.226
Professional, scientific, and technical activities	0.428	0.002	0.031	0.406
Administrative activities and related services	0.264	0.001	0.012	0.250
Public administration	0.369	0.002	0.013	0.352
Education	0.209	0.004	0.009	0.199
Healthcare	0.363	0.003	0.037	0.331
Culture, sports, leisure, entertainment	0.410	0.004	0.019	0.394
Other types of services	0.407	0.002	0.027	0.382
Activities of households	0.000	0.000	0.000	0.000
Source: own calculations.				

However, one should not conclude that the resource potential of this region plays a crucial role in the economic development of the entire system, since the high values of g^{BE} coefficients for minerals characterize only their absence in Europe (this may extend to other industries in other regions). More informative results were obtained at the end of the study when the structures of creation and use of a regional product were analyzed.

Table 2 shows the spatial multipliers of direct costs (amounts by columns). Let us interpret the results obtained using the example of the "Oil production" industry for the European part of Russia: if the demand for the output of the corresponding industry for Europe increases by 1 ruble, then intermediate consumption in the European part of the Russian Federation will increase by 0.107 rubles (regional multiplier), in the Asian part of the Russian Federation – by 0.013 rubles (interregional multiplier), in the Russian Federation in total – by 0.120 rubles (national multiplier).

Analyzing the spatial multipliers of direct material costs, one can notice a high share of the Asian part of Russia in the structure of direct costs of the European part for the industries "Coke production" and "Production of petroleum products". This is due to Europe's specialization in the sectors whose production requires raw materials resources, which Asia possesses. We also point out a high share of Europe in the structure of direct costs in Asia for industries such as "Light industry", "Chemical industry", and others.

Table 3 shows the spatial multipliers of total costs (amounts by columns). Let us interpret the results obtained using the example of the "Oil production" industry for the European part of Russia: if the demand for final consumption of products of the corresponding industry for Europe increases by 1 ruble, then material costs in the European part of the Russian Federation will increase by 0.701 rubles (regional multiplier), in the Asian part of the Russian Federation – by 0.477 rubles (interregional multiplier), in total in the Russian Federation – by 1.178 rubles (national multiplier).

Table 3. Spatial multipliers of total costs as of 2019

Industry	Europe (*s*)		Asia (*s*)	
	Europe (*r*) B^{EE}	Asia (*r*) B^{EA}	Europe (*r*) B^{AE}	Asia (*r*) B^{AA}
Agricultural industry	1.943	0.056	0.180	1.830
Forestry and logging	1.594	0.469	0.145	1.975
Fish farming and fishing	0.679	0.770	0.061	1.500
Coal mining	0.334	1.682	0.132	1.879
Oil production	0.701	0.477	0.021	1.154
Gas production	0.362	0.850	0.017	1.143
Extraction of ferrous metal ores	1.600	0.109	0.584	1.130
Extraction of non-ferrous metal ores	0.980	0.869	0.113	1.751
Extraction of other minerals	1.075	0.413	0.067	1.476
Food industry	2.492	0.061	0.983	1.634
Light industry	2.367	0.046	0.876	1.624

End of Table 3

Industry	Europe (*s*)		Asia (*s*)	
	Europe (*r*) B^{EE}	Asia (*r*) B^{EA}	Europe (*r*) B^{AE}	Asia (*r*) B^{AA}
Woodworking	2.224	0.138	0.198	2.293
Pulp and paper industry	2.281	0.095	0.732	1.722
Printing and copying	2.462	0.059	1.582	0.980
Coke production	1.613	0.570	0.001	2.213
Production of petroleum products	1.738	0.381	0.053	2.103
Chemical industry	2.402	0.116	0.849	1.717
Other non-metallic mineral products	2.311	0.152	1.291	1.151
Ferrous metals	2.352	0.270	1.233	1.398
Non-ferrous metals	1.467	0.654	0.253	1.883
Production of finished metal products	2.420	0.167	1.629	0.994
Mechanical engineering	2.688	0.108	1.212	1.618
Other productions	2.324	0.098	0.448	2.039
Electricity generation and distribution	1.958	0.551	0.091	2.266
Gas production and distribution	2.219	0.291	0.001	2.283
Production and distribution of thermal energy	2.333	0.268	0.087	2.348
Water supply, waste collection and disposal	2.244	0.154	0.265	2.129
Construction	2.177	0.093	0.396	1.896
Trade and repair of ATSiM	1.761	0.027	0.075	1.735
Land transport	1.895	0.078	0.098	1.862
Pipeline transport	2.104	0.096	0.118	2.023
Other transport	2.190	0.082	0.101	2.027
Hotels and catering	2.135	0.045	0.252	1.929
Information and communication	1.946	0.024	0.123	1.855
Financial and insurance activities	1.513	0.009	0.034	1.489
Real estate transactions	1.431	0.028	0.056	1.393
Professional, scientific, and technical activities	1.790	0.021	0.133	1.707
Administrative activities and related services	1.497	0.023	0.063	1.437
Public administration	1.742	0.034	0.097	1.657
Education	1.415	0.029	0.058	1.373
Healthcare	1.765	0.039	0.174	1.641
Culture, sports, leisure, entertainment	1.786	0.038	0.113	1.705
Other types of services	1.771	0.028	0.131	1.666
Activities of households	1.000	0.000	0.000	1.000

