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Inter-sector Inter-Region Model for Russian Economy: Methodology and Application

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ABSTRACT

The paper presented is intended to analyze an approach to a long-term inter-sector and inter-regional economic analysis as based on an optimization model. This approach was developed in IEIE SB RAS and resulted in several directions of application. One of them is investigation of interactions between a national economy and its energy production segment. The model being discussed includes input-output tables for six regions of Russian economy supplemented with model blocks for interregional transportations. It includes a natural block of energy production, processing and transportation. The last version of this model combines 45 products of different economic sectors including 8 ones of an energy sector (rough oil, gas and coal, two kinds of petroleum products, coal processing, electricity and heat), and 6 Russian macro-regions; it is a composition of two sub-models for 2 time periods: 2008-2020 and 2021-2030. Each of the sub-models treats time changes in simplified manner – it means that all the variables are defined for the last year of the period and the variables of the basic year are fixed as exogenous ones. The dynamics of investments into fixed capital is treated as non-linear functions being adapted with the help of linearization techniques.

Keywords: Inter-regional Economic Analysis Optimization Model, Energy Sector, Economic Growth
JEL Classifications: E170

1. INTRODUCTION

Energy aspect plays the significant role in economic development of the country and there are plenty of research trying to understand the role of natural resources in regional economic growth. The importance of energy sector for export oriented countries was discussed a lot, different econometric methods were used to prove this point of view (Nyangarika et al., 2018). Some researchers try to analyze only some group of regions, such as Arctic ones, focusing on energy system structure's study (Tabachkova et al., 2020); some researches tried to estimate the elasticity of energy intensity on the regional scale (Burakov, 2016) that could be implemented both for different countries and regions.

In our research we made not the econometric analysis but the optimization one. The goal was to present the optimization model that could be used under different conditions and predict the impact of energy sector's performance on GDP in long-term period. Our approach takes into account the high level of regional diversification in Russian Federation. Without any doubt this model could be used to predict the consequences of COVID19 for Russian regions with including parameters for this year in the model. So the most important thing is that our model could be used as the reliable instrument for making forecast in accordance to today's conditions.

The main advantage of approach is that it's very adaptive: it was firstly presented in USSR and is still implemented for modern economic reality. Changing the input parameters researchers will get the reliable long-term estimations of different economic variables' impact on the regional growth.

Modern versions of OMMM (Optimization Multi-sector Multi-region Model) are based on the following statistical data:

- Aggregated Input-Output Tables for the Russian national economy for each year from 1995 up to 2004 which include 20 sector products;
- Tables of goods and services consumed in Russia (in consumer prices of next year) which include 20 sector products,
- Russian National Input-Output Tables for 2011-2017 which include more than 100 sector products, and
- Other statistics provided by the Russian Statistics (ROSSTAT).

There are certain difficulty in calculating regional input-output tables. Unfortunately, neither ROSSTAT, nor regional statistical bodies have started with issue such data since the beginning of the economic reforms, at least in regularly and in complete patterns. That is why we, since the end of 1980s, have to adjust regional differences of input coefficients to update current regional IO tables. For this purpose, we apply certain kinds of RAS methods.

A basic advantage of the OMMM-Energy is a combination of different approaches such as the input-output, inter-regional and energy balances. This allows evaluating the complex effects and efficiencies of the policy measures undertaken in the spheres of production, processing and consumption of energy. Previously, the model was applied to evaluating economic consequences of the:

- The concentration of energy-intensive productions and gasification in the South Siberia regions;
- The fast development of nuclear energy in the national economy;
- A reduction of energy intensity in a production sector of the national economy;
- A wide application of heat pump technologies in different regions of the national economy;
- Large-scale utilization of the waste heat produced by industries, agriculture and households;
- A program for use of renewable energy sources, and many others of less significance.

We consider the novelty of the paper presented as, first, critical comparison of analytical strength of the model of the type we deal to analytical strength and options of MRIO analysis. Secondly, we applied the model to estimate economic consequences of forcing Russian energy products out from European markets. At present a danger of displacement of Russian energy carriers from European markets is increasingly urgent. At a time when European gas demand reduces and competition strengthens (European Gas Market, 2015), gas supply could grow. For example, the new gas production technologies applied by the USA allowed the country to increase its production of natural gas quickly and refuse of its import what made this resource available for other markets. Further use of new technologies by the US or other countries could make the world's gas supply higher that could reduce gas prices if gas demand is stable. Thus, it is expectable for the European market that additional gas produced will replace coal too as gas is an environmentally friendly and more effective fuel. Moreover, some European countries have political motives to reduce purchases of Russia's gas.

