THE PRACTICE OF THE USE OF MULTIREGIONAL IO MODELS IN STRATEGIC FORECASTS OF RUSSIAN ECONOMY

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ABSTRACT

The paper represents the experience of solving some applied problems with the use of the optimization multiregional input-output models of the economy of Russia. These problems were solved in 2002-2008 in the course of long-term forecasting that came in demand in the period of economic rise.

The models in use provide for the national economic forecast balanced by sectors and regions, which allows focusing on more special cases as the development of a specific sector or a region. On the other hand, taking constraints on productive capacities and resources into account, multiregional IO models enable estimating of the attainability of some forecasted indicators of economic development.

The paper introduces to the results of studying the following problems: estimating the possibility of doubling the GDP of Russia for the period of 2001-2010; forecasting the perspective demand for electric energy and transportation services as possible constraints to economic growth; and testing the consistency of isolated regional long-term forecasts of economic development.

Introduction

The paper represents the experience of the use of optimization multiregional input-output models (OMIOM) in the studies of applied forecasting problems that were urgent for the Russian economy in 2002-2008.

The active studies in the field of long-term forecasting with the use of the OMIOM apparatus were recommenced in the Institute of Economics and Industrial Engineering SB RAS (Novosibirsk) in 2002 and go on till now. Theses studies followed an intermission because in 90ies, in the course of the system crisis of the Russian economy, the interest to long-term forecasts was lost to a considerable degree/

Federal authorities of Russia realized that successful reforms require for developing the strategic vision of the future. Even in 1992, in the beginning of economic collapse, Governmental Regulation № 602 of 19.08.1992 "About Measures for Realization of the Program of Deepening Economic Reforms" provided for the elaboration of the complex forecast of development and allocation of productive forces under the conditions of market economy. In 1995 the Federal Law "About State Forecasting and Programs of Socio-Economic Development of Russian Federation" was adopted. The Law provided for developing short-, middle- and long-term forecasts on regular basis. But in the conditions of transitional uncertainty Ministry of Economic Development and Trade of the Russian Federation (RF) was focused on short- and middle-term forecasts not giving too much attention to regional aspects.

After the economic growth in Russia reached a positive trajectory, it became evident that time horizons in forecasting were to be extended. Since the early 2000es middle-term, and then long-term forecasts of the socio-economic development of the national economy and its regions came to more and more demand. Economic stabilization and positive prospects of growth claimed for a strategic approach for the distribution of the federal funds designated for the support and stimulating of some economic activities and territories. The need in the explicit and predictable governmental socio-economic policy as well as the demand for development targets for long-term prospects initiated the elaboration of several long-term forecasts of the socio-economic development of the RF. The last of them is the forecast for 2020 that is contained in the governmental Conception of the Long-Term Development of the RF that is currently in force.(Kontceptcia, 2008)

Long-term forecast became mandatory components of development strategies for industries and regions such as the Energetic Strategy of the RF, or the Transportation Strategy of the RF, or the Strategy of the Socio-Economic Development of Siberia or Far East. These strategies have different time horizons (till 2020, 2025 and 2030). So, towards the beginning of the world financial crisis of 2008 some experience in long-term forecasting under the conditions of market economy was accumulated in Russian practice.

Despite of the crisis influence on Russian economy the governmental forecasts developed under the conditions of high growth rates are not revised yet; formally, they are currently in force. The Conception of the Long-Term Development of the RF till 2020 is based on rather optimistic forecasts: even the variant with minimal growth rates (called as "inertial" variant) implies the possibility of reaching 4% average annual growth rate of the GDP. The scenario of "energy-raw materials development" foresees 5-6% growth rate, and the scenario of "innovation development" predicts 6,5% growth rate.

The first and the second scenarios imply the decrease in population to 137 millions in 2030, while the third one has the premise of the growth of population up to 146 millions as the result of the active demographic policy. The second and the third scenarios are investment-oriented; they imply the increase in the fixed capital accumulation rate from the current 21% of the GDP to 35-37%. All scenarios were developed for favorable external conditions including 4% annual average growth of the world economy and positive dynamics of oil prices for "Urals: from $88 per barrel in 2011 to $97 in 2015, $116 in 2020 and $136 in 2025.

In the frames of the scenarios described above and on the base of the OMIOM apparatus the authors developed the sectoral and spatial aspects of the macroeconomic forecast till 2030. The task was reduced to forecasting the sectoral and spatial patterns of the Russian economy under the conditions formulated in the external macroeconomic forecast of the Ministry of Economic Development and Trade.

At present the OMIOM apparatus in use includes 2 basic models called as "point" (dynamic IO model) and "spatial"(multiregional IO model) models.(Ershov, 2007a) Forecasts for Russia as a whole are performed on the base of the optimization IO dynamic model. This model is used as an instrument for long-term forecasting in the cut of types of economic activities without taking spatial aspects of economic development into account. Spatial forecasts are performed on the base of the optimization multiregional IO model. Both models are constructed on the same database of 2007 in the cut of 40 sectors corresponding to the new nomenclature of economic activities developed with the Rosstat in 2004. (The list of sectors is attached in Supplement 1). Both models produce forecasts to 2030.