Source: own calculations.

If we analyze the structures of direct and total costs of the European part of Russia for the "Oil production" industry, we can see a high share of Asia in the total costs of Europe and a low share in direct costs. This is due to the fact that most of the oil is exported (given the specifics of registering foreign trade results, such values of the multipliers are quite logical).

Tables 4 and 5 show the product use balances for the European and Asian parts of the Russian Federation, respectively. We interpret the results obtained using the example of the economy of the European part of the Russian Federation as a whole: out of 100% of the products produced and imported by Europe, 42.8 and 55.4% are spent within the region on intermediate and final consumption, while 0.8 and 0.9% go to meet the corresponding needs of the Asian part.

Considering the balance of the Asian part, we see that this economic zone sends about 10.5% of the produced product to Europe. This is due to the high level of the raw material base, which is demonstrated by the importance of Asia's interregional influence in the relevant industries. If we talk about the contribution of the European part, it is most significant for the industries such as "Printing and copying", "Other mineral non-metallic products" and "Production of finished metal products".

Table 4. Balance of use of goods and services in the European part of the Russian Federation as of 2019, %

Industry	IC for Europe	IC for Asia	FC for Europe	FC for Asia
Agricultural industry	62.6	0.0	37.4	0.0
Forestry and logging	66.0	0.0	34.0	0.0
Fish farming and fishing	61.2	0.0	38.8	0.0
Coal mining	88.8	0.0	11.2	0.0
Oil production	66.1	0.0	33.9	0.0
Gas production	77.4	0.0	22.6	0.0
Extraction of ferrous metal ores	25.7	3.4	67.4	3.5
Extraction of non-ferrous metal ores	50.8	0.0	49.2	0.0
Extraction of other minerals	68.2	0.0	31.8	0.0
Food industry	24.3	1.2	69.9	4.6
Light industry	21.0	0.8	74.2	4.0
Woodworking	44.2	0.0	55.8	0.0
Pulp and paper industry	60.9	2.1	35.8	1.3
Printing and copying	89.2	9.0	1.6	0.2
Coke production	65.8	0.0	34.2	0.0
Production of petroleum products	49.5	0.0	50.5	0.0
Chemical industry	56.8	2.6	39.2	1.4
Other non-metallic mineral products	77.7	10.5	10.8	1.0
Ferrous metals	53.3	5.6	38.6	2.5
Non-ferrous metals	68.8	0.0	31.2	0.0
Production of finished metal products	59.2	8.0	29.0	3.7
Mechanical engineering	38.8	2.2	54.3	4.7
Other productions	47.9	0.3	51.6	0.3
Electricity generation and distribution	62.6	0.0	37.4	0.0
ECONOMY AS A WHOLE	**42.8**	**0.8**	**55.4**	**0.9**

Source: own calculations.