2. HISTORY AND LITERATURE REVIEW

Russia is the largest country in the world covering 12% of the Earth's land area and spanning four climate zones (Canada, being the second largest country, covers twice less area). Russia extends from the East to the West for about ten thousand kilometers. The enormous size of Russia results in the different climate conditions, landforms and remoteness of many regions from the seas. Average January temperatures in different regions varies from 6°C to −50°C; June ones – from 1°C to 25°C; and atmosphere precipitations – from 150 to 2000 mm per year. The extent of permafrost is 65% of a total Russian territory (in the regions of Siberia and the Russian Far East). Moreover, the natural resources are unevenly distributed within the territory of the country – about 80% of them are concentrated in the western areas (in Siberia and the Far East). The proximity of the Russian European regions to seas and European markets, as well as historical factors made these regions more economically developed. These regions cover 23% of the total area of Russia; 82% of all the Russian population lives here and they produce ¾ of t*he Russian GDP. There are 83 administrative regions in Russia, and the difference between them in levels of production and populations' incomes per capita is rather high.

Due to the high environmental and economic heterogeneity of the Russian territory, the development and implementation of regional policies becomes one of the key factors of the national development. Awareness of this fact resulted in the progress of regional studies in the Soviet Union and later in Russia. In the 1960s we started the application of MRIOs.

The OMMM was proposed in the 1960s and described in (Granberg, 1973) for the 1st time. The first Soviet Union experimental forecasts for 1966-1975 involving 16 economic sectors and 11 regions were made in 1967. Another series of forecast calculations for 1975-1990 was made in the next years up to 1978. MRIOs of a Siberian type were involved in the UN Project on The Future of the World Economy in 1978-1982 at the suggestion of the UN AG Secretariat. Two systems of models – SYRENA and SONAR, both OMMM-based ones – were developed in the middle of the 1980s. The first model focuses on a national economy–region problem, while the second one (consisting of OMMM-Energy and several models for economic sectors) – addresses a national economy–economic sector problem. Since that time such OMMM was applied to forecast economic regional and sector development as well as to analyze how regions and sectors interact. This model also allows understanding how the supply shocks and investment project impact upon the national economy and regional ones.

To model regional interactions instead of specifying trade coefficients, the import/export of products to/from neighboring regions are added to the equations for balances of products. Therefore, such model includes not only production IO matrixes, but also matrixes of the inter-regional transportation of products. An international export-import is represented only for regions capable to do so, i.e. the frontier ones. In such basic model, which we describe here, the volumes of export/import are determined for each identified sector; however, in some further versions of this model, they are endogenous, and the models include a national foreign export -import balance assuming that the country has a zero balance of trade (in the prices of the world markets) (Granberg et al., 2007).

In our opinion, such approach to modeling regional interactions has its advantages and disadvantages. The fact that it hampers an analysis of spillovers between regions – it is difficult to find out the dependence of output increments and final demand – make up such disadvantage. Moreover, a number of methodical and informational issues concern a transportation block – no counter flows are included into models of sector products transportation, and this brings about the roughening solutions which are the higher, the bigger the level of aggregation of sectors is. Certain difficulties lie in calculating coefficients of intra- and inter-regional transportation. In fact, a segment of demand for transportation sectors has to be set endogenously (to include counter flows costs) while coefficients of transportation costs – proportionally to average distances of transportation (Granberg, 1973, Suslov et al., 2007).

However, the transportation matrixes introduced into such model allows an optimization setting of the problem which is also desirable. This, in its turn, makes the structure of production and transportation more flexible, and this fact can be regarded vital for long-term forecasting made by applying such models. A comparative analysis of production efficiencies in different regions is available too as well as an introduction of additional alternative production technologies to produce a product of one species. However, as the model is linear, it is supplemented with the constraints for the output variables – (5).

An investment block of the model reflects the dynamics of production. All the variables of output, final demand, interim demand and demand for production factors in each region are defined for the last year of the time period of the model. Total investments for each kind of fixed capital are also specified. This is done through setting a law of investment growth and such laws for each kind of fixed capital as well. Generally, a power law is applied to specify functional dependencies of investments made in the last year of the time period on total investment made over the whole time period. Such dependencies enter the model as linear approximations. There are two kinds of output variables to model an investment process – the outputs received on production capacities existed up to the beginning of the period (old capacities) and those received on production capacities incorporated during the period (novel capacities) the investment coefficients for which are calculated according to different techniques.

An objective function of the model is households' total consumption including consumption of public goods. Generally, such model has the fixed sector and regional structure of consumption. A sum of α_i^r coefficients in the constraint (1) is equal to 1: $\sum_{i=1}^{n}\sum_{r=1}^{R}\alpha_i^r = 1$

and the model is resulted to be a closed one for most variables of the final demand such as capital investments, investments in reserves (they are included in the sector's consumption of their own products $a_{jj}^{r1} \cdot x_j^{r1}$ - see the balance constraints 1), population's consumption, and variables of domestic net export.

