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# Oil Industry's Technological Impact on Russian Economy based on an Input-Output Model

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**Abstract**
*The purpose of this study is to determine the role and extent of the oil industry's contribution to other sectors of the economy, as well as track the impact of oil production on all value chains up to the production of the final product. The novelty of the research is the fact that, in contrast to the traditional approach, which considers only natural indicators, due to the combination of data from the intersectoral and fuel balances, the authors calculate the role and importance of the oil industry in the development of other industries in value terms. The result of the study is the conclusions about the mechanisms for creating added value in the process of the movement of raw materials along the production chain. The results obtained can be used for a more detailed analysis of the dependence of national economies on the level of development of technologies and innovations in the oil industry.*

**Key-words:** Input-output Model, Fuel Balance, Power Balance, Oil Production, Cross-sectoral Balance.

## 1. Introduction

The oil industry certainly has an impact not only on related sectors of the national economy, such as energy, petrochemicals, mechanical engineering, transport, and geological exploration, but also on all sectors of the economy as a whole. Most industries and sectors of the modern economy depend on decisions taken by the government regarding oil industry regulation. In the modern world, the industries interpenetration in the production process is very high, both due to the complexity of the latter, and due to cluster approach implementation to the territories development. One wrong decision not foreseen by the state in relation to one industry can lead to negative consequences and even a

recession in another one. The oil industry is particularly sensitive to these changes. First, oil is a basic resource for the petrochemical industry. Secondly, oil products are used both in the energy sector and in biopharmaceuticals. Finally, given the size and geographical scale of our country the expenses on logistics are substantial. Thus, the cost of a huge number of final products depends on transport costs, i.e. prices for gasoline, diesel, aviation fuel, kerosene. To define the role and assess oil industry importance in the development of other industries of Russia's economy, we studied the input-output and fuel and energy balances of the Russian Federation.

The input-output balance methodology is quite popular with various authors. Some authors consider this concept in terms of performance measurement (ten Raa: 2012; ten Raa: 2019; Balk: 2008; Amores, ten Raa: 2014). Other authors consider the input-output tables from the point of view of the formation of regional models of intersectoral balance (Flegg, Tohmo: 2013; Kowalewksi: 2015; Tobben, Kronenberg 2015). A number of authors have studied the influence of intersectoral interactions on the development of specific industries (Caliendo et al.: 2018; Burstein, Cravino: 2015; Foerster et al.: 2011). I n our paper, we used a similar approach and, based on the combination of input-output and fuel balance data, we examined the impact of the oil industry on specific sectors of the economy.

## 2. Methods

At the first stage, the purpose of the study was to determine the changes in the cost and price of energy in the fuel and energy complex of Russia during the transition through the stages of the technological cycle - from production to processing and final use of fuel and energy resources. All this will allow to correlate the productivity of the domestic market and exports, and compare weighted average prices for different end users by fuel type.

The source data for the analysis were tables of resources and use of goods and services in the Russian Federation for 2015 (Federal State Statistics Service: n.d) (Appendix 1), fuel and energy balance of the Russian Federation for 2015 (IEA: 2018) (Appendix 2), as well as data from International Energy Agency in the form of Sankey charts and tables (IEA: n.d).

The peculiarity of the analysis is to compare the data of fuel and energy balance and inter-sectoral one. It is important to note that this problem has not yet been investigated in the Russian scientific and expert literature. Due to the fact that the inter-sectoral balance of the Russian Federation is published once in 5 years, the latest statistics on it is dated by 2015. To compare the inter-sectoral and fuel and energy balances, we have identified indicators with data either available or calculated in both balances, determined their values in rubles and tons of oil equivalent, and calculated relative

indicators in rubles/t.o.e., which characterize the cost and price of fuel or energy. Then the indicators are ranked by the technological cycle of production stages, conversion and use of energy.

The research methodology is grounded on assessing region energy efficiency indicators taken from fuel and energy balance. It includes models for forecasting the fuel and energy complex of the region based on the calculation of the fuel and energy balance under various scenarios that characterize the volume of fuel production and consumption (Saneev et al.: 2013).

In turn, inter-sectoral models based on input-output tables of the Russian regions were used in scenario calculations and such indicators forecasting as electricity demand and freight traffic volumes. In the first stage, the prediction was carried out in monetary units, and then the forecasts have been adjusted for tariff changes with the use of expert assessments (Yershov et al.: 2009).