Table 5. Balance of use of goods and services in the Asian part of the Russian Federation as of 2019, %

Industry	IC for Europe	IC for Asia	FC for Europe	FC for Asia
Agricultural industry	2.0	50.5	1.2	46.3
Forestry and logging	23.1	35.3	11.9	29.7
Fish farming and fishing	26.5	11.1	16.7	45.7
Coal mining	33.0	15.3	4.2	47.6
Oil production	18.9	19.1	9.7	52.3
Gas production	19.9	11.1	5.8	63.2
Extraction of ferrous metal ores	0.0	49.0	0.0	51.0
Extraction of non-ferrous metal ores	9.8	9.1	9.5	71.5
Extraction of other minerals	18.9	34.0	8.8	38.3
Food industry	0.0	21.1	0.0	78.9
Light industry	0.0	17.4	0.0	82.6
Woodworking	0.1	45.4	0.1	54.4
Pulp and paper industry	0.0	62.1	0.0	37.9
Printing and copying	0.0	97.8	0.0	2.2
Coke production	9.8	49.3	5.1	35.9
Production of petroleum products	1.3	48.6	1.3	48.8
Chemical industry	0.0	64.4	0.0	35.6
Other non-metallic mineral products	0.0	91.6	0.0	8.4
Ferrous metals	0.0	68.9	0.0	31.1
Non-ferrous metals	26.9	23.8	12.2	37.0
Production of finished metal products	0.0	68.2	0.0	31.8
Mechanical engineering	0.0	32.2	0.0	67.8
Other productions	0.0	50.3	0.0	49.7
Electricity generation and distribution	2.0	50.5	1.2	46.3
ECONOMY AS A WHOLE	**7.5**	**35.2**	**3.0**	**54.3**
Source: own calculations.				

Tables 6 and 7 show the balances of products creation for the European and Asian parts of the Russian Federation, respectively. Let us interpret the results obtained using the example of the economy of the European part of the Russian Federation as a whole: if we consider the manufactured and imported product together, then 100% of its value includes 42.1 and 2.3% of the material costs of Europe and Asia, respectively, 45.8% of gross value added and 9.8% of imports.

The contribution of the Asian part of the Russian Federation to the European one is quite high in the structure of use; however, the share of costs incurred by Asia for Europe in the structure of product creation is much lower, which is comparable with the proportions of production in the corresponding economic zones. Significant contributions from the Asian part of the Russian Federation are observed for the oil refining industry, metallurgy and energy. Significant contributions from the European part of the Russian Federation are typical for the industries such as "Printing and copying", "Construction", "Other mineral non-metallic products", "Production of finished metal products", etc.

The first calculations based on the two-zone model of the input-output balance were carried out at IEIE SB RAS more than 30 years ago. But then there was another object of research – the country

Table 6. Balance of creation of goods and services in the European part of the Russian Federation as of 2019, %

Industry	MP from Europe	MP from Asia	GVA	Imports
Agricultural industry	42.0	0.3	47.1	10.6
Forestry and logging	45.1	2.0	51.7	1.1
Fish farming and fishing	33.0	1.1	52.5	13.3
Coal mining	36.5	5.9	34.6	23.1
Oil production	10.4	1.3	85.1	3.3
Gas production	12.1	0.6	59.8	27.5
Extraction of ferrous metal ores	30.9	5.2	59.8	4.1
Extraction of non-ferrous metal ores	34.3	5.7	45.2	14.8
Extraction of other minerals	27.6	4.6	65.8	2.0
Food industry	63.1	0.9	23.4	12.5
Light industry	22.4	0.1	13.6	63.9
Woodworking	55.3	3.3	35.2	6.2
Pulp and paper industry	51.0	1.3	30.2	17.5
Printing and copying	65.0	0.3	33.0	1.7
Coke production	53.5	23.4	21.5	1.6
Production of petroleum products	48.1	20.9	28.4	2.6
Chemical industry	43.1	0.8	22.6	33.5
Other non-metallic mineral products	55.6	4.0	30.5	9.9
Ferrous metals	59.3	8.7	25.3	6.7
Non-ferrous metals	40.5	6.0	43.6	9.9
Production of finished metal products	54.8	2.7	26.7	15.8
Mechanical engineering	38.1	0.7	16.8	44.4
Other productions	45.8	1.3	31.6	21.3
Electricity generation and distribution	62.8	8.5	28.6	0.1
Gas production and distribution	56.9	7.8	35.3	0.0
Production and distribution of thermal energy	64.7	8.7	26.5	0.1
Water supply, waste collection and disposal	63.9	3.2	30.5	2.4
Construction	53.2	1.4	42.7	2.8
Trade and repair of ATSiM	41.4	0.7	57.9	0.0
Land transport	46.5	0.9	51.2	1.4
Pipeline transport	57.3	1.1	40.3	1.3
Other transport	55.0	0.3	38.5	6.2
Hotels and catering	55.2	0.7	43.2	1.0
Information and communication	44.1	0.1	46.2	9.6
Financial and insurance activities	30.0	0.0	67.2	2.8
Real estate transactions	23.2	0.3	76.2	0.2
Professional, scientific, and technical activities	39.4	0.2	52.6	7.9
Administrative activities and related services	21.2	0.1	58.9	19.8
Public administration	29.3	0.2	70.5	0.0
Education	20.1	0.4	78.1	1.4
Healthcare	32.4	0.2	67.2	0.1
Culture, sports, leisure, entertainment	40.8	0.4	58.4	0.4
Other types of services	40.4	0.2	58.9	0.5
Activities of households	0.0	0.0	100.0	0.0
ECONOMY AS A WHOLE	**42.1**	**2.3**	**45.8**	**9.8**