We present principle constraints of the basic OMMM below. It includes n segments of products and services (except transport services), T kinds of transport and R regions. Within the model there are several investment-generating sectors (which enter a set G) and as many kinds of investment, respectively. Each regional block r includes 5 kinds of constraints – the inequalities (1)-(5). The objective function is set not for a regional block but for the model in whole.

$$x_i^{r0} + x_i^{r1} - \sum_{j=1}^{n} a_{ij}^{r0} x_i^{r0} - \sum_{j=1}^{n} a_{ij}^{r1} x_i^{r1} - U_i^{r1} - a_i^r \bullet Z - \sum_{\tau=1}^{T}\sum_{s\neq r} x_i^{rs}$$

$$+\sum_{\tau=1}^{T}\sum_{s\neq r} x_i^{rs} - NEX_i^r \le b_i^r, i = 1,...,n \quad (1)$$

$$x_\tau^{r0} + x_\tau^{r1} - \sum_{j=1}^{n} a_{\tau j}^{r0} \cdot x_j^{r0} - \sum_{j=1}^{n} a_{\tau j}^{r1} \cdot x_j^{r1} - \sum_{s\neq r}\sum_{j=1}^{n} a_{\tau rj}^{rs} \cdot x_j^{rs}$$

$$-\sum_{s\neq r}\sum_{j=1}^{n} a_{\tau rj}^{sr} \cdot x_j^{sr} \ge b_\tau^r, \quad \tau = 1,\dots \mathrm{T} \quad (2)$$

$$\sum_{j=1}^{n} l_j^{r0} \cdot x_j^{r0} + \sum_{j=1}^{n} l_j^{r1} \cdot x_j^{r1} + \sum_{\tau=1}^{\mathrm{T}} l_\tau^{r0} \cdot x_\tau^{r0} + \sum_{\tau=1}^{\mathrm{T}} l_\tau^{r1} \cdot x_\tau^{r1} \le L^r \quad (3)$$

$$\sum_{j=1}^{n} k_{gj}^{r0} \cdot x_j^{r0} + \sum_{j=1}^{n} k_{gj}^{r1} \cdot x_j^{r1} + \sum_{\tau=1}^{\mathrm{T}} k_{g\tau}^{r0} \cdot x_\tau^{r0} + \sum_{\tau=1}^{\mathrm{T}} k_{g\tau}^{r1} \cdot x_\tau^{r1}$$

$$-f(u_g^{r0}, u_g^{r1}) \le 0, g \in G \quad (4)$$

$$\xi_i^{r0} \le x_i^{r0} \le \zeta_i^{r0}, \quad \xi_i^{r1} \le x_i^{r1} \le \zeta_i^{r1} i = 1,\dots,n \quad (5)$$

$$\xi_i^{r0} \le x_i^{r0} \le \zeta_i^{r0}, \quad \xi_i^{r1} \le x_i^{r1} \le \zeta_i^{r1} \max Z \quad (6)$$

Here endogenous variables are:

x_i^{r0} и x_i^{r1} - production outputs of *i*-sector in *r*-region obtained by old and novel production capacities;

x_τ^{r0} и x_τ^{r1} - transportation work made by transport of kind τ in *r*-region within the framework of transport capacities of the transport infrastructure available as of the beginning of the period and that one developed over the period, respectively;

u_i^{r1} - a volume of capital goods *i* invested in *r*- region in the last year of the period;

Z - total consumption of households;

x_i^{rs} –- a fraction of output of *i*-sector transported from *r*-region to *s*-region;

Exogenous variables are:

a_{ij}^{r0} и x_τ^{r1} - intra-regional input coefficients (*i*-sector product per output of *j*-sector in) in *r*-region at old and new production capacities correspondently;

$a_{\tau j}^{r0}$ и $a_{\tau j}^{s1}$ - amount of transport service of kind τ consumed per a unit of sector i product at old and new production capacities correspondently;

$a_{\tau rj}^{rs}$ и $a_{\tau rj}^{sr}$ - - amount of transport service of kind τ consumed to bring a unit of sector j product from s-region r-region;

$l_j^{r0}, l_j^{r1}, l_\tau^{r0}$ и l_τ^{r1} - labor input coefficients at old capacities and novel capacities in production sector j and transport sector τ respectively in r-region;

$k_{gj}^{r0}, k_{gj}^{r1}, k_{g\tau}^{r0}$ и $k_{g\tau}^{r1}$ - investment input coefficients of g- kind of investment good at old capacities and novel capacities in production sector j and transport sector τ respectively in r-region;

α_i^r - a share of sector i from region r in the Russian total volume of consumption;

u_g^{r0} - investments of kind g made in r-region in a basic year;

NEX_i^r - net international export (export minus import) of products of i-sector from r-region;

b_i^r - a fixed share of demand for products of i-sector in r-region.

The inter-regional production and distribution balances of products and services (except transportation services) reflect both intraregional consumption flows and export ones (1). However, how the exported products and services are going to be consumed is not presented in these balances while the imported products and services are included into domestic consumption. The export and import between counties are fixed values in this version of the model.

The transportation balances reflect intra-regional transportation flows as well as export/import ones. The $a_{\tau j}^{rs}, a_{\tau j}^{sr}, a_{\tau rj}^{rs}$ и $a_{\tau rj}^{sr}$ coefficients are calculated on the basis of both average transfer distances and indices of weight of a transferred product unit of a given sector.

The labor balances are the constraints describing labor demand in a given region, while supply is specified exogenously on the basis of the demographic forecasts available.

