DOI: 10.15838/esc.2019.6.66.7
UDC 332.13, LBC 65.05

Sectoral and Territorial Specifics of Value-Added Chains in Russia: the Input-Output Approach*

Evgenii V. Lukin
Vologda Research Center of the Russian Academy of Sciences
Vologda, Russian Federation, 56A, Gorky Street, 160014
E-mail: lukin_ev@list.ru
ORCID: 0000-0002-1159-281X; ResearcherID: I-8183-2016

Abstract. This paper shows the growing role of domestic demand in the development of the modern economy. We consider the capacity of domestic markets of the largest countries of the world. We prove that the low volume of domestic demand inhibits economic dynamics and worsens the quality of socio-economic development of the Russian Federation. We consider that a promising direction for expanding domestic consumer and investment demand is the implementation of state policy to increase the incomes of the population, companies and the state in the framework of lengthening their own value-added chains that produce goods and services for final use. In this regard, the goal of this study is to analyze the existing value-added chains, assess the degree of their fragmentation, sectoral and territorial specifics. The input-output theory serves as a methodological basis for our study. The information source is represented by basic input-output tables and the data of the Unified Interdepartmental Statistical Information System. The novelty of the research consists in adjusting the multidisciplinary approach to the assessment of fragmentation of production to suit the needs of the regional level and in identifying modern patterns in the functioning of Russian value-added chains on the basis of the approbation of the approach on the materials of Russian regions. According to the results of the calculations we reveal the average position of 125 branches of the Russian economy in the supply and sales chains. We substantiate the degree of fragmentation of production chains of various industries; we substantiate the factors that determine the

* The article was prepared with financial support under the grant of the President of the Russian Federation no. MK-2135.2019.6.

For citation: Lukin E.V. Sectoral and territorial specifics of value-added chains in Russia: the input-output approach. *Economic and Social Changes: Facts, Trends, Forecast,* 2019, vol. 12, no. 6, pp. 129–149. DOI: 10.15838/esc.2019.6.66.7

length of a production process. We calculate the average distance along the sales chain, which the goods cover to the moment of their use by the end consumer. We consider regional fragmentation of production in Russia. We reveal a number of statistically significant dependencies between the position of regions in the value-added chains and their socio-economic development performance.

Key words: value-added chains, input-output tables, fragmentation of production, length of the production chain, distance to the end user.

1. Introduction

Modern global economy becomes fragmented and multipolar. There is a process of globalized paradigm. Due to objective reasons (decentralization of global management, reduction of production costs as a result of digitalization, development of robotics, etc.), it becomes economically more profitable to produce goods in close proximity to the consumer, rather than transport them around the world from low-cost countries. Production moves to countries of consumer demand, countries with a developed domestic market.

In terms of the capacity of the domestic market, Russia is significantly inferior to a number of other countries (USA, China, India, Japan) and the European Union *(Tab. 1)*. Per capita aggregate domestic demand according to purchasing power parity (PPP) in Russia is 2.6 times lower than in the United States and 2 times lower than in Germany[1].

The small capacity of the domestic market is one of the main factors constraining economic development. It leads to under-consumption of goods and services by the population, reduction of enterprises' incentives to increase production and deepen the processing of raw materials. The result was lack of domestic demand for many types of products, export of low-tech goods. This situation is worsened by the spiraling development of the economy: due to lost value added, incomes of companies, state, and population decline. This leads to a decrease of consumers' demand and investment opportunities.

Table 1. Total domestic demand in 2017 (without PPP)

	Final consumption		Gross accumulation		Total domestic demand	
	Volume, trillion USD	Share, % from total	Volume, trillion USD	Share, % from total	Volume, trillion USD	Share, % from total
Global	59.296	100.0	20.184	100.0	79.481	100.0
USA	16.053	27.1	3.986	19.7	20.038	25.2
EU	13.129	22.1	3.497	17.3	16.626	20.9
China	6.468	10.9	5.169	25.6	11.637	14.6
Japan	3.653	6.2	1.158	5.7	4.811	6.1
Germany	2.672	4.5	0.750	3.7	3.422	4.3
India	1.857	3.1	0.760	3.8	2.617	3.3
Russia	1.117	1.9	0.353	1.7	1.470	1.8
Source: own calculations based according to World Bank data.						

[1] Total population of Russia is 146.8 million people, U.S. – 325.1 million people, Germany – 82.8 million people. Conversion coefficient PPP (GDP) for Russia is 0.42, for the U.S. – 1, for Germany – 0.85. Accordingly, the total domestic demand per capita for PPP in Russia is equal to 24.0 thousand USD, in the U.S. – 61.6, in Germany – 48.6 (calculations based on World Bank data).

Figure 1. Dynamics of transport cargo turnover in Russia in 1991–2018, % to 1991

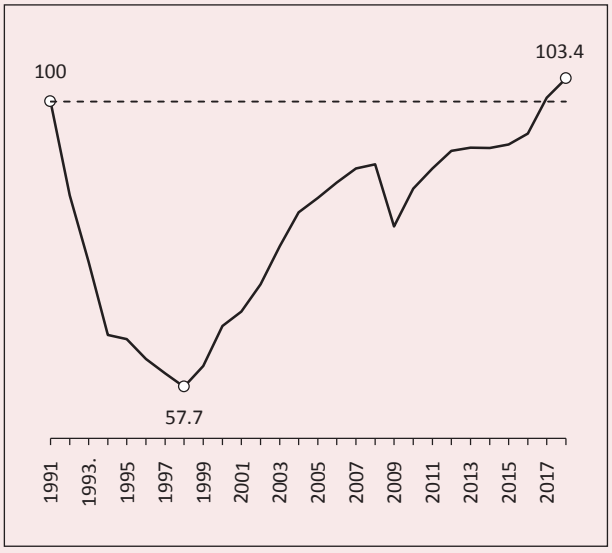
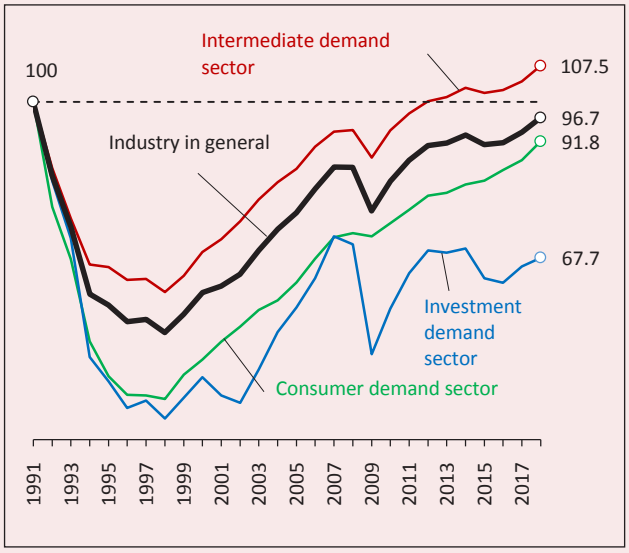


Figure 2. Dynamics of industrial production in Russia in 1991–2018, % to 1991



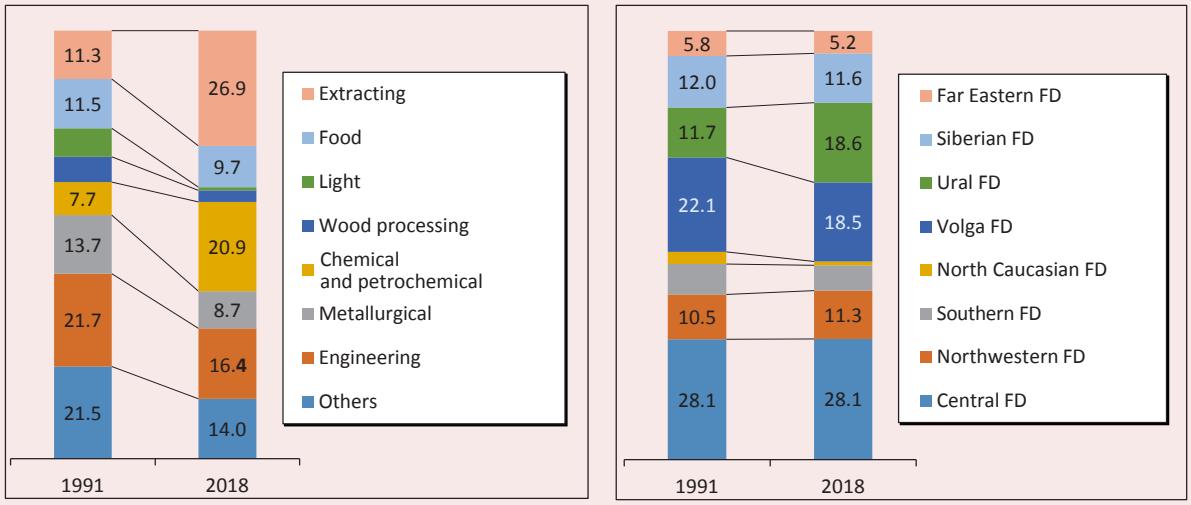
Source: calculated according to Rosstat data.