Source: own calculations.

Table 7. Balance of creation of goods and services in the Asian part of the Russian Federation as of 2019, %

Industry	MP from Europe	MP from Asia	GVA	Imports
Agricultural industry	3.6	38.8	47.6	10.0
Forestry and logging	2.4	47.6	49.4	0.5
Fish farming and fishing	2.8	36.5	59.5	1.3
Coal mining	2.4	51.0	45.6	1.0
Oil production	0.4	10.2	88.2	1.2
Gas production	0.3	8.1	91.4	0.2
Extraction of ferrous metal ores	1.7	35.6	59.8	2.8
Extraction of non-ferrous metal ores	2.1	43.1	51.7	3.0
Extraction of other minerals	1.5	31.7	66.2	0.5
Food industry	5.7	53.7	20.6	19.9
Light industry	0.7	4.1	2.5	92.8
Woodworking	3.5	60.8	29.4	6.3
Pulp and paper industry	5.1	46.5	24.1	24.2
Printing and copying	13.0	54.9	28.6	3.6
Coke production	1.0	77.9	20.0	1.1
Production of petroleum products	0.8	69.1	27.5	2.6
Chemical industry	4.1	27.5	15.3	53.1
Other non-metallic mineral products	9.1	41.7	27.7	21.6
Ferrous metals	7.9	55.8	23.0	13.2
Non-ferrous metals	6.2	43.8	45.3	4.7
Production of finished metal products	7.7	28.8	14.5	49.1
Mechanical engineering	4.5	16.6	8.6	70.3
Other productions	7.5	40.1	28.9	23.4
Electricity generation and distribution	1.1	65.4	33.4	0.1
Gas production and distribution	1.0	59.6	39.3	0.2
Production and distribution of thermal energy	1.1	68.5	30.4	0.1
Water supply, waste collection and disposal	6.6	59.6	29.4	4.4
Construction	11.0	43.9	42.1	3.0
Trade and repair of ATSiM	1.1	42.7	56.2	0.0
Land transport	1.5	46.5	51.2	0.9
Pipeline transport	1.8	55.1	42.3	0.8
Other transport	1.4	49.0	42.2	7.4
Hotels and catering	6.5	49.0	43.6	1.0
Information and communication	1.6	40.2	42.9	15.2
Financial and insurance activities	0.4	29.0	65.5	5.1
Real estate transactions	0.9	22.5	76.2	0.3
Professional, scientific, and technical activities	2.7	35.1	48.7	13.5
Administrative activities and related services	1.0	20.2	59.5	19.3
Public administration	1.0	28.0	71.0	0.0
Education	0.9	19.3	78.8	1.0
Healthcare	3.3	29.6	67.1	0.1
Culture, sports, leisure, entertainment	1.9	39.3	58.4	0.5
Other types of services	2.6	38.0	58.7	0.7
Activities of households	0.0	0.0	100.0	0.0
ECONOMY AS A WHOLE	2.7	34.5	54.5	8.3
Source: own calculations.				

in the context of "the RSFSR – the rest of the USSR". The composition of the economy reflected in the input-output tables was also different: only the branches of the manufacturing sector were represented; as for intangible services, whose share in the economy is currently quite large and continues to grow, there was not even such a thing as gross output. The industry classifier was also more aggregated. In this regard, the performed research has obvious signs of novelty according to the mentioned criteria.

Conclusion

The quantitative estimates of the interaction between the European and Asian parts of the Russian Federation presented in this paper show that the contribution of Asian regions is most significant for the products of mining industries.