The investment balances specify the investments made not over the last year of the period but over the time period in whole. They balance the demand represented as a sum of the output multiplied by investment coefficients and total output of capital goods produced over the whole period. The functions $f(u_g^{r0}, u_g^{r1})$ which represent a total volume of g- investment made in r-region play a key role. In assumption that $u_g^{r1} = (1+\rho_g^r)\cdot u_g^{r0}$ where ρ_g^r is an average annual rate of growth of g-investment made in r-region, the functions $f(u_g^{r0}, u_g^{r1})$ depend on ρ_g^r and could be easily calculated and then substituted by their linear approximations. In fact, it is the rates of investment growth ρ_g^r which we approximate.

Modern versions of OMMM are based on the following statistical data:
1. Aggregated Input-Output Tables for the Russian national economy for each year from 1995 up to 2004 which include 20 sector products;
2. Tables of goods and services consumed in Russia (in consumer prices of next year) which include 20 sector products,
3. Russian National Input-Output Table for 1995 which includes more than 100 sector products, and other statistics provided by the Russian Statistics (ROSSTAT).

There some difficulty in calculating regional input-output tables. Unfortunately, neither ROSSTAT, nor regional statistical bodies have started with issue such data since the beginning of the economic reforms, at least in regularly and in complete patterns. That is why we, since the end of 1980s, have to adjust regional differences of input coefficients to update current regional IO tables. For this purpose we apply certain kinds of RAS methods.

3. OMMM WITH ENERGY BLOCK

Russian energy sector is the largest and most important one for the economy of the country. Russia possesses about 13% of the world oil reserves, more than 35% of the world gas reserves and 12% of the world coal reserves, and this could be regarded as a basic competitive advantage of our economy which could last long. The energy sector produces about 15% of GDP while it consumes approximately a quarter of the national investments. However, it produces about 60% of a total Russian export and as many percents of a consolidated budget of the Russian Government. This fact displays that energy production has an extremely strong indirect influence on the economy of Russia, and therefore, there is a need for a comprehensive analysis of interrelations between the national economy and its energy sector. Moreover, given the extremely heterogeneous distribution of energy resources – mostly in Siberia and the Far East regions, and high concentration of the population and non-energy productions in European area of the country, of inter-regional interactions plays a key role.

The studies on interactions between the national economy and its energy sector, which has brought the relatively noticeable results, started only the 1970s due to the energy crisis (Mann, 1978, Bullard and Pilati, 1976, Dantzig and Parikh, 1976, Hogan, 1974, Hudson and Jorgenson, 1974, Van der Voort, 1982). They applied both large models with an energy sector included and combinations of economic and energy models united in a general model. The researchers' priority issues were the problems of tax and trade policies and how prices for energy resources influence the structures of energy consumption and national economy. Later, the modeling focuses on long-term forecasting of energy consumption, the development of fuel-energy complexes and what such complexes could contribute to economic development of the country (Chateau and Quercia, 2003, The Energy Market, 2002, The National Energy, 2009, Voß et al., 1995). These studies were made in the Soviet Union and later in Russia by the ISEM SB

RAS, INEI RAS, IEIE SB RAS by applying IO models. Having started the development of its own approach since the 1980s, the IEIE SB RAS applies a multi-regional IO model, later called as OMMM-Energy.

OMMM-Energy is an optimization multi-sector multiregional model which presents an energy sector and its energy production in their physical indicators. It was developed on the basis of "classical" OMMM discussed before. A current model includes 45 economic sectors, with 8 products among them, and 6 Russian economic zones (the European zone, Ural region, Tyumen Oblast, West Siberia, East Siberia and Far East). It succeeds basic advantages and disadvantages of the OMMM-prototype and differs from the latter in a number of aspects.

Firstly, it is a two-period forward recurrence model containing two sub-models – one for 2008-2020 and the second - for 2021-2030. The investment dynamics is reflected in both of them through an OMMM-prototype; this means that a law of investment growths is set as a non-linear one and then it is linearized. The solutions of the first model become basic indicators for the second one.

Secondly, the energy sectors are presented in greater detail. This was done, among other purposes, to present energy products in physical indicators. A current model includes 8 energy products such as solid fuel, processed coal, oil and associated gas, gas and condensed fluid, dark- oil products, light oil, electric power and heat. This allows monitoring ratios between primary and final energy produced.

Thirdly, some non-energy sectors which are important for analyzing the energy sector were specified such as the industry producing equipment required for production, transportation and consumption of energy, petroleum chemistry and some others.

Finally, we modified the model to allow for the specifics of how any fuel-energy complex can operate such as:

1. Specific reproduction of capacities in the oil-and-gas sector;
2. The development of resource industries highly depends on whether geophysical prospecting have been done and its results if it has been done; it also depends on to what degree the fuel resources have been developed in different regions and in the country in whole;
3. Complementary outputs of different energy technologies (e.g. oil and associated gas, or gas and condensed fluid)
4. Specific transportation of oil and gas (a pipeline system);
5. Availability of alternative technologies for energy and heat production at heat stations, condensing plants, nuclear power plants, boiler plant, and etc. which operate on different fuel (coal, fuel oil, and gas).