In the process of the Russian economy's reformation, a significant part of existing Soviet economic ties between regions was destroyed. The share of interregional turnover in country's GDP decreased from 25% to 16% in 1990–1994 [1]. The revival of interregional ties is slow. It became possible to restore the volume of transport cargo turnover only in 2017 (*Fig. 1*), the volume of industrial production is still inferior to the level of 1991 (*Fig. 2*). At the same time, the locomotives of growth are the industries of extraction and intermediate processing of raw materials. At the same time, there is a decline in a number of country's industries which are the most important for investment and consumer demand sectors – machine-building, light industry.

The multidirectional dynamics of the development of different sectors of industry is reflected in the change of output structure (*Fig. 3*). These transformations, in turn, cause the redistribution of gross value added (income) in favor of export-oriented industries of intermediate demand. Practiced profit-taking at the stage of raw materials' extraction and production of semi-finished products lead to depression of final products' production, degradation of production of machinery production means [2]. As the result, the domestic demand for basic and applied science, RW and R&D, TA decreases, the material and technical base of education and health care deteriorates [2], the number of research organizations and its personnel declines (*Tab. 2*). A serious challenge is also the compression of the populated and used space of the country, an indicator of which is the negative dynamics of the population and the volume of economic activity in rural areas [3].

In general, the result of market reforms, carried out in Russia, was the formation of an economic model, the growth of which largely depends on the external environment and the

Figure 3. Industrial structure in Russia in 1991 and 2018, % to total



a) Sectoral structure

b) Territorial structure

Source: calculated according to Rosstat data.

Table 2. Number of organizations that have carried out research and development

Organization	1991	2017	2017 to 1991, %
Research organizations	1831	1577	86.1
Construction organizations	930	273	29.4
Project and survey organizations	559	23	4.1
Pilot plant	15	63	by 4.2 times
Educational institutions of higher education	450	970	by 2.2 times
Organizations of the industry which had research, project and construct divisions	400	380	95,0
Others	379	658	173.6
Total	4564	3944	86.4
Reference: number of personnel engaged in research and development, thousand people	1677.8	707.9	42.2
issued patents for inventions, thousand units	66 (1990)	34	51.5
Source: Rosstat.			

results of export-import activities. The quality of economic growth under the current model cannot be considered satisfactory. It reinforces the lag behind the industrialized countries in scientific, technological, and innovative spheres and in the volume of commodity production of the real economy's high-tech sectors. Dependence on technology import has reached critical levels. According to the Ministry of Industry and Trade of the Russian Federation [4], the import share in several strategic industries exceeded 80% in 2014, in the machine tool industry – more than 90%, in heavy engineering – 80%, light industry – up to 90%, in electronics – up to 90%, in pharmaceutical and medical industry – up to 80%[2].

[2] In September 2014, RF Government approved "The plan on import substitution in Russian manufacturing", which contained 22 sectoral import substitution plans until 2020. According to experts, most indicators are not achieved. Available at: https://tagilcity.ru/news/economy/06-11-2018/importozameschenie-v-rossii-chto-poluchilos-za-pyat-let

The country faces the problem of choosing new long-term strategy of qualitative economic growth. To change the situation, the government policy on increasing incomes of all economic entities (population, companies, state) at the expense of forming own value-added chains (VAC), producing goods for final production.

The implementation of such policy is impossible without an analysis of existing value-added chains, taking into account its sectoral and territorial specifics: it became the purpose of this study.

2. Theoretical aspects of the research

First, let us define the concepts of gross value-added and value-added chain.

According to the UN guide to National Accounts[3], gross value-added is equal to products' output minus intermediate consumption. It reflects the value of all goods and services that are available for different uses, except for intermediate consumption. The share of gross value-added in output characterizes the part of product's value, which was directly created by its manufacturer. Accordingly, the greater this weight, the less intermediate goods and services are purchased for production, and the weaker economic ties with enterprises-suppliers are. A high proportion of value-added is usually found in industries that are at the beginning of the production chain and are associated with the supply of materials, components and services for later use [5].

In research literature, a value-added chain is understood as a full range of activities that are carried out by enterprises in order to bring a product or service from the development stage to consumer [6]. The growth process of VAC characterizes the geographical fragmentation of production in accordance with the principles of comparative advantage.

The concept of VAC (or rather global VAC) emerged in the 1970s as an attempt to resolve an issue of why some countries develop faster than others. For this, we analyzed the participation of countries in global labor division, assessed its involvement in the process of creating value across all technological chain – from the moment of product's planning to its consumer's implementation.

Currently, the analysis and forecast of territories' involvement in VAC goes on. Cross-sectoral analysis is a recognized analytical tool for the study of inter-territorial cross-sectoral relations. International data bases of cross-country "input – output" tables TiVA[4], WIOD[5], GTAP[6] are created. Considerable experience in the field of theoretical and methodological aspects of the development of inter-territorial cross-sectoral models [7-10] (including inter-regional models [11–15]) has been gained.

3. Methodology of the research

This study is also based on methodology of input-output tables. According to it, in closed economy, if we look from the *point of sale*, for each *i* sector ($i = 1, ..., n$) the value of x_i gross output is totally equal to the volume of its final usage f_i] and the volume of intermediate sales to economic sectors $\sum_j z_{ij}$ (*Fig. 4*).

[3] National Accounts: practical introductory course. New York: UN, 2006. Available at: https://unstats.un.org/unsd/publication/seriesf/seriesf_85r.pdf

[4] TiVA (Trade in Value-Added) contains traditional indicators of foreign economic activity, as well as indicators characterizing the participation of national economies in the global VAC. Information is given for 65 countries (including Russia), broken down into 36 industries.

[5] WIOD (World Input-Output Database) includes national and inter-country cross-industry "input-output" tables for 43 countries (including Russia) within 56 industries.

[6] GTAP (Global Trade Analysis Project) contains information on bilateral trade, transport tariffs, and protectionist measures in 140 countries according to 57 products.

Figure 4. Input-output tables of production and distribution

Industries		Intermediate consumption Consumers					Final usage	Total usage
		1	…	j	…	n		
Manufacturers	1	z_{11}	…	z_{1j}	…	z_{1n}	f_1	x_1
	…	…	…	…	…	…	…	…
	i	z_{i1}	…	z_{ij}	…	z_{in}	f_i	x_i
	…	…	…	…	…	…	…	…
	n	z_{n1}	…	z_{nj}	…	z_{nn}	f_n	x_n
GAV		v_1	…	v_j	…	v_n		
Total resources		x_1	…	x_j	…	x_n		

If we denote the costs of *i* sector's products on production of product unit of *j* sector through $a_{ij} = z_{ij}/x_j$, then the gross output x_i could be written as

$$x_i = f_i + \sum_j a_{ij} x_j \ . \qquad (1)$$

The iterative application of formula (1), the gross output of sector *i* is expressed as a sequence of periods reflecting the use of this sector's products in the production chain:

$$x_i = f_i + \sum_j a_{ij} f_j + \sum_{j,k} a_{ik} a_{kj} f_j + \sum_{j,k,l} a_{il} a_{lk} a_{kj} f_j + \ldots \ . \qquad (2)$$

The first part from the right side of the equation (2) – f_i – shows the value of final sales of *i* sector's products, the second – volume of direct intermediate sales of *i* sector's products across all *j* sectors ($j = 1, \ldots, n$), used as resources in its first cycle of production processes. Another part points at indirect intermediate sales of *i* sector across all sectors (including *i* sector), which are used as resources in its production processes of the first, second, third and following circles [8].