Due to the fact that the indirect and full costs consider only those product flows that relate to intermediate consumption, it seems advisable in the future to develop the methodology in the direction of accounting for investment goods. In addition, in the future, it is planned to attempt to build regional tables of the use of domestic and imported goods for more detailed accounting of intermediate import costs and a deeper assessment of the impact of foreign trade on the economy of the regions.

The problem of disaggregating the classifier of economic activities remains relevant, since the aggregated representation of industries in input-output tables contains an implicit hypothesis about the complete interchangeability of all products included in one industry. Calculations based on more detailed tables will allow us to obtain more reliable indicators of interregional interactions, and the degree of interdependence of the economies of the macro regions should increase. These calculations can be carried out after the Rosstat's promised publication of detailed tables for 2021.

Such tables will make it possible to make the transition from a two-zone analysis of the economy to a multi-regional one at a higher level. In addition, the problem of interregional "supplies" of services provided by economic entities of one region to consumers of other regions seems to be relevant. Including them in the number of products involved in interregional exchange will help to carry out a more complete analysis of the specifics of interregional relations. When making calculations using a multi-regional model, we find it most relevant for assessing the role of the Central Federal District as the main provider of financial, information and trade services for enterprises and the population of other districts.

The calculations performed allow us to state that the relationship between the two macro zones has the following specifics: the development of the Asian part of the country has a greater positive impact on the economy of the European part of the Russian Federation than the development of the European part on the Asian economy, since the range of goods produced in the European part of the Russian Federation is much wider than in the Asian part, especially investment goods, in particular machinery and equipment. Therefore, investments in the Asian part and the growth of production here will have a significant indirect impact on the economy of the European part. This kind of effect will be even more significant when it is included in the interregional model of "supply" of services, for many of which Europe clearly dominates and actually serves a significant part of their market in Asia. The further disaggregation of the classifier of activities presented at the model level will make it possible to obtain more accurate quantitative estimates of the interaction features of the two macro zones.

References

Azorín J., Alpañez R., Sánchez-de-la-Vega M. (2022). A new proposal to model regional input–output structures using location quotients: An application to Korean and Spanish regions. *Regional Science*, 101(5), 1219–1237. DOI: https://doi.org/10.1111/pirs.12692

Blam Y.Sh., Mashkina L.V. (2019). Problems and prospects for the development of the forestry and logging industry. *Vserossiiskii ekonomicheskii zhurnal EKO=All-Russian Economic Journal ECO*, 11, 45–62 (in Russian).

Dondokov Z.B.-D. et al. (2014). Input-output analysis of the economy of the Republic of Buryatia based on input-output tables. *Regional'naya ekonomika: teoriya i praktika=Regional Economics: Theory and Practice*, 28(355), 55–62 (in Russian).

Dushenin A.I., Ibragimov N.M., Ershov Y.S. (2023). Multipliers in the analysis of interregional interactions. *Journal of Siberian Federal University. Humanities & Social Sciences*, 16(9), 1630–1643.

Ershov Iu.S. (2012). Spatial aspect of the Russian Economy and prospects of its development: Before and after the crisis. *Regional Research of Russia*, 2(1), 1–11.

Ershov Iu.S., Ibragimov N.M., Dushenin A.I. (2021). Input-output table regionalization and multiregional input-output model development algorithm. *Journal of Siberian Federal University. Humanities & Social Sciences,* 14(7), 1018–1027.

Flegg A., Tohmo T. (2013). Estimating regional input coefficients and multipliers: The use of the FLQ is not a gamble. *Regional Studies*, 50(2).

Flegg A., Webber C. (2000). Regional size, regional specialization and the FLQ formula. *Regional Studies*, 34, 563–569. DOI: https://doi.org/10.1080/00343400050085675

Fujimoto T. (2018). Appropriate assumption on cross-hauling national input–output table regionalization. *Spatial Economic Analysis*, 14(1), 106–128.

Fukui S. (2023). Estimating input coefficients for regional input-output tables using deep learning with mixup. *Papers 2305.01201, arXiv.org*. Available at: https://arxiv.org/abs/2305.01201

Gabela J. (2020). On the accuracy of gravity- RAS approaches used for inter-regional trade estimation: Evidence using the 2005 interregional input–output table of Japan. *Economic Systems Research*, 32(4), 521–539. DOI: https://doi.org/10.1080/09535314.2020.1753662.