A classic OMMM assumes that any sector product is manufactured by "old" and "novel" production capacities. The capacities, which operated from the beginning to the end of a predictable period and by which the product was produced over the period, we consider as old ones. Those, which were produced through investments into extension of capacities to yield a sector output growth, we consider as novel ones. A notion of "old capacities" for resource industries differs from that for processing industries as the resource industries deal with production of irreproducible resources. In this context, each share of investments requires an additional share of the commercial oil and gas reserves and can be regarded as new capacities costs. Moreover, an annual volume of capacities retired in oil-and-gas sectors is relatively high.

Due to the said specifics, we applied another approach to modeling reproduction process in these industries, not that one which was applied in the OMMM prototype, i.e. the variables of investments are considered as nonlinear functions of extracting capacities put into operation over the predictable period. Such functions, firstly, reflect the rises in costs for new capacities because of transition from more to less efficient oil and gas fields, and secondly, they allow us to take into account an increased volume of capacities retired.

In addition, we introduced a new block of oil-and-gas reserves which reflect a ratio between novel production capacities and new commercial reserves put into operation in a given region or in the sector in whole. To do so, we consider urgent as we need know a ratio between a degree of redundancy of oil reserves and annual gas production. According to the reproduction laws for these industries, such redundancy lies in certain fixed limits. If it is higher than an allowable value, the freezing of large funds invested into geological prospecting may occur; if it drops below the bottom, our forecasts of oil-and-gas production may happen unreliable. Thus, such degrees of redundancy being fixed serve as an upper limit for variables of commissioning novel facilities while the investments into reserves (geological prospecting) are included into a total investment balance.

We use OMMM-Energy both as individual analysis instrument and together with some other constructions. Its supplementation with econometric models of energy consumption is seen as a fruitful approach. E. g. we use regressions for energy intensity (energy input) coefficients to explain factors influencing them and to substantiate their values for future periods which helps to improve our forecast scenarios (Suslov et al., 2016). Another function of econometrical analysis of energy consumption is setting the problem to be analyzed with the help of IRIO model. As a such we select and treat the problem of energy intensity differences seen in the scope of the world economies.

4. APPLICATION OF OMMM-ENERGY

A basic advantage of an OMMM-Energy is a combination of the different approaches such as input-output, inter-regional, and energy balances. This allows evaluating complex effects and efficiencies of the policy measures undertaken in production, processing, and consumption of energy. Previously, such a model was applied to evaluating economic consequences of:

1. The concentration of energy-intensive productions and gasification in the South Siberia regions;
2. The fast development of nuclear energy in the national economy;
3. Reduction of energy intensity in a production sector of the national economy;

4. Wide application of heat pump technologies in different regions of the national economy;
5. Large-scale utilization of the waste heat produced by industries, agriculture and households;
6. Program for use of renewable energy sources, and many others of less significance.

This model is quite applicable to assessing of how changes in external conditions, for example, external economic threats, may impact on the Russian economy. At present a danger of displacement of Russian energy carriers from European markets is increasingly urgent. At a time when European gas demand reduces and competition strengthens (European Gas Market, 2015), gas supply could grow. For example, the new gas production technologies applied by the USA allowed the country to increase its production of natural gas quickly and refuse of its import what made this resource available for other markets. Further use of new technologies by the US or other countries could make the world's gas supply higher that could reduce gas prices if gas demand is stable. Thus, it is expectable for the European market that additional gas produced will replace coal too as gas is an environmentally friendly and more effective fuel. Moreover, some European countries have political motives to reduce purchases of Russia's gas. Our expert analysis shows that an expectable proportion of the displacement of Russia's coal and gas will be 2-3 in physical terms, i.e. in tons of coal and thousands of cubic meters of gas.

4.1. Export of Russia's Energy Resources

As the Rosstat data shows, a share of the Russia's fuel and energy complex in the country total export grew from 40% in 1995 to 70% in 2011, and then it dropped to 60% in 2016 (Table 1). Though a major source of Russia's federal revenues comes from export of oil and oil products, it is worth seeing how the Russian economy and its regions will react to possible fluctuations of other energy exports, specifically, of coal and gas exports, the shares of which in Russia's total energy export revenues varied from 20 to 48% in the previous period (Table 1).

Application of an OMMM-Energy allows the macroeconomic estimates of how fluctuations in energy exports impact on the regional production and geographical orientation of export. A subject under our study is export of coal by Kuznetsk (Kemerovo Oblast) and export of natural gas by Tyumen region (Tyumen Oblast and the federal autonomous okrugs) both west-oriented.

4.1.1. Coal export

The Russia's coal export became 5.9 times higher from 1999 to 2016 and it reached 165 million tons which is its maximum value over recent years. An average annual growth was nearly 8 million tons in 2000-2016, and 10, 16, and even 20 million tons – in certain years. This resulted in the fact that its share in a volume of the national production increased from its minimal value 8.9% (1994) to 43%. At the same time, the export fluctuations towards a decrease (as compared to a previous year) observed in the period under study didn't exceed 4.7 million tons.