In the first decade of 2000, Russia began to apply the practice of forming a unified fuel and energy balance, which is built as a result of integrating the balances of electric and thermal energy, natural gas, coal, liquid fuel, and other solid fuels into one table. This practice corresponds to the international one, and the unified fuel and energy balance in its structure corresponds to the energy balances formed by the International Energy Agency. As a result of the unified fuel and energy balances analysis of Russia for the period from 2000 to 2010, it was found that the largest increase in fuel consumption occurred in the transport sector, which can be explained by the increase in the number of vehicles used by individuals (Bashmakov: 2012).

There are certain problems associated with providing reliable information at the stage of forming the fuel and energy balance, and these problems are even more obvious when trying to combine the fuel and energy and inter-sectoral balance, for example, in the context of economic activities (products) by fuel and energy consumption in natural and monetary terms. Experts note that when compiling the fuel and energy balance, the cases double accounting, inconsistency of information, and incomplete coverage may take place. In addition, the All-Russian Classifier of Economic Activities divides various fuel and energy complex organizations activities within a certain energy resource into several branches. Rather indicative in this connection are such industries as "Land Transport Activities" and "Petroleum Products Production". The former consumes fuel from the latter as intermediate demand products, but a significant part of the produced petroleum products is sold in retail to meet the final demand of the population. It brings up the question: how to distinguish in the fuel and energy balance the share of petroleum products consumed by the transport sector and by the population. It is likely that such accounting cannot be done directly, since gas stations do not divide customers into private and corporate, at least in the context of statistical data for the Russian Federation, there is no such information, and any corporate analytics of this kind is commercially sensitive information. The

same issue concerns electricity and heat consumption in the residential sector. In monetary terms, part of the energy consumption is related to final demand, while the other part is related to intermediate demand from the "Real Estate Transactions" sector. As a result, it is quite difficult to correlate the physical and monetary volumes of fuel and energy consumption for each type of activity.

## 3. Results

Energy resources consumption is presented directly as a result of economic activity and indirectly as consumption of goods and services produced for other industries use. The energy contribution to the total industry output consists of the amount of energy consumed to produce goods and services that are later used in the production process, as well as energy that is employed directly in the production process. The calculations are based on objective economic data - the Input-Output Tables of the Russian Federation inter-sectoral balance matrix for 2015. The information is presented in the context of 22 aggregated industries; there are three types of primary energy: products of the oil and gas industry, coal, oil shale and peat.

The energy sector includes four types of activities (products):

1. Coal and brown coal (lignite); peat (Inter-Sectoral Balance Code 10)
2. Oil and natural gas; services associated with oil and gas extraction, except exploration works (Inter-Sectoral Balance Code 11)
3. Coke-oven products and petroleum products (Inter-Sectoral Balance Code 23)
4. Electricity, gas, steam and hot water (Inter-Sectoral Balance Code 40)

Products (1) and (2) are classified as extractive industries of the inter-sectoral balance and resources of the fuel and energy balance.

Product (3) is produced based on primary energy resources transformation into petroleum products. Product (4) is based on primary energy resources transformation into electrical, thermal energy, or by producing these types of energy.

Consumers of fuel and energy in the economy are:

- Primary energy resources are consumed by industries (3) and (4) for converting to other fuels/energy.
- Primary energy resources, as well as fuel/energy after processing, are products of intermediate consumption by economic sectors. In the fuel and energy balance, their consumers are industry, transport, non-energy use, and other sectors besides residential.
- Residential sectors – households, public sector, non-profit organizations.

- Exports of fuels/energy is the same in the inter-sectoral balance and energy one.

The inter-sectoral balance allows to identify what industries consume primary products and to what extent. In this case, we are interested in mineral resources. Table I shows an excerpt from the inter-sectoral balance for the first three product groups only for the industries where these products are involved. The data is taken in millions of rubles in the buyers prices for 2015.