From the point of supply, the volume of used x_j resources by *j* sector is constituted by the cost of $\sum_i z_{ij}$ intermediate resources, purchased from other industries, and the consumption of fixed capital, wages and profits corresponding to gross value-added of v_j sector. After denoting the share of *i* sector's products, used in the production of *j* sector, through $b_{ji} = z_{ij}/x_i$, x_j, it could be written as

$$x_j = v_j + \sum_i x_i b_{ji} \ . \qquad (3)$$

If we iteratively apply the formula (3), x_j would be expressed as the sequence of periods, reflecting the process of *j* resources supply with resources:

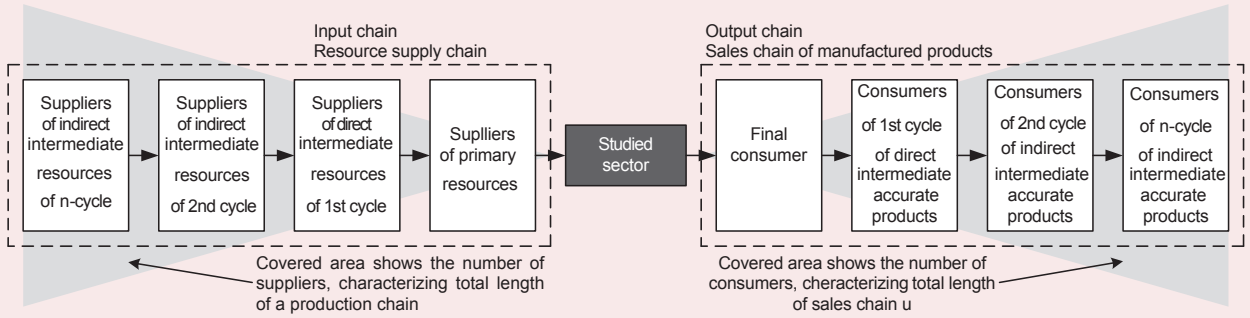
$$x_j = v_j + \sum_i v_i b_{ji} + \sum_{i,k} v_i b_{ik} b_{kj} + \sum_{i,k,l} v_i b_{ik} b_{kl} b_{lj} + \ldots \ . \qquad (4)$$

The first part from the right side of the equation (4) – v_j – characterizes the cost of primary resources, purchased by *j* sector (labor, administrative services, capital), the second one – the volume of direct interim purchases conducted by *j* sector in *i* sectors ($i = 1, \ldots, n$), which is required for the first cycle of production process of *j* sector. Another parts characterize indirect intermediate purchases of products conducted by *j* sector in all sectors (including *j* sector itself), used as resources in production process of *j* sector of the second, third and following cycles.

Table 3. Interpretation of indicator values u and d [18]

	Distance to final consumer (*u*)	Length of production chain (*d*)
More	Large share of intermediate consumption (small share of final consumption) in gross output Complex and strong intermediate supply links with technologically related industries	Large share of intermediate products (small share of value-added) in consumed resources Complex and strong intermediate links for the supply of consumable resources with technologically related industries
Less	Small share of intermediate consumption (large share of final consumption) in gross output Simple and weak intermediate connections for the supply of products from technologically related industries	A small fraction of intermediate goods (a large share of value-added) to the consumed resources Simple and weak intermediate links for the supply of consumable resources with technologically related industries

Figure 5. Value-added chain of the sector



To define average position of sector's output in a sale chain[7] (distance to final consumer), the authors of work [16] suggest multiplying each summand and distance to final consumer plus 1 and normalizing on the sector's gross output

$$u_i = 1 \cdot \frac{f_i}{x_i} + 2 \cdot \frac{\sum_j a_{ij} f_j}{x_i} + 3 \cdot \frac{\sum_{j,k} a_{ik} a_{kj} f_j}{x_i} + 4 \cdot \frac{\sum_{j,k,l} a_{il} a_{lk} a_{kj} f_j}{x_i} + \ldots . \quad (5)$$

In the situation, when the whole output of *i* sector is directed at final consumption, u_i indicator takes the value 1. The more the distance, required for the product to pass in order to reach final consumer, is, the higher the u_i value is.

Similarly, to fix the average position of the sector in the supply chain [8] (the length of production chain), the following indicator is used in works [17, 18]:

$$d_j = 1 \cdot \frac{v_j}{x_j} + 2 \cdot \frac{\sum_i v_i b_{ji}}{x_j} + 3 \cdot \frac{\sum_{i,k} v_i b_{ik} b_{kj}}{x_j} + 4 \cdot \frac{\sum_{i,k,l} v_i b_{ik} b_{kl} b_{lj}}{x_j} + \ldots . \quad (6)$$

d_j takes minimum value in case of low share of intermediate products in resources consumed by *j* sector (in case, when the production does not require any intermediate products).

Generally, *u* and *d* variables characterize fragmentation of production by showing the position of sectors in sales and supply chains (*Tab. 3*; *Fig. 5*).

Acquisition of accurate *u* and *d* values is hindered by never-ending summation of parts in equations (5) and (6). Therefore, in practice, alternative expressions are used, based on relations known in the cross-sectoral balance[9]. It is shown in work [16] that alternative way of calculation provides same results.

[7] Output supply chain.
[8] Input demand chain.
[9] We mean the reverse matrix of Leont'ev $I + A + A^2 + \ldots = (I - A)^{-1}$ and reverse matrix of Gosh $I + B + B^2 + \ldots = (I - B)^{-1}$.

Distance to final consumer is defined as

$$U_i = 1 + \sum_j a_{ij} U_j \ . \quad (7)$$

or in matrix form:

$$U = [I - A]^{-1} 1 \ , \quad (8)$$

where I – single matrix; A – matrix with a_{ij} typical element; 1 – single vector.

The indicator, characterizing the length of a production chain, can be written as

$$D_j = 1 + \sum_i b_{ji} D_i \ , \quad (9)$$

or in matrix form:

$$D = 1 \cdot [I - B]^{-1} \ , \quad (10)$$

where B – matrix with b_{ji} typical element.

In case of an open economy, U and D indicators are calculated similarly according to formulas (8) and (10), but with taking into account goods and services' export and import.

Weighting of U and D indicators while aggregating is conducted, respectively, on the basis of sectors' value-added and cost of goods, used for final consumption.

If we examine the economy of regions as a set of sectors, the use of these indicators, taking into account the specific weight of corresponding sectors in the economy, will allow characterizing the position of regions in value-added chains. We propose calculations of aggregated indicators U and D in regional economy (U_R and D_R respectively), defined as the sum of products of U_i and D_j sectoral indicators and specific weights of sectors in gross output (w):

$$U_R = \sum_i U_i w_i \ , \quad (11)$$

$$D_R = \sum_j D_j w_j \ , \quad (12)$$

It should be noted that the assessment of fragmentation of production by similar methods was carried out in the economies of the United States [16, 19], China [20, 21], Poland [22], Asia [23] and in the global context [18, 24]. For Russia, only sales chains were investigated [25, 26], supply chains were investigated for the first time.

3. Source of the data

To calculate indicators characterizing the fragmentation of production in the Russian economy, we used data from basic "costs-output" tables of Rosstat for 2011 for 125 sectors, as well as UISIS data on an amount of shipped goods of own production, performed works and services for 2017 within 263 sectors (these sectors were aggregated according to 125-branch nomenclature of "costs-output" tables) for entities of the Russian Federation. Given the fact that regional input-output tables are not developed by official statistics, to calculate regional indicators, we used the assumption of similarity of average technological processes in similar sectors across the country and in selected regions (country sectoral values of indicators U and D were taken).

4. Fragmentation of production in Russian economy

The weighted average number of production stages in the Russian economy turned out to be less than 2, i.e. production resources undergo less than two repartitions on average before reaching a final consumer[10]. It could be explained by a growing role of services in Russian economy (in 2018, it formed more than 60% of gross value-added), which require less production stages and are situated closer to final demand that production of commodity-producing industries.