The researchers state that a growth in coal export activities was caused by several factors. The restructure of the Russia's coal sector (the unprofitable coal closures, privatization, integration, and transfer of the ownership of coal enterprises to energy or metallurgical holdings) happened in the 1990s and 2000s resulted in the coming of strategic investors to this sector. The sector, which had been unprofitable and government-subsidized, has become

Table 1: Dynamics of the structure of energy export revenues in Russia

Year	A share of the energy export in a total export by the fuel-energy complex, %						Share of the fuel-energy complex in total exportrevenues (%)
	Oil	Oil products	Natural gas	Coal	Coke and semi-coke	Electric power	
1994	40.0	14.4	40.8	2.6	0.3	1.9	44.0
1995	38.2	15.5	41.4	3.2	0.3	1.4	40.4
1996	39.0	18.3	38.6	2.6	0.2	1.3	46.8
1997	37.0	18.2	41.2	2.1	0.2	1.3	46.0
1998	35.0	14.6	46.1	2.2	0.3	1.8	40.3
1999	44.4	17.1	35.6	1.4	0.4	1.0	43.7
2000	46.5	20.1	30.6	2.1	0.1	0.5	52.7
2001	46.5	17.4	33.0	2.3	0.2	0.6	53.8
2002	50.1	19.4	27.7	2.0	0.3	0.6	54.3
2003	51.6	18.7	26.5	2.3	0.3	0.7	56.4
2004	56.4	18.7	21.2	2.7	0.5	0.5	56.9
2005	54.4	22.0	20.4	2.5	0.3	0.4	63.6
2006	52.1	22.8	22.4	2.2	0.1	0.4	65.1
2007	54.0	23.2	19.9	2.4	0.2	0.3	63.9
2008	50.3	24.9	21.7	2.4	0.3	0.3	68.5
2009	50.5	24.2	21.0	3.7	0.2	0.4	66.1
2010	51.2	26.6	18.1	3.5	0.2	0.4	66.3
2011	50.1	28.6	17.6	3.1	0.2	0.4	70.2
2012	50.1	28.7	17.1	3.6	0.2	0.3	68.8
2013	47.9	30.2	18.2	3.3	0.1	0.3	68.7
2014	45.6	34.3	16.4	3.4	0.1	0.2	67.8
2015	42.8	32.2	20.0	4.5	0.2	0.4	61.0
2016	45.3	28.3	20.4	5.5	0.2	0.4	57.9

Sources: Calculated by authors

profitable, economically efficient, and showing a well over two-time growth of labor productivity (Churashev and Markova, 2011, pp. 39-45). The growing production potential of the sector faced a stagnated domestic market. At a time when a metallurgy demand for coking coal and the coal-based energy production do not grow as well as a share of coal used by coal chemistry is too miniscule (less than 1% of the total consumption), these production growths in the sector became export-oriented (Churashev and Markova, 2011, pp. 49-51). Such orientation was also encouraged by a rise of the world's coal prices.

It is worth saying that the specifics of a national coal export is that its dynamics depends on such a factor as Kuzbass' production. An explosive nature of the dynamics of the Kuznetsk coal production (when the modernization carried out in the coal sector gave 7.2% average annual rate over 1999-2007 and 4.7% over 1999-2016) was not in line with tendencies of the stagnated domestic consumption that created a problem of overproduction. The orientation on preservation of foreign market niches despite high transport tariffs predetermined a dominated place of the export in the ways how coal was used: according to the expert assessment, 61.5% of the total coal produced by Kuznetsk in 2015 came to export, 14.5% – for needs of coking, 11.7% – for providing power plants, 5.8% – for public utility industries, and 6.1% - for other consumers (Plakitkina, 2016). The official publications of Rosstat provide no statistics about participation of certain regions in the national coal export. According to the electronic data which refer to the regional administration for Kemerovo Oblast, coal export in the region grew from 85 million tons in 2010 to 117.5 million tons in 2014 and 115.9 million tons in 2015, i.e. 46%, 56%, and 54% of the regional production, and 74%, 77%, and 76% of the national export in those years, respectively. In 2016, according to the preliminary estimates, 124.5 million tons of coal or 55% of 227 million tons produced here (which is a maximum volume over all history of Kuzbass, including the Soviet time) were exported that made 76% of the country's coal export. In the solutions of an initial (central) version of the model describing the situation in the economy in the last year of Kuzbass's export is 77.8% of the national coal export and 55% of the regional production. The regional export to the western direction reaches 90 million tons of coal.

4.1.2. Gas export

Having been entirely focused on Europe, Russia's export of gas by pipelines showed quite an uneven dynamics over 1999-2016. This, unlike the coal export dynamics, wouldn't allow speaking about tendencies either of growth or decrease. Such an uneven character of export can be mostly explained by an additional gas supply made by Russia's export monopolist Gazprom in the cold weather years. Due to a higher domestic demand (because of a higher consumption by the population and higher use of gas either as a fuel or raw materials), there can be observed a tendency of a decreased export share in the national production. In 2005 the national export showed its maximum volume (209 billion cubic meters) and its minimum one (168 billion cubic meters) in the first year of the economic crisis (2009). It was the greatest annual drop ever recorded (27 billion cubic meters). As for annual export growths, they were positive during 11 out of 17 years, in other years – negative at a negative average annual growth (0.3 billion cubic meters) in general over the whole period. The share of gas export by pipelines in gas production (together with co-produced gas) varied from 35% to 27% in 1999-2016. In the central version of the model, the share is 31% and complies with the situation observed.