Table 1 - Excerpt from the Inter-sectoral Balance for the First Three Product Groups

| Economic sectors | Coal and brown coal (lignite); peat | Natural oil and gas; services related to oil and gas production, other than geological exploration | Coke-oven products and petroleum products |
|---|---|---|---|
| Agriculture, hunting and the services provided in these areas | 3,170 | 140 | 163,313 |
| Forestry, logging and services in these areas | 9 | 0 | 34,233 |
| Fisheries, fish farming and services in these areas | 95 | 0 | 71,766 |
| Mining of coal, brown coal and peat | 155,530 | 358 | 50,634 |
| Production of crude oil and natural gas; services provided in these areas | 283 | 516,894 | 128,043 |
| Mining of uranium and thorium ores | 15 | 0 | 208 |
| Metal ores mining | 290 | 0 | 25,775 |
| Mining of other minerals | 170 | 207 | 39,280 |
| Food production, including beverages | 2,147 | 132 | 37,956 |
| Production of tobacco products | 0 | 0 | 702 |
| Textile production | 15 | 0 | 1,164 |
| Manufacture of apparel; dressing and dyeing of fur | 8 | 0 | 657 |
| Production of leather, leather products and footwear | 3 | 0 | 200 |
| Wood processing and manufacture of wood and cork products, other than furniture | 16 | 0 | 15,551 |
| Production of pulp, wood pulp, paper, cardboard and products made of them | 2,271 | 0 | 11,427 |
| Publishing and printing activities, replication of recorded media | 4 | 0 | 1,375 |
| Production of coke; production of petroleum products | 63,700 | 3,137,138 | 954,314 |
| Chemical production (except for production of gunpowder and explosives) | 2,118 | 0 | 337,749 |
| Production of rubber and plastic products | 13 | 17 | 5,271 |
| Production of other non-metal mineral products | 7,603 | 953 | 48,123 |
| Metallurgical production | 158,218 | 0 | 149,791 |

| | | | |
|---|---|---|---|
| Production of finished metal products | 149 | 0 | 8,790 |
| Production of machinery and equipment (except for production of weapons and ammunition) | 696 | 77 | 14,316 |
| Production of office and computer equipment | 0 | 0 | 90 |
| Production of electric machines and electrical equipment except for production of insulated wires and cables | 21 | 0 | 5,873 |
| Production of electronic components, equipment for radio, television and communications | 18 | 68 | 1,652 |
| Production of medical devices; measuring, monitoring, control and testing instruments; optical devices, photo and film equipment; watches | 15 | 0 | 1,881 |
| Production of cars, trailers and semi-trailers | 12 | 0 | 3,479 |
| Manufacture of ships, aircraft, spacecraft and other vehicles; manufacture of other machinery and petrochemical products | 1,179 | 11 | 27,407 |
| Production of furniture and other products not included in other groups | 15 | 0 | 4,426 |
| Processing of secondary raw materials | 9 | 0 | 4,761 |
| Production, transmission and distribution of electricity, gas, steam and hot water | 180,236 | 1,329,332 | 140, 041 |
| Water collection, purification and distribution | 204 | 0 | 5,103 |
| Construction | 351 | 6,572 | 314,716 |
| Trade in motor vehicles and motorcycles, their maintenance and repair (except for sale of motor fuel) | 17 | 12 | 16,830 |
| Wholesale trade, including trade through agents, except for trade in motor vehicles and motorcycles | 707 | 156,661 | 126,738 |
| Retail trade, except for motor vehicles and motorcycles; repair of household goods and personal items; retail sale of motor fuel | 200 | 5 | 92,245 |
| Hotel and restaurant operations | 106 | 0 | 5,462 |
| Land transport operation | 634 | 52,207 | 532,865 |
| Water transport operation | 182 | 0 | 39,761 |
| Air and space transport operations | 30 | 6 | 220,322 |
| Auxiliary and additional transport operations | 694 | 398 | 149,131 |
| Communication | 206 | 0 | 14,049 |
| Financial mediation | 0 | 0 | 7,545 |
| Insurance | 0 | 0 | 4,755 |

| | | | |
|---|---|---|---|
| Support activities in the field of financial mediation and insurance | 0 | 0 | 92 |
| Real estate operations | 610 | 561 | 19,837 |
| Rent of machinery and equipment without an operator; rental of household goods and personal items | 25 | 0 | 14,753 |
| Activities related to the use of computer technology and information technology | 2 | 18 | 1,434 |
| Research and development | 26 | 26 | 7,054 |
| Provision of other services | 797 | 6,567 | 36,623 |
| Public administration and military security; social insurance | 4,512 | 0 | 118,671 |
| Education | 735 | 0 | 6,494 |
| Health and social services | 3,479 | 16 | 28,182 |
| Collection of waste water, waste and similar operations | 210 | 3 | 24,079 |
| Activities of public organizations | 30 | 0 | 1,673 |
| Recreation and entertainment, culture and sports activities | 296 | 0 | 6,982 |
| Providing personal services | 195 | 0 | 3,277 |

Thus, we see that all raw materials are directly involved in the creation of final products in almost all sectors of the national economy. During the analysis, similar tables were compiled for basic prices, trade and transport margins, taxes, intermediate and final consumption.