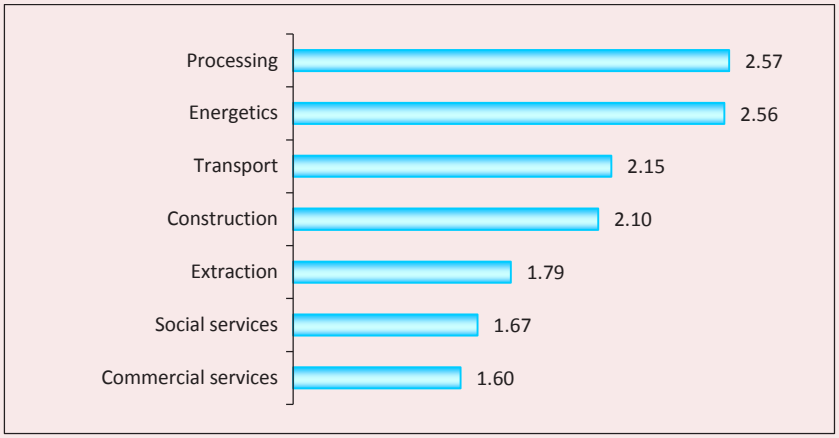
[10] Of interest is the fact that average number of production stages in USA also does not exceed 2 (according to 2002 data). Besides, production fragmentation, in the last 50 years, has had a trend of declining there [17], which explains a switch in D. Trump's industrial policy turn to reindustrialization and transfer of enterprises into the United States.

4.1. Sectoral specifics of Russian VAC

The most fragmented sectors of Russian economy are industrial sectors[11]. Average length of production chain (*D*) in processing productions is 2.57, in energetics – 2.56 (*Fig. 6*). In its production consumption structure, intermediate industrial products (raw materials, electricity, semi-finished products) prevail (occupying more than 70%), which cases the necessity to provide many operations on its procession (*Tab. 4*).

Transport sector has, averagely, 2.15 stages of production due to active usage of engineering products (which passes a large number of repartitions on its way to manufacture) and road maintenance services. Similar length of production chain – 2.10 – is in the construction, which is

Figure 6. The length of the production chain (*D*) in 7 enlarged sectors of the Russian economy



Source: calculated according to Rosstat data.

Table 4. Structure of production consumption of 7 enlarged branches of the Russian economy, % to total

Sectors-producers	Sectors-consumers						
	Extraction	Processing	Energetics	Construction	Transport	Commercial services	Social services
Extraction	25.6	23.6	10.7	2.6	1.1	0.9	2.0
Processing	26.4	45.1	7.8	58.3	23.7	15.7	23.7
Energetics	8.2	5.2	52.4	1.8	7.6	4.7	10.4
Construction	2.8	1.1	1.9	7.9	4.9	3.4	16.2
Transport	13.3	6.8	1.8	5.8	30.4	21.4	10.3
Commercial services	22.7	17.5	24.8	22.5	30.7	49.9	28.2
Social services	0.8	0.6	0.6	1.2	1.5	4.1	9.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Reference: industry	60.3	73.9	71.0	62.6	32.4	21.3	36.1
Source: calculated according to Rosstat data.							

[11] The study identified 7 enlarged sectors of the economy: extraction (sections A,B,C according to OKVED), processing (D), energetics (E), construction (F), transport (I), commercial (G, H, J, K) and social (L, M, N, O) services.

presumed to be one of the most multiplicative sectors of the economy (it has the highest share of consumption of processing industry's products – more than 58% in total amount of consumed resources; it is very close to final consumer).

The most fragmented sectors are the spheres of commercial and social services, as well as extractive sectors. The short length of production chains in it is largely caused by weak interaction with technologically related sectors on the line of consumed resources supply and the intensive usage of direct labor costs (this is especially valid for social services –governance, education and health; *Tab. 5*).

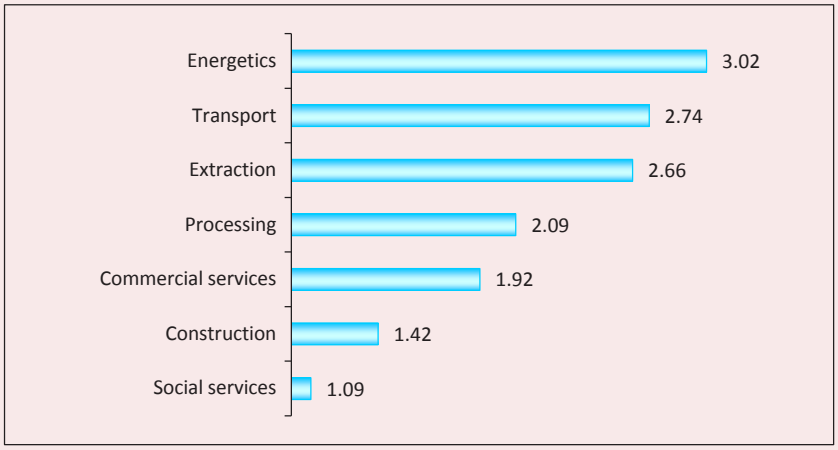
The ranking of sectors according to distance to a final user (length of a supply chain) is given in *Figure 7*. Social services (U = 1.09) and construction (1.42) can be attributed to sectors, output in which is almost completely spent on final consumption.

A pronounced distance from the final consumption is typical for energetics (3.02), transport (2.74), and extraction (2.66). Its products are used as resources and intermediate goods in technologically related industries. Processing (2.09) and commercial services (1.92) are located roughly in the middle of the VAC.

Table 5. Structure of gross value-added of 7 enlarged branches of the Russian economy, % to total

Costs	Extraction	Processing	Energetics	Construction	Transport	Commercial services	Social services
Salary	16.2	43.9	46.4	37.3	46.9	27.7	77.8
Other production taxes	0.1	1.4	3.3	0.5	1.8	1.0	1.1
Consumption of fixed capital	6.2	7.5	8.8	1.8	6.8	14.1	15.9
Net profit	77.5	47.2	41.6	60.4	44.5	57.2	5.3
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Source: calculated according to Rosstat data.							

Figure 7. Distance to the final consumer (U) in 7 enlarged branches of the Russian economy



Source: calculated according to Rosstat data.

Since enlarged branches of the economy are considered very heterogeneous in its production structures, we will enlarge the scale and consider *U* and *D* in a 32-branch breakdown.

The farthest from final consumers – approximately three stages away according to the VAC – are mining sectors ($U \approx 4$; *Tab. 6*). Closer ($U \approx 3$) are several intermediate sectors of processing industry oil refining, chemistry, metallurgy, woodworking), energetics, financial activity, transport, and communications. Real estate operations, polygraphy, mechanical engineering, agriculture, and fishing are one stage away from final consumers ($U \approx 2$). Other sectors send almost all its output directly to households and government officials ($U \approx 1$), providing them with food, clothing, nutrition, accommodation, health care, and education.

Variation of values of *D* indicator, characterizing the length of production chains, is much shorter in Russian economy. In two VAC stages away from suppliers of primary resources (employees, public authorities, investors; $D \approx 3$), 12 sectors of economy are situated, in one stage ($D \approx 2$) – 18 more sectors. Two sectors cooperate with other economic sectors quite poorly, purchasing most of necessary resources (labor, administrative services, and capital) directly from primary resource suppliers ($D \approx 1$).