Greaney T., Kiyota K. (2020). The gravity model and trade in intermediate inputs. *The World Economy*, 43(8), 2034–2049. Available at: https://doi.org/10.1111/twec.12947

Holy V., Safr K. (2023). Disaggregating input–output tables by the multidimensional RAS method: A case study of the Czech Republic. *Economic Systems Research*, 35(1), 95–117. DOI: https://doi.org/10.1080/09535314.2022.2091978

Isard W., Keunne R. (1953). The impact of steel upon the Greater New York - Philadelphia Industrial Region. *Review of Economics and Statistics*, 35(4), 289–301. DOI: https://doi.org/10.2307/1924389

Jackson R., Járosi P. (2020). Consistent regional commodity-by-industry input-output accounts. *Working Paper 2020-03, Regional Research Institute, West Virginia University.*

Junius T., Oosterhaven J. (2003). The solution of updating or regionalizing a matrix with both positive and negative entries. *Economic System Research*, 15(1), 87–97.

Kronenberg K., Fuchs M. (2022). The socio-economic impact of regional tourism: an occupation-based modelling perspective from Sweden. *Journal of Sustainable Tourism*, 30(12), 2785–2805. DOI: https://doi.org/10.1080/09669582.2021.1924757.

Lahr M., Ferreira J., Többen J. (2020). Intraregional trade shares for goods-producing industries: RPC estimates using EU data. *Regional Science*, 99(6), 1583–1605. DOI: https://doi.org/10.1111/pirs.12541

Lamonica G., Recchioni C., Chelli M., Salvati L. (2020). The efficiency of the cross-entropy method when estimating the technical coefficients of input–output tables. *Spatial Economic Analysis*, 15(1), 62–91. DOI: https://doi.org/10.1080/17421772.2019.1615634

Liu C., Lenzen M., Murray J. (2013). A disaggregated emissions inventory for Taiwan with uses in hybrid input-output life cycle analysis (IO-LCA). *Natural Resources Forum*, 36(2). DOI: https://doi.org/10.1111/j.1477-8947.2012.01439.x

Malov V.Iu., Melentyev B.V. (2022). Transport system as an object of government management. *Vestnik transporta=Transport Bulletin*, 1, 9–11 (in Russian).

Mi Z., Meng J., Zheng H., Shan Y., Wei Y., Guan D. (2018). A multi-regional input-output table mapping China's economic outputs and interdependencies in 2012. *Scientific Data*, 5(1). DOI: https://doi.org/10.1038/sdata.2018.155

Mikheeva N.N. (2005). Statistical evaluation of input-output tables for the Russian Far East. Prostranstvennaya ekonomika=Spatial Economics, 2, 61–79 (in Russian).

Mínguez R. (2009). Cell-corrected RAS method (CRAS) for updating or regionalizing an input-output matrix. *Journal of Regional Science*, 49(2), 329–348.

Morrissey K. (2016). A location quotient approach to producing regional production multipliers for the Irish economy. *Regional Science*, 95(3), 491–507. DOI: https://doi.org/10.1111/pirs.12143

Novikova T.S., Suslov V.I., Gulakova O.I. (2021). Price aspects of evaluating investment projects. *Ekonomika regiona=Economy of Regions*, 17(1), 16–30 (in Russian).

Oosterhaven J. (1980). Review of Dutch regional input-output analysis. *The Annals in Regional Science*, 14(3), 6–14. DOI: https://doi.org/10.1007/BF01287309

Oosterhaven J., Hewings G. (2014). Interregional input-output models. In: *Handbook of Regional Science*. DOI: https://doi.org/10.1007/978-3-642-23430-9_43

Pereira-López X., Carrascal-Incera A., Fernández-Fernández M. (2020). A bidimensional reformulation of location quotients for generating input–output tables. *Spatial Economic Analysis*, 15(4), 476–493. DOI: https://doi.org/10.1080/17421772.2020.1729996

Pereira-López X., Sánchez-Chóez N., Fernández-Fernández M. (2021). Performance of bidimensional location quotients for constructing input–output tables. *Journal of Economic Structures*, 10(7). DOI: https://doi.org/10.1186/s40008-021-00237-5

Richardson H. (1972). *Input-Output and Regional Economics.* London: Weidenfeld & Nicolson.