## 4. Discussion

A number of indicators need to be calculated in order to superimpose data from the inter-sectoral balance on the fuel and energy balance. To do this, we use the following indicators in millions of rubles.

i=1..n–products by columns of Inter-Sectoral Balance (ISB)

j=1..n – products by lines of (ISB)

N – set of products, total

M– multiple products, extractive industries (coal, oil and gas)

T–a set of products that transform fuel/energy (production of petroleum products, electricity, steam and hot water)

$a_{ij}$– table elements of goods and services in basic prices

$m_{ij}$– markup table elements equal to the sum of trade and transport and tax margins

$va_i$ - added value of the product i

$F_j$– final consumption of the product j by all sectors of the economy

$X_j$ –export of j product

Fuel and energy balance indicators, /t.o.e.:

CoalM – coal extraction

OilM – oil extraction

GasM – natural gas extraction

OilP – production of oil products

EnOut – produced electricity and heat, at the output, minus losses

ErD – electricity and heat (e/h) used in the economy (in the domestic market in intermediate and final demand)

ErX - electricity and heat export

Table II. shows the fuel and energy balance data on the final energy use.

Table 2 - Fuel and Energy Balance Data on Final Energy use, mln./t.o.e., 2015

| Fuel | Coal | Oil and Gas | Oil Products | Electricity and heat | Total |
|---|---|---|---|---|---|
| Extraction | 200.3 | 1060.6 | | | 1260.9 |
| Transformation: oil products-input | | 283.6 | | | 283.6 |
| Transformation: oil products-output | | | 283.6 | | 283.6 |
| Transformation: e/h energy - input | 59.6 | 199.7 | 6.7 | 73.6 | 349.9 |
| Transformation: e/h energy - output | | | | 216.0 | 216.0 |
| Used in the economy (ErD) | 27.4 | 141.2 | 114.6 | 169.2 | 452.4 |
| Export (ErX) | 99.7 | 412.5 | 135.2 | | 647.4 |

To combine data from the fuel and energy and inter-sectoral balances, some indicators must be calculated.

Cost of fuel for extractive industries with extra charges:

$$CM_i = \sum_{i=1}^{M}\left(\sum_{j=1}^{N} a_{ij} + va_i\right) + \sum_{i=1}^{M}\sum_{j=1}^{N} m_{ij}, \text{ for } i \in M$$

Input cost of fuel and energy for transforming industries:

$$CT_i^{inp} = \sum_{i=1}^{T}\left(\sum_{j=1}^{M+T} a_{ij} + \sum_{j=1}^{N} m_{ij}\right), \text{ for } i \in T, j \in M, j \in T$$

Output cost of fuel and energy for transforming industries:

$$CT_i^{out} = \sum_{j=1}^{N} a_{ij}, \text{ for } i \in T$$

The cost of intermediate and final consumption of fuel and energy, with extra charges for the domestic market:

$$ED = \sum_{j=1}^{M+T}\left(\sum_{i=1}^{N} a_{ij} + \sum_{i=1}^{N} m_{ij}\right) + \sum_{j=1}^{M+T} F_j + MF_j, \text{ for } j \in M, j \in T, i \in N - T, i \notin T$$

Export of fuel and energy, with export margins MX

$$EX = \sum_{j=1}^{M+T} X_j + MX_j, \text{ for } j \in M, j \in T$$

The price of 1 t.o.e. of extracted coal

$$P^{coal} = \frac{CM_{coal}}{CoalM},$$

Average price of 1/t.o.e. oil and natural gas produced. Separate price calculation is not possible, because the ISB has only one product "oil and gas production".

$$P^{oil\&gas} = \frac{CM_{oil\&gas}}{OilM+GasM},$$

The price for oil products, rub.//t.o.e.

$$P^{oilP} = \frac{CT^{out}_{OilP}}{OilP},$$

Average price of electricity and heat, rub.//t.o.e.

$$P^{EnOut} = \frac{CT^{out}_{EnOut}}{EnOut},$$

The average price of fuel and energy resources consumed in the intermediate demand of economic sectors (mining, manufacturing, and services) and the final demand of economic sectors:

$$P^{ErD} = \frac{ED}{ErD},$$

Average price of fuel and energy resources exported:

$$P^{ErX} = \frac{EX}{ErX}.$$

Cost 1 /t. o. e. = Costs, million rubles / volume, million rubles /t.o.e.