Table 6. Averaged U and D values for 32 branches of the Russian economy

U, D	Number	Sector
$U \approx 4$	2	Extraction of fuel and energy minerals (3.65); extraction of minerals, except fuel and energy (3.51)
$U \approx 3$	12	Production and distribution of electricity, gas and water (3.17); production of coke, petroleum products and nuclear materials (3.10); metallurgical production (2.91); forestry (2.87); pulp and paper production (2.75); transport and communications (2.74); wood processing and production of wood products (2.71); chemical production (2.63); production of other non-metallic mineral products (2.63); financial activities (2.58); production of rubber and plastic products (2.54); production of finished metal products (2.53)
$U \approx 2$	10	Publishing and printing activities (2.38); real estate transactions, rent and provision of services (2.06); production of electrical, electronic, and optical equipment (2.00); other production (1.95); fishing, fish farming (1.95); production of machinery and equipment (1.93); agriculture (1.90); wholesale and retail trade (1.85); production of vehicles and equipment (1.63); provision of other public, social, and personal services (1.55)
$U \approx 1$	8	Textile and clothing production (1.49); construction (1.42); food, including beverages, and tobacco production (1.34); hotels and restaurants (1.32); public administration and military security, compulsory social security (1.13); leather, leather goods and footwear production (1.12); education (1.08); health and social services (1.05)
$D \approx 3$	12	Manufacture of rubber and plastic products (2.89); manufacture of vehicles and equipment (2.80); other production (2.72); manufacture of finished metal products (2.71); manufacture of food products, including beverages, and tobacco (2.64); metallurgical production (2.63); manufacture of other non-metallic mineral products (2.57); pulp and paper production (2.55); electricity, gas and water production and distribution (2.54); leather, leather goods and footwear production (2.53); machinery and equipment production (2.53); chemical production (2.51)
$D \approx 2$	18	Production of electrical, electronic, and optical equipment (2.47); fishing, fish farming (2.44); wood processing and production of wood products (2.43); textile and clothing production (2.41); publishing and printing activities (2.40); production of coke, petroleum products, and nuclear materials (2.35); construction (2.11); transport and communications (2.06); hotels and restaurants (2.03); forestry (2.02); agriculture (2.01); mining, except fuel and energy (1.91); provision of other municipal, social and personal services (1.82); health and social services (1.72); public administration and military security; compulsory social security (1.69); wholesale and retail trade; repair of motor vehicles, motorcycles, household goods and personal items (1.67); extraction of fuel and energy minerals (1.63); financial activities (1.51)
$D \approx 1$	2	Education (1.49); real estate transactions, rent, and services (1.45)
Source: calculated according to Rosstat data.		

In *Table 7*, there is a structure of production costs of economic sectors, characterizing relation of consumption of primary and intermediate resources and allowing understanding reasons of length of particular production process. Thus, high labor intensity (the weight of labor costs) determines the small length of the production chain in education, health, and public administration, a significant capital intensity (the weight of consumption of fixed capital) – in mining and real estate operations. Sectors of processing industry (which is logical)

Table 7. Structure of production costs of Russian economic sectors, % to total

Sector	Primary resources			Intermediate sectoral resources	*D*
	Salary	Other production taxes	Consumption of fixed capital		
Production of coke, petroleum products, and nuclear materials	3.1	0.4	1.8	94.7	2.353
Metallurgical production	10.0	0.6	2.2	87.2	2.626
Production of food products, including beverages, and tobacco	11.0	0.4	1.7	86.9	2.638
Chemical production	12.0	0.6	2.5	84.9	2.513
Manufacture of rubber and plastic products	13.7	0.4	1.6	84.3	2.885
Other productions	14.6	0.3	3.3	81.9	2.718
Pulp and paper production	14.7	0.7	2.8	81.7	2.551
Agriculture	18.2	-3.0	4.2	80.6	2.005
Production and distribution of electricity, gas, and water	15.7	1.1	3.0	80.2	2.538
Production of vehicles and equipment	18.6	0.1	2.7	78.6	2.801
Production of other non-metallic mineral products	18.7	0.6	2.5	78.2	2.570
Wood processing and production of wood products	19.4	0.6	2.6	77.4	2.426
Production of leather, leather products, and footwear	22.2	0.2	1.1	76.6	2.532
Fishing, fish farming	20.1	0.6	3.4	75.9	2.442
Textile and clothing production	22.8	0.2	1.3	75.8	2.412
Production of finished metal products	20.1	0.4	3.9	75.6	2.714
Publishing and printing activities	25.6	0.4	1.5	72.4	2.401
Construction	26.9	0.4	1.3	71.5	2.105
Production of machinery and equipment	26.2	0.4	2.3	71.2	2.527
Extraction of fuel and energy minerals	17.4	1.9	10.0	70.7	1.631
Production of electrical, electronic, and optical equipment	25.7	0.4	4.4	69.4	2.472
Hotels and restaurants	27.8	0.5	3.0	68.7	2.028
Transport and communications	27.8	1.1	4.0	67.1	2.059
Forestry	31.5	0.1	2.7	65.6	2.018
Mining, except for fuel and energy	30.0	1.2	5.1	63.7	1.908
Wholesale and retail trade	32.3	0.6	9.4	57.7	1.668
Provision of other public, social, and personal services	41.9	0.8	6.1	51.3	1.823
Financial activity	45.4	4.9	4.6	45.1	1.510
Real estate transactions, rentals, and services	27.1	0.8	28.9	43.2	1.451
Health and social services	58.4	0.7	1.9	39.0	1.719
Public administration and military security; compulsory social security	43.4	0.3	17.5	38.8	1.693
Education	67.4	1.7	3.0	27.9	1.490
Source: calculated according to Rosstat data.					

have longer production chains, since it is material-intensive and purchases the bulk of the resources they need from other sectors of the economy. In general, the results of correlation analysis show that higher the material intensity and the lower the labor and capital intensity of production are, the longer the production chain of a particular industry is (*Tab. 8*).

Concluding review of the industry specifics of Russian VAC, we will show, without describing detailed results, highest and lowest values of *D* and *U* indicators of economic sectors in he most available scale (in 125-sectoral breakdown; *Tab. 9)*.

The longest production chains, usually with little value-added at each stage, have different sub-sectors of engineering, the shortest – services in the field of finance, real estate, and education. There is a strong negative correlation between the degree of fragmentation of production and the level of value added created at different stages of production (*Fig. 8*).

According to the index, which characterizes the number of stages between production and final demand, the highest values are shown in sectors producing raw materials: coal, iron ore, coke, gas; the least – light industry, public organizations.

Table 8. Correlation of industry characteristics with *D* and *U* indicators

Characteristics of sectors	*D*	*U*
Material consumption (ratio of intermediate consumption to output)	0.969*	0.005
Labor intensity (the ratio of wages to output)	-0.356*	-0.216*
Capital intensity (ratio of consumption of fixed capital to output)	-0.276*	0.012
Profitability (ratio of net profit to output)	-0.640*	0.142

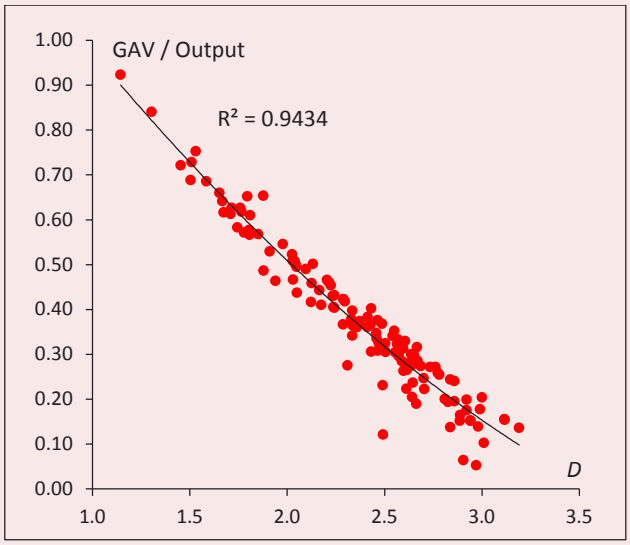
Note: marked * coefficients of correlation are important when p<0.05.
Source: calculated according to Rosstat data.