The share of gas production by Tyumen region (Tyumen Oblast together with the adjacent autonomous districts) in the national gas production was 90-92% all over the 1990s and 2000s. Since the 2010s it has started to decrease slowly due to a fast growth of production by Eastern Siberia and the Russian Far East (only 84% in 2016). According to the central version of the model, which takes into account the targets provided by the Energy Strategy 2009 (the active development of fields in a shelf zone of the European part of the country), such a tendency will considerably deepen and the share of this region in the national production will drop to 67% in 2030.

Currently, there is no official statistics about export volumes of pipeline gas from Tyumen region by Gazprom, which is an individual exporter in the Russian Federation. We can give only several figures concerning the past. According to the Tyumen Oblstat, the region exported 90.3 billion cubic meters of natural gas in 1989 or 89% of all the USSR export (101 billion cubic meters). This share will supposedly be lower because Russia lost Turkmenistan and Uzbekistan gas. As the Tyumen region produced 544 billion cubic meters of natural gas in 1989, which is 88% of gas produced by the Russian Soviet Federated Socialistic Republic, a share of export was only 16.5% of the regional gas production. According to the central version of the model, the latter increased to 27% in the last year of the forecast period while a regional share in the national export, on the contrary, decreased to 61%. At the same time, a regional gas export in the western direction reaches 148 billion cubic meters.

To model an uncertainty factor of market conditions for energy export, we use parametric methods for data analysis, i.e. we analyze how the economies of these two Siberian regions could response on restrictions for coal and gas export in the west direction which increased in monotone arithmetic progression in the last year of the forecast period (2030). The computed versions of the scenario are compared with the initial central one.

The methodical approach applied here assumes that the reduced of earnings of foreign currency due to a decreased export of coal and gas causes a decreased import of engineering products in certain proportions, in particular, those of investment purpose. According to Rosstat a share of import of engineering products in a total import of goods (in dollar terms) grew from 31% in 2000 to 53% in 2008, having reached its maximum value. In recent years its share decreased (from 50% in 2012 to 45% in 2015). On the other hand, a share of the investment and +intermediate goods in total import rose from 54% in 2006 to 64 % in 2015, including investment goods – from 17% to 23%, respectively, (with its maximum value 25% in 2012). If products of investment purpose are considered as engineering products, then it is possible to assess a share of investment engineering products in a total sectoral import – it grew from 36% in 2006 to 52% in 2015.

According to the input-output tables over 1995-2003, an import share in a total domestic demand for engineering products (at purchasers' values) varied from 31% to 50%. According to the input-output tables for 2011 (at base prices), it is equal to 43.2%. Our pessimistic economic scenario suggests that the country's dependence on import of engineering products would increase up to 62% of a total import of goods, and a share of import in a total domestic demand for engineering products would be nearly 70% by 2030.

5. RESULTS AND DISCUSSION

The Table 2 presents the results of two variants of the step-by-step calculations, i.e. without import-substitution measures in the engineering industry and with them. Distinctions between these two variants show which of them would better according a GDP criterion – that one requiring additional investments for new engineering capacities (on the scale of all economy) to compensate short-deliveries of the imported products (other things being equal) or that one suggesting a reduction of investments into the energy industry and energy-based industries because of a lower external demand for energy and, therefore, lower production energy resources. To track how the national economy response to changes in export activities of a certain region, we assume that both variants assume that the coal basins of the European part of Russia, Eastern Siberia, and the Russian Far East don't change their production and export programs, i.e. a reduced overseas demand for Kuzbass' coals causes no changes in coal productions in other regions. Parameters of the changes of regional export are presented in the Column 1, Table 2.

In the first variant of the calculations, the GDP drop shows an even rise from 1.1 to 3.7% points with increase of restrictions for regional export, while the second variant (with import-substituting measures) allows avoiding GDP losses if the reduction of regional export is less than 40 million tons of coal and 50 billion cubic meters of natural gas, as well as making GDP losses nearly 3 times less in case of the maximum export restrictions (Section 2.1, Table 2). The last column of the Section 3 (Table 2) shows how a significance of import-substituting measures progresses if and when potential export restrictions increase, i.e. the difference between GDP losses rises in cases of both absence and existence of import-substituting measures.