Price for 1/ t. o. e. = Cost of 1 / t.o.e. + extra charges for 1/t.o.e.

Extra charges are related to trade and transport and tax margins. The amount of margins for each product is determined by the sum of elements in the tables of trade and transport and tax margins, or by the difference between elements in the Table of goods and services in consumer prices and the Table of goods and services in basic prices.

Price change during the transition by stage-this indicator reflects the difference in the price for 1 / t.o.e. fuel/energy:

- For oil products at the input – the difference between the price of oil purchased by the refinery and the cost of oil produced;
- For oil products at the output – the difference between the selling price of oil products, without extra charges, and the price of oil purchased by the refinery;
- For electric(heat)energy at the input – the difference between the cost of supplying purchased fuel for power plants and boilers and the cost of extracting it;
- For electric (heat)energy output – the difference between the selling price for consumers of electric and heat energy, and the price of fuel consumed;

- For comparison, the indicator "the same without losses" is calculated - in this case, the cost of electricity and heat is attributed to the amount of FER at the input, not at the output. FER at the output are reduced by the amount of losses that depend on the efficiency of the stations and losses in the networks. This indicator is needed to assess how much of the added value of electricity and heat is determined by technological factors, and how much is determined by economic factors;
- In intermediate consumption of FER for economy sectors - the difference between the price of fuel/energy supply and the purchase price for intermediate consumption, taking into account the structure of the fuel/energy consumed;
- In final consumption of FER for economy sectors - the difference between the price of fuel/energy supply and the purchase price by households, public and non-profit sectors, taking into account the structure of fuel/energy consumed;
- Export – the difference between export prices and selling prices of fuel/energy, including export margins.
- Prices in terms of oil, in dollars per barrel, are calculated:

$$Pd = Pr \cdot \frac{TB}{Exd}$$

Where Pd – price per barrel of oil, US dollars

Pr – price per barrel of oil, Rubles,

TB – the ratio of converting energy units from ton of oil equivalent (t.o.e.) to barrels is 0.1364 barrels per ton;

Exd – the average annual exchange rate of the US dollar to Russian rubles, in 2015, equal to 61.3194 rubles/USD.

The price of oil products per 1 liter of standard fuel is determined:

$$\mathrm{RPop} = \mathrm{OPOutRub} \cdot \frac{1000}{0.8}$$

Where RPop – estimated retail price of petroleum products, including margins, RUB/liter;

OPOutRub – estimated retail price of light oil products (output price of oil products), RUB//t.o.e.

0.8 – average weight of light oil products (gasoline and diesel fuel), kg / liter.

The estimated selling price of electric power (EPe), rubles/kWh:

$$\mathrm{EPe} = \mathrm{EOutRub} \cdot 11{,}630$$

Where EOutRub – price of electric and thermal energy at the output, RUB //t.o.e.

11,630 – conversion rate/t.o.e. in kWh, kWh //t.o.e.

Table III presents the results of a combined analysis of the inter-sectoral balance and the fuel and energy balance of the Russian Federation in monetary terms.

Table 3 - Results of Combined Analysis of Inter-sectoral and Fuel and Energy Balances of the Russian Federation

| Stage | Product | Volume, mln./ t.o.e. | Costs, million rubles | Costs 1/ t.o.e., rubles | Mark-up, million rubles | Mark-up на 1 /t.o.e., rubles | Proce for 1/t.o.e. |
|---|---|---|---|---|---|---|---|
| Resources | Coal and brown coal; peat | 200 | 806,973 | 4,029 | 22,927 | 114 | 4,143 |
| | Oil and natural gas | 1,061 | 8,978,465 | 8,465 | 19,430 | 18 | 8,484 |
| Transformation | Oil products: raw materials received | 284 | 4015,255 | 14,158 | 239,452 | 844 | 15,002 |
| | Oil products: FER produced | 284 | 7,182,568 | 25,326 | 0 | 0 | 25,326 |
| | Electricity, gas, steam and hot water: fuel received | 350 | 3,284,083 | 9,386 | 827,700 | 2,366 | 11,751 |
| | Electricity, gas, steam and hot water: energy produced | 216 | 6,954,304 | 32,196 | 0 | 0 | 32,196 |
| | The same les losses | 350 | 6,954,304 | 19,875 | 0 | 0 | 19,875 |
| Final consumption | Used in the economy | 452 | 8,392,836 | 18,552 | 1,419,192 | 3,137 | 21,689 |
| | Export | 647 | 8,055,695 | 12,443 | 4,742,010 | 7,325 | 19,768 |