Table 9. Products with highest and lowest *U* and *D* values

Rank	Length of production chain			Distance to final consumer	
	Product	*D*	GVA/O*	*Product*	*U*
1	Motor vehicles, trailers, and semi-trailers	3.191	0.14	Coal and brown coal (lignite); peat	4.432
2	Equipment for agriculture and forestry	3.117	0.15	Iron ores	4.427
3	Other products of primary processing of ferrous metals	3.115	0.16	Production of coke ovens	4.376
4	Insulated wires and cables	3.011	0.10	Natural gas	4.156
5	Pipes and pipe elements	3.001	0.20	Secondary raw materials	4.104
…	…	…	…	…	…
121	Services in the field of education	1.510	0.73	Services in the field of health	1.049
122	Support services in the field of financial intermediation	1.505	0.69	Suitcases, handbags and similar goods; saddlebags and harness	1.039
123	Financial intermediation services	1.454	0.72	Tobacco products	1.025
124	Services related to real estate	1.303	0.84	Leather clothing	1.006
125	Rental services for cars and equipment, household products and personal items	1.145	0.92	Services of public organizations, not included in other groupings	1.000

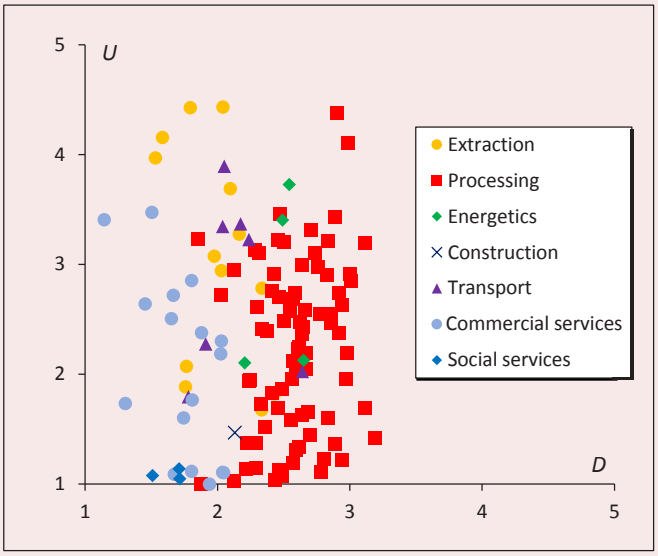
GVA/O – relation of gross value-added to output.
Source: calculated according to Rosstat data.

Figure 8. Dependence between the length of the production chain (*D*) and the share of value-added in the output of 125 sectors of the Russian economy



Source: calculated according to Rosstat data.

Figure 9. Scatter diagram of the values of *U* and *D* indicators of 125 branches of the Russian economy



Source: calculated according to Rosstat data.

The graphical distribution of sectors, depending on the length of its production and sales chains, is shown in *Figure 9*. Statistical connection between *D* and *U* values is not noticeable (correlation coefficient is -0.005).

Table 10. Distribution of Russian regions by size of U_R и D_R indicators

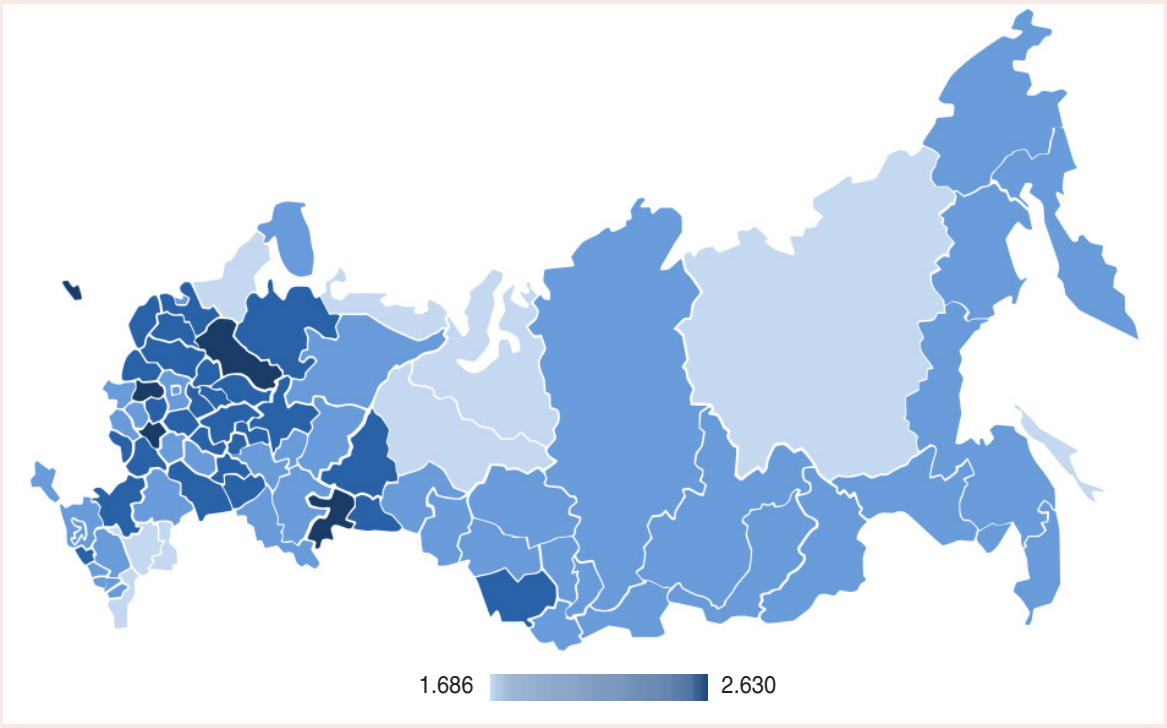
Length of production chain (D_R)		Distance to final consumer (U_R)			
		$U_R \approx 2$	$U_R \approx 3$		$U_R \approx 4$
		$U_R \in [1.6; 2.5)$	$U_R \in [2.5; 3.0)$	$U_R \in [3.0; 3.5)$	$U_R \in [3.5; 3.7]$
$D_R \approx 2$	$D_R \in [1.7; 2.0)$	–	Kalmykia, Karelia, and Dagestan republics	Khanty-Mansiysk AO, Sakhalin and Astrakhan oblasts, Sakha (Yakutia) republic	Nenets AO, Yamalo-Nenets AO
	$D_R \in [2.0; 2.3)$	Buryatia Rep., Primorsky Krai, Krasnodar Krai, Korsk Obl, Chechen Rep, Novosibirsk Obl., Bryansk Obl., Saint Petersburg, Stavropol Krai, Crimea Rep., Sevastopol, Altai Rep., Penza Obl., Moscow Obl., Kamchatka Krai, Oryol Obl., Adygea Rep., Kabardino-Balkar Rep., Tambov Obl., North Ossetia – Alania Rep., Ingushetia Rep.	Tyva Rep., Irkutsk Obl., Khakassia Rep, Tomsk Obl., Perm Krai, Tyumen Obl. (without AO), Krasnoyarsk Krai, Jewish AO., Tatarstan Rep., Omsk Obl., Volgograd Obl., Amursk Obl., Murmansk Obl., Bashkortostan Rep., Khabarovsk Krai, Moscow, Udmurt Rep.	Chukotka AO, Komi Rep., Orenburg Rep., Magadan Obl., Zabaykalsky Krai	Kemerovo Obl.
	$D_R \in [2.3; 2.5)$	Samara Obl., Belgorod Obl., Leningrad Obl., Tula Obl., Altai Krai, Arkhangelsk Obl. (without AO), Nizhny Novgorod Obl., Tver Oblast., Smolensk Obl., Rostov Obl., Novgorod Obl., Kirov Obl., Ryazan Obl., Yaroslavl Obl., Voronezh Obl., Kostroma Obl., Kurgan Obl., Mari El Republic, Chuvash Rep., Karachay-Cherkess Rep., Ivanovo Obl., Vladimir Obl., Mordovia Rep., Pskov Obl., Ulyanovsk Obl.	Sverdlovsk Obl., Saratov Obl.	–	–
$D_R \approx 3$	$D_R \in [2.5; 2.7]$	Kaluga Obl., Kaliningrad Obl.	Lipetsk Obl., Vologda Obl., Chelyabinsk Obl.	–	–

Source: calculated according to Rosstat data.