Round J.I. (1972). Regional input-output models in the UK: A reappraisal of some techniques. *Regional Studies*, 6(1), 1–9. DOI: https://doi.org/10.1080/09595237200185011

Sayapova A.R. (2004). Input-output tables in the analysis and forecasting of structural parameters of the regional economy. *Problemy prognozirovaniya=Studies on Russian Economic Developmen*t, 6, 28–41 (in Russian).

Shen T. (1960). An input-output table with regional weights. *Regional Science*, 6, 113–199. DOI: https://doi.org/10.1111/j.1435-5597.1960.tb01706.x

Siroen J. (2014). Gravity Models, Interregional Input-Output, and Trade In Value Added: A New Approach Applied to Brazil Internal and International Trade [conference presentation abstract]. 22nd International Input-Output Conference & 4th Edition of the International School of I-O Analysis 14-18 July 2014, Lisbon, Portugal.

Stone R. (1961). Input-Output and National Accounts. Organization for Economic Cooperation and Development.

Suslov N.I., Buzulutskov V.F. (2018). About one approach when considering dynamics in models of the MRIOM class (using the example of MRIOM-FEC). *Mir ekonomiki i upravleniya=World of Economics and Management*, 18(4), 112–125 (in Russian).

Suslov V.I., Ibragimov N.M., Domozhirov D.A. (2021). Modeling and analysis of spatial equilibrium in the Russian economy. *Region: ekonomika i sotsiologiya=Region: Economics and Sociology*, 4, 82–96 (in Russian).

Tarahomi F., Bazzazan F. (2021). A method for preparing multi-regional input-output tables despite data limitation: FLQ-Gravity. *Journal of Economic Cooperation & Development*, 42(2).

Tsyplakov A.A. (2022). Stationarity and growth in an agent-based economic model. *Mir ekonomiki i upravleniya=World of Economics and Management*, 22(1), 84–102 (in Russian).

Wiedmann T., Suh S., Feng K. et al. (2011). Application of hybrid life cycle approaches to emerging energy technologies – the case of wind power in the UK. *Environmental Science and Technology*, 45(13), 5900–5907. DOI: https://doi.org/10.1021/es2007287

Zaitseva I. (2002). *Multiregional Analysis on the base of Input-Output Table* [conference presentation abstract]. 14th International Conference on Input-Output Techniques, Montreal, Canada, 10-15th October. Available at: https://www.iioa.org/conferences/14th/papers.html

Zhuoying Z. (2002). The compilation of China's interregional input-output model. *Economic Systems Research*, 27(2), 238–256. DOI: https://doi.org/10.1080/09535314.2015.1040740

Information about the Authors

Victor I. Suslov – RAS Corresponding Member, Doctor of Sciences (Economics), Professor, head of laboratory, Institute of Economics and Industrial Engineering, Siberian Branch of the Russian Academy of Sciences (17, Academician Lavrentiev Avenue, Novosibirsk, 630090, Russian Federation; e-mail: suslov@ieie.nsc.ru)

Alexandr I. Dushenin – postgraduate student, Novosibirsk State University (1, Pirogov Street, Novosibirsk, 630090, Russian Federation; e-mail: a.dushenin@g.nsu.ru); Junior Researcher, Institute of Economics and Industrial Engineering, Siberian Branch of the Russian Academy of Sciences (17, Academician Lavrentiev Avenue, Novosibirsk, 630090, Russian Federation)

Yuri S. Ershov – Senior Researcher, Institute of Economics and Industrial Engineering, Siberian Branch of the Russian Academy of Sciences (17, Academician Lavrentiev Avenue, Novosibirsk, 630090, Russian Federation; e-mail: eryus@mail.ru)

Naimdzhon M. Ibragimov – Doctor of Sciences (Economics), Associate Professor, Institute of Economics and Industrial Engineering, Siberian Branch of the Russian Academy of Sciences (17, Academician Lavrentiev Avenue, Novosibirsk, 630090, Russian Federation; e-mail: naimdjon@ieie.nsc.ru); Professor, Novosibirsk State Technical University (20, Karl Marx Avenue, Novosibirsk, 630073, Russian Federation); Professor, deputy dean of the Faculty of Economics, Novosibirsk State University (1, Pirogov Street, Novosibirsk, 630090, Russian Federation)

Received October 14, 2024.