## 5. Conclusion

Thus, based on the combination of data from the inter-industry and fuel and energy balances of the Russian Federation, the structure of consumption of primary hydrocarbon raw materials by production stages is analyzed, not only in natural terms, but also in cost terms. The costs of production and conversion of oil and petroleum products were allocated, and both total margins and margins per 1 ton of oil equivalent were calculated.

This analysis allows us to trace in more detail the dependence of the national economy on the Russian oil industry, and draw conclusions about the mechanisms of creating added value in the process of movement of raw materials along the production chain. As we can see from the above analysis, all industries use oil or its derivatives directly or indirectly in their production cycles.

For this reason, effective inter-sectoral production and regulatory interaction is crucial. It is important to evaluate the regulatory impact of new tools implementation to regulate the industry that will directly influence the oil industry and organizations included in it, but will also effect related industries, whose activities directly depend on management decisions taken in the sphere that is an "anchor" one for them.

**References**


Amores, A.F., Ten Raa, T. (2014). Firm efficiency, industry performance and the economy: three-way decomposition with an application to Andalusia. *Journal of Productivity Analysis, 42*(1), 25-34.

Balk, B.M. (2008). *Price and Quantity Index Numbers: Models for Measuring Aggregate Change and Difference.* Cambridge: Cambridge University Press, 283.

Bashmakov, I.A. (2012). Energy balances of the Russian Federation and subjects of the Russian Federation as the basis for developing and monitoring energy efficiency programs. *Energosovet, 4,* 21-29.

Burstein, A., Cravino, J. (2015). Measured aggregate gains from international trade. American Economic Journal: Macroeconomics, 7(2), 181-218.

Caliendo, L., Parro, F., Rossi-Hansberg, E., Sarte, P.-D. (2018). The impact of regional and sectoral productivity changes on the U.S. economy. *Review of Economic Studies, 85*(4), 2042-2096.

*Federal State Statistics Service.* (n.d). Available: https://www.gks.ru/accounts

Flegg, A.T., Tohmo, T. (2013). Regional Input-Output Tables and the FLQ Formula: A Case Study of Finland. *Regional Studies, 47*(5), 703-721.

Foerster, A.T., Sarte, P.D.G., Watson, M.W. (2011). Sectoral versus aggregate shocks: A structural factor analysis of industrial production. *Journal of Political Economy, 119*(1), 1-38.

IEA. (n.d). Data and Statistics. https://www.iea.org//statistics/

IEA. (2018). Russian Federation Balance (2018). https://www.iea.org/Sankey/#?c=Russian%20Federation&s=Balance

Kowalewksi, J. (2015). Regionalization of National Input–Output Tables: Empirical Evidence on the Use of the FLQ Formula. Regional Studies, 49(2), 240-250.

Saneev, B.G., Sokolov, A.D., Muzychuk, S.YU., Muzychuk, R.I. (2013). Methodological approach to assessing energy efficiency indicators of the economy when changing the structure of the fuel and energy balance (on the example of the Baikal region). *Spatial Economics, 4*, 90–106.

Ten Raa, T. (2012). Performance measurement in an input-output framework. *Journal of Economic Structures, 1*(1), 1-5.

Ten Raa, T. (2019). *"Performance: the output/input ratio",* in: T. ten Raa, W. Greene (eds.), The Palgrave Handbook of Economic Performance Analysis. Cham: Palgrave Macmillan, pp. 77-95.

Tobben, J., Kronenberg, T. (2015). Construction of multi-regional input–output tables using the charm method. *Economic Systems Research, 27*(4), 487-507.

Yershov, Yu. S., Melnikova, L.V., Suslov, V.I. (2009). Practice of using optimization multi-regional intersectoral models in strategic forecasts of the Russian economy. *Bulletin of NSU. Series: Socio-Economic Sciences, 9*(4), 9-23.