4.2. Regional specifics of Russian VAC

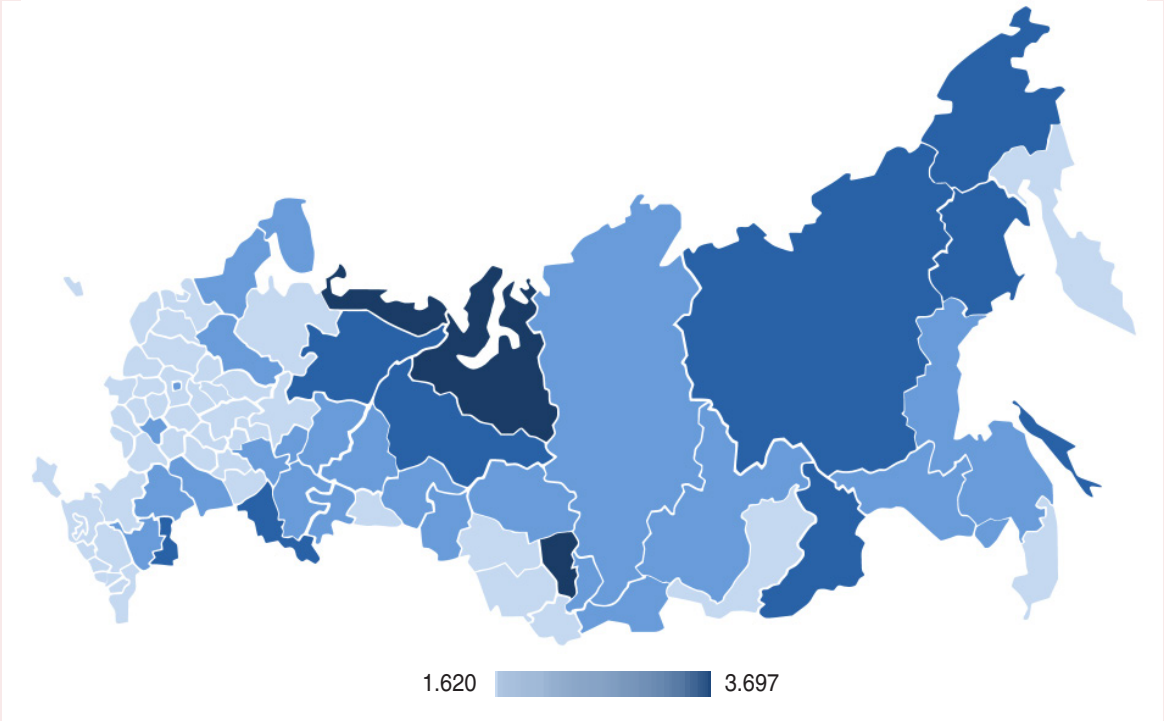
The scope of *D* and *U* sectoral values and the diversity of industrial specialization in Russian regions has led to a significant territorial differentiation of VAC. It is logical that position of a certain region in production and sales chains is defined by the nomenclature of its products. Thus, the furthest from primary resources suppliers ($D_R \approx 3$) are the regions, economic structure of which includes resource-intensive production of the automotive (the Kaluga and Kaliningrad oblasts) and metallurgical (the Lipetsk, Vologda, and Chelyabinsk oblasts) orientation (*Tab. 10*). The most Russian regions (80 out of 85) have similar lengths of production chains ($D_R \approx 2$) and they are situated, averagely, one stage away from primary resources suppliers. Among them, the shortest production chains – $D_R \in [1,7; 2,0)$ – belong to regions with weakly diversified economy, specializing in the production of oil, gas, and iron ore (Khanty-Mansi, Nenets, and Yamalo-Nenets autonomous okrugs, Sakha (Yakutia) and Karelia republics, the Sakhalin and Astrakhan oblasts),wholesale (republics of Kalmykia and Dagestan).

Figure 10. Aggregated D_R indicator on the economy of Russian regions



Source: calculated according to Rosstat data.

Figure 11. Aggregated U_R indicator on the economy of Russian regions



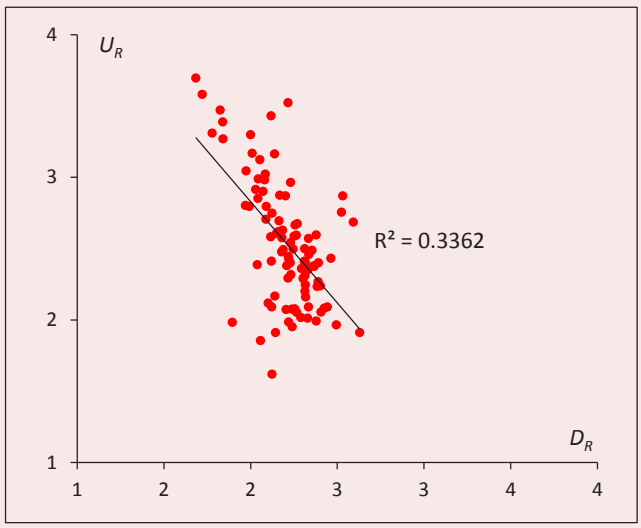
Source: calculated according to Rosstat data.

The longest sale chains – $U_R \in [3{,}0; 3{,}7]$ – are typical for resource-producing regions (Nenets, Yamalo-Nenets, Khanty-Mansiysk, and Chukotka AO, Sakha (Yakutia) and Komi republics, Kemerovo, Sakhalin, Astrakhan, Orenburg, and Magadan oblasts, Zabaykalsky Krai), products of which, before reaching final Russian consumer, go, averagely, through 2–2.5 repartitions. Values of indicator of U_R regions, specializing in processing industry[11] (Omsk, Kaluga, Vladimir, Lipetsk, Tula, Nizhny Novgorod, Novgorod, Sverdlovsk, Chelyabinsk and Vologda oblasts, Krasnoyarsk Krai), are within 2.1–3 range. Lowest U_R values are noticed in regions, where industry is poorly developed, and the economy is dominated by agriculture, food production, trade, and the health, education, and public administration sectors (Ingushetia, Tyva, North Ossetia – Alania, Altai, Kalmykia, Adygea, Dagestan, Crimea, Chechen, Karachay-Cherkess, Kabardino-Balkar republics; Kamchatka and Stavropol krais; Sevastopol).

Geographical redistribution of regional D_R and U_R indicators across the country is given in *Figures 10 and 11*. Regional enterprises in European part of Russia, averagely, take higher position in production chains. Because of their proximity to the places of population accumulation, semi-finished products from all over the country (from the regions of Siberia and the Far East through the Urals) are sent there for the production of final products.

There is a strong negative connection between the place of region in production and sale chains (correlation coefficient between D_R and U_R is equal to -0,580; *Fig. 12*). On average, the region, which is close to final consumers in supply chains, end up further away from primary resource suppliers in production chains. It means that in Russian VAC, on regional level, there is a clear territorial labor division, when some regions are specialized in extraction of various minerals, and others – in its primary processing and production of final goods from semi-finished products.

Figure 12. The scatter diagram of values of aggregated U_R и D_R indicators of Russian regions in 2017



Source: calculated according to Rosstat data.

[11] Share of gross value-added, created by processing productions, exceeds 30% of GRP.

Table 11. Correlation of regions' characteristics of socio-economic development with DR and UR indicators

Characteristics	D_R	U_R
Average per capita GRP	-0.544*	0.574*
The capital intensity of GRP	-0.355*	0.229*
The weight of unprofitable organizations	-0.226*	0.203*
Average per capita investment in fixed assets	-0.519*	0.497*
Per capita export volume	-0.318*	0.439*
Average per capita imports	-0.020	0.078
Average per capita number of small businesses	0.187	0.004
Average per capita income of consolidated budget	-0.453*	0.523*
Average per capita number of government employees	-0.326*	0.380*
Average per capita expenditure on research and development	-0.017	0.198
Costs of technological innovation	-0.252*	0.353*
Per capita population income	-0.452*	0.522*
Average monthly accrued wages of employees	-0.514*	0.622*
Per capita actual household consumption	-0.387*	0.437*
Average per capita number of passenger cars	0.240*	-0.022
Average per capita area of residential premises	0.483*	-0.153
Crude birth rate	-0.539*	0.250*
Overall mortality rate	0.627*	-0.241*
Migration growth rate	0.151	-0.333*
Population morbidity	-0.158	0.427*
Unemployment rate	-0.210*	-0.155
Crime rate	-0.158	0.475*

Note: correlation coefficients marked with * are important when $p<0.05$.
Source: calculated according to Rosstat data.

At the same time it is remarkable that the position of a region in VAC heavily defines the level of its socio-economic development. Heavy correlation of D_R and U_R indicators is noticeable with average per capita GRP, investments in fixed capital, population's incomes and consolidated budget (*Tab. 11*).

Values of all these indicators are averagely higher in regions which are located at the beginning of production chain and at the end of sale chain. At the same time, the middle link is the most "deprived" regions with developed processing industry. It might be observed that the state, as a whole, poorly copes with the task of redistributing income on VAC. This conclusion is confirmed by other researchers [27].

5. Conclusion

Conducted research allowed quantitative assessment of the degree of production fragmentation in Russian economy on the basis of analysis of production and sale chains of sectors and regional economies (as set of sectors). Its results allow drawing the following conclusions.