In our opinion, an important result, which reflects an interconnected influence of export of raw materials and import of final products on the country's macroeconomic indicators, is that both variants of the calculations, including those options of import substitution, which do not cause a GDP drop, show a decrease of domestic demand

Table 2: Regional losses and growths of GDP as a function of a decreased gas export by pipelines supplied by Tyumen region and a decreased coal export by Kuzbass in the western direction

Drops of coal export (million tons) and gas export (billion cubic meters)	European part of Russia	Western Siberia	Eastern Siberia	Russian Far East	Tyumen Region	Ural	Russian Federation
1. No import-substituting measures							
1.1. The losses (-) and growths (+) of GDP (GRP) as compared to the central variant, percentage points							
20 (coal), 30 (gas)	−0.8	−4.9	0.2	−1.6	−0.3	−3.0	−1.1
40 (coal), 50 (gas)	−1.7	−6.9	0.4	−2.3	−0.8	−4.5	−2.0
60 (coal), 70 (gas)	−2.3	−7.7	0.3	−3.4	−4.3	−5.5	−2.9
80 (coal), 90 (gas)	−3.5	−8.2	0.8	−3.8	−5.4	−5.7	−3.7
1.2. Региональная структура потерь и приростов суммарного ВРП (ВВП), %							
1.2. Regional structure of losses and growths of GRP (GDP), %							
20 (coal), 30 (gas)	49.6	27.5	−1.4	5.9	1.8	16.6	100
40 (coal), 50 (gas)	57.7	21.9	−1.4	4.9	2.7	14.2	100
60 (coal), 70 (gas)	56.7	16.9	−0.8	5.0	10.0	12.1	100
80 (coal), 90 (gas)	64.2	13.8	−1.6	4.3	9.7	9.5	100
2. Import-substituting measures							
2.1. The losses (−) and growths (+) of GDP (GRP) as compared to the central variant, percentage points							
20 (coal), 30 (gas)	0.02	0.13	0.22	0.02	0.03	−0.26	0.03
40 (coal), 50 (gas)	0.09	0.02	0.36	0.09	−0.08	−0.24	0.07
60 (coal), 70 (gas)	0.2	−4.0	0.45	−1.5	−2.6	−1.8	−0.4
80 (coal), 90 (gas)	−0.8	−5.0	0.6	−2.1	−3.8	−2.5	−1.3
2.2. Regional structure of losses and drops of a total GRP (GDP), %							
20 (coal), 30 (gas)	61.2	29.2	57.5	2.6	7.7	−58.1	100
40 (coal), 50 (gas)	85.1	2.1	37.4	5.3	−8.1	−21.9	100
60 (coal), 70 (gas)	−28.3	56.9	−7.3	14.1	39.3	25.2	100
80 (coal), 90 (gas)	40.6	24.3	−3.4	6.8	19.5	12.2	100
3. Difference of GDP (GRP) growths (indicators 2.1 minus indicators 1.1), percentage points							
20 (coal), 30 (gas)	0.8	5.1	0.001	1.6	0.3	2.8	1.16
40 (coal), 50 (gas)	1.7	6.9	−0.03	2.4	0.7	4.3	2.05
60 (coal), 70 (gas)	2.5	3.7	0.14	1.9	1.7	3.8	2.42
80 (coal), 90 (gas)	2.7	3.2	−0.20	1.7	1.6	3.1	2.43

A sign "minus" means the indicator is included in a total growth with an opposite sign. Sources: the OMMM-Energy Solution (to different extents). When a reduction of regional export doesn't exceed 40 million tons of coal and 50 billion cubic meters of gas, a minimal drop is quite insignificant and makes 0.3-0.6% points in case of import substitution measures as compared to the Central variant of the model, and in the maximum option (80 million tons of coal and 90 billion cubic meters of gas) it is 2.4% points, i.e. 4 times higher. With no import substitution measures, a loss in domestic demand in the maximum option reaches 4.7% points. It means that at given ratios of potential drops of energy export to import of engineering products, import substitution measures do not allow avoiding negative consequences of dramatic drops in export and import completely, but could significantly mitigate them.

Though a share of regional exporters in the total GDP losses is rather high (23-29%) in options with no import-substitution measures, the European part of Russia suffers the highest losses – its share increases with each parametrical step from 50% to 64% (see Section 1.2, Tab. 2). It is interesting that the East Siberian economic region suffers no losses at all due to the capital and material resources redistributed from the closest regional exporters, while an drops amplitude between regional coal exporters (from 5 to 8% points) is narrower, though deeper (Section 1.1, Table 2), than between regional gas exporters (from 0.3 to 5% points). A greater sensitivity of Western Siberia to export restrictions (as compared to the Tyumen region) correlates to high values of the effects of import substitution measures (Section 3, Table 2).

The regional structure of compensating machine productions in the adaptive options is as follows: the European part of Russia (77-89%), Western Siberia (11-17%), Ural (1-5%), and Tyumen region (2%), i.e. the European part of Russia prevails. Though such regional structure is the same in all options, an insignificant GRP drop can be seen only in the last option (maximum export restrictions) (Section 2.1 and Table 2).

Our scenario calculations differ from forecasts in that we do not avoid extreme options. We intentionally chose a pessimistic economic scenario (rather low rates of economic growth, a high dependence of the national economy on import of machine productions, and possibility of dramatic annual reductions of energy export in the western direction) to show that potential GDP losses due to a reduced regional export of coal and gas could be very significant (but highly differed by regions) and compensated, though not completely, by import-substitution measures.

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