1. Position of a sector in production or sale chain is usually different, because the structure of products' output is not identical to the structure of purchasing intermediate materials. For example, processing productions are at the end of a production chain and in the middle of a sale chain. At the same time, there is no correlation between lengths of production and sale chains on disaggregated sectoral level in

Russia (unlike, for example, in the United States [19]). A possible explanation might be a significant disparity in export-import operations, characterized by the export of raw materials and the import of high-value products (in a closed economy, the length of production and sale chains are equal).

2. The length of production chain of a specific sector is defined by the ratio of primary and intermediate resources consumption. Material-intensive productions include more production stages, labor- and capital-intensive – respectively less. The share of gross value-added decreases as the production chain lengthens. The more fragmented production is, the fewer value-added is created at each of its stage.

3. Position of sectors in sale chain correctly reflects ranking, when one production serves as primary supplier of services for another. For example, producers of books (U = 1.935) purchase supplies from paper manufacturers (U = 2.245), which, in turn, use products of pulp producers (U = 3.211). This feature is extremely valuable for practical use in the design of VAC.

4. Russian economy has significant differentiation of regions' position in VAC and clear territorial labor division from USSR times. There is dependence between a place of region in production and sale chains. A region, which averagely stands at the end of sale chains (i.e. specializes in final production output), turns out to be further away from suppliers of fixed resources in production chain (i.e. uses more semi-products)

5. Position of the region in VAC affects the results of its socio-economic development. Comparison of D_R and U_R values with key indicators of regional development allowed pointing out its interconnections with GRP, investments in fixed capital, export, incomes of consolidated budget, population consumption (and even with fertility, mortality, morbidity, and crime)

The novelty of the research, justifying its contribution to the development of science, is the adaptation of cross-sectoral approach to assessment of production fragmentation to regional level and identification of modern regularities in the functioning of Russian VAC on the basis of its approbation on the materials of RF entities. Materials of the article might be useful for decision-makers who justify economic policy on the regional level. Prospects of following studies are connected with methodological and analytical provision of using proposed instruments in state economy's regulation. It is important to take into account the sectoral specialization of regions in existing national VAC, as well as to develop public policy directions of its extension on the basis of foresight research of industrialized countries' production and sale chains.

References

1. Granberg A.G. *Osnovy regional'noi ekonomiki* [Basics of regional economy]. Moscow: GU HSE, 2004. 495 p.
2. Gubanov S. Neo-industrial development paradigm: A brief summary. *Ekonomist=Economist*, 2017, no 11, pp. 22–39. (In Russian).
3. Lukin E.V. Trends of the development of Russian socio-economic space. *Voprosy territorial'nogo razvitiya=Territorial Development Issues*, 2014, no. 7 (17). Available at: http://vtr.isert-ran.ru/article/1425 (In Russian).
4. Kul'kov V.M. Is the transition period in the Russian economy finished? *Ekonomicheskie i sotsial'nye peremeny: fakty, tendentsii, prognoz=Economic and Social Changes: Facts, Trends, Forecast*, 2015, no. 4 (40), pp. 45–59. (In Russian).

5. Muradov K.Yu. Is Russia embedded in global value chains? *Vestnik NGUEU=Bulletin of NSUEM*, 2015, no. 4, pp. 92–117. (In Russian).
6. Kaplinsky R. Globalisation and unequalisation: what can be learned from value chain analysis? *Journal of Development Studies,* 2000, vol. 37 (2), pp. 117–146. DOI: 10.1080/713600071.
7. Shirov A.A. Use of "input-output" tables to justify economic policy decisions. *Problemy prognozirovaniya=Studies on Russian Economic Development*, 2018, no. 6, pp. 12–25. (In Russian).
8. Miller R.E., Blair P.D. *Input-Output Analysis: Foundations and Extensions*. Cambridge: Cambridge University Press, 2009. 768 p.
9. Oosterhaven J., Hewings G. Interregional input-output models. In: *Handbook of Regional Science*. Berlin, Heidelberg: Springer, 2014. Pp. 875–901. DOI: 10.1007/978-3-642-23430-9_43.
10. Cadarso M.A., Monsalve F., Arce G. Emissions burden shifting in global value chains – winners and losers under multi-regional versus bilateral accounting. *Economic Systems Research,* 2018, vol. 30 (4), pp. 439–461. DOI: 10.1080/09535314.2018.1431768.
11. Granberg A.G., Suslov V.I., Suspitsyn S.A. Economic and mathematical research of multi-regional systems. *Region: ekonomika i sotsiologiya=Region: Economics and Sociology*, 2008, no. 2, pp. 120–150. (In Russian).
12. Faturay F., Lenzen M., Nugraha K. A new sub-national multi-region input-output database for Indonesia. *Economic Systems Research*, 2007, vol. 29 (2), pp. 234–251. DOI: 10.1080/09535314.2017.1304361.
13. Oosterhaven J., Polenske K.R. Modern regional input-output and impact analyses. *Handbook of Regional Growth and Development Theories*, 2009. Pp. 423–439.
14. Zhang Z., Shi M., Zhao Z. The Compilation of China's interregional input-output model 2002. *Economic Systems Research*, 2015, vol. 27 (2), pp. 238–256. DOI: 10.1080/09535314.2015.1040740.
15. Mi Z., Meng J., Zheng H., Shan Y., Wei Y.M., Guan D. A multi-regional input-output table mapping China's economic outputs and interdependencies in 2012. *Scientific Data,* 2018, vol. 5, article number: 180155. DOI: 10.1038/sdata.2018.155.
16. Antràs P., Chor D., Fally T., Hillberry R. Measuring the upstreamness of production and trade flows. *American Economic Review*, 2012, vol. 102 (3), pp. 412–416. DOI: 10.3386/w17819.
17. Fally T. *Production Staging: Measurement and Facts*. University of Colorado-Boulder, 2012. 64 p.
18. Miller R.E., Temurshoev U. Output upstreamness and input downstreamness of industries/countries in world production. *International Regional Science Review*, 2017, vol. 40 (5), pp. 443–475. DOI: 10.1177/0160017615608095.
19. Fally T. *On the Fragmentation of Production in the US*. University of Colorado-Boulder, 2011. 49 p.
20. Chen B. Upstreamness, exports, and wage inequality: Evidence from Chinese manufacturing data. *Journal of Asian Economics*, 2017, vol. 48, pp. 66–74.
21. Ju J., Yu X. Productivity, profitability, production and export structures along the value chain in China. *Journal of Comparative Economics*, 2015, vol. 43 (1), pp. 33–54.
22. Hagemejer J., Tyrowicz J. Upstreamness of employment and global financial crisis in Poland: The role of position in global value chains. *Economics of European Crises and Emerging Markets*, 2017, pp. 217–236. DOI: 10.1007/978-981-10-5233-0_10.
23. Ito T., Vézina P.-L. Production fragmentation, upstreamness, and value-added: Evidence from factory Asia 1990–2005. *Journal of the Japanese and International Economies*, 2016, vol. 42, pp. 1–9. DOI: 10.1016/j.jjie.2016.08.002.
24. Beladi H., Chakrabarti A., Hollas D. Cross-border mergers and upstreaming. *World Economy*, 2017, vol. 40 (3), pp. 598–611. DOI: 10.1111/twec.12320.
25. Kuznetsov D., Sedalishchev V. Study of an average position of Russian economic sectors in value-added chains. *Ekonomicheskaya Politika=Economic Policy*, 2018, vol. 13, no. 2, pp. 48–63. DOI: 10.18288/1994-5124-2018-2-03. (In Russian).

26. Lukin E.V. Assessment of a position of Russian regions' economy in value-added chains. *Problemy razvitiya territorii=Problems of Territory's Development*, 2019, no. 2 (100), pp. 27–36. DOI: 10.15838/ptd.2019.2.100.1. (In Russian).
27. Ilyin V.A., Povarova A.I. Problems of regional development as a reflection of efficiency of public administration. *Ekonomika regiona=Economy of Region*, 2014, no. 3 (39), pp. 48–63. (In Russian).

Information about the Author

Evgenii V. Lukin – Candidate of Sciences (Economics), Leading Researcher, deputy head of department, Vologda Research Center of the Russian Academy of Sciences (56A, Gorky Street, Vologda, 160014, Russian Federation; e-mail: lukin_ev@list.ru)

Received October 10, 2019.