The "point model" has 4 forecasting periods: 2008-2010, 2011-2015, 2016-2020 and 2021-2030. The model contains of common IO balances: the balances of production and distribution of outputs, the balances of labour resources, the balances of gross investments and constraints on foreign trade balances. The objective function maximizes the sum of final demand components such as the final demand of house holdings, of governmental institutions, of nonprofit organizations attending to house holdings, and the accumulation (change in stocks) of circulating tangible assets. The realization of the dynamic IO model provides for the forecasted tables of distribution of goods and services in the economy for the last years of the forecast period as well as for all interim time points. (The formal statement of the model is attached in Supplement 2) The presence of the "point" model facilitates the subsequent statement and realization of the "spatial" model.

The "spatial" model consists of 8 regional blocks united with the conditions of interregional transportation-economic links and with the territorial pattern of final demand. Each region is presented with the semi-dynamic optimization IO model that provides for the calculation of the state of economy for the last year of a forecast period. The set of constraints in regional blocks duplicates the structure of the "point" model. The optimal solution of the model represents a consistent set of forecasted regional IO tables for the last year of a forecast period. The tables are produced in the cut of 7 federal districts and Tyumen oblast and 40 types of economic activities. (Regions are listed in Supplement 3, the formal statement of the model is written in Supplement 3; the conventional scheme of the model structure on the example of 3 regions is in Supplement 5)

As distinct from the "point" IO model the "spatial" one is realized in the semi-dynamic statement. The practice of development and realization of 2-period and 3-period (fully dynamic) models demonstrated their unhandiness. The use of a forward recurrence turned out to be more expedient: first the problem is solved for 2008-2020, and then it is solved for 2021-2030 from the base of 2020. The use of multiregional IO model complicates estimates for shorter periods. The OMIOM specifics of modeling investments requires for the use of periods of 10-15 years, which provides for higher-quality estimates of average annual growth rates of regional economies.

The computations were matched with macroeconomic premises of the Ministry of Economic Development and Trade. Under such conditions the sectoral and spatial forecasts produced on the base of the OMIOM answer the following question: "What would be sectoral and spatial patterns of the economy, if the Russian economy as a whole reaches the rates forecasted with the Ministry?" It should be noted that governmental pre-crisis forecasts were distinguished with the over-optimism caused with very high retrospective growth rates; they did not take the transient nature of the growth factors into account, such as the long period of the favorable foreign market conditions. It was accepted as possible that 5-6% annual average growth rates would be achievable in the long prospect under the decreasing population though the economic history does not provide such precedents. Governmental forecasts also implied the stable increase in foreign investment inflows into Russia, as well as the possibility of the change the positive sign of the trade balance for a negative sign.

Table 1

Basic macroeconomic indicators of regions' development in 2008-2030.
"Energy-raw materials" scenario (average annual growth rates in percents)

	RF	CFD	NWFD	SoFD	VFD	UFD	SiFD	FEFD
Gross output								
2008-2020	105.6	105.8	105.8	105.9	105.5	104.8	105.6	105.6
2021-2030	104.1	103.9	104.5	104.6	104.2	103.7	104.4	104.4
Gross regional product (GRP)								
2008-2020	105.4	105.5	105.9	106.0	105.4	104.8	105.6	105.6
2021-2030	103.8	103.6	104.2	104.3	103.9	103.4	104.2	104.0
Fixed investments								
2008-2020	109.1	107.7	109.3	109.3	110.2	109.2	110.3	109.0
2021-2030	105.8	105.2	105.9	106.3	105.8	105.6	106.2	106.5
Final demand								
2008-2020	105.8	105.1	105.9	106.4	106.1	106.1	106.2	105.9
2021-2030	104.0	103.6	104.1	104.3	104.1	104.0	104.2	104.4

Table 2

Basic macroeconomic indicators of regions' development in 2008-2030.
"Innovation" scenario (average annual growth rates in percents)

	RF	CFD	NWFD	SoFD	VFD	UFD	SiFD	FEFD
Gross output								
2008-2020	106.2	106.5	106.4	106.4	106.2	105.3	106.1	106.1
2021-2030	105.2	105	105.4	105.6	105.6	104.5	105.2	105.2
Gross regional product (GRP)								
2008-2020	106.5	106.8	106.8	106.9	107.0	105.5	106.3	106.4
2021-2030	106.0	105.6	106.6	106.7	106.0	105.6	106.4	106.3
Fixed investments								
2008-2020	110.6	109.4	110.6	110.8	111.8	110.3	111.6	110.1
2021-2030	107.0	106.2	107.3	107.4	107.3	106.7	107.3	107.8
Final demand								
2008-2020	106.5	105.8	106.6	107.1	106.7	106.8	106.9	106.6
2021-2030	105.0	104.6	105.1	105.3	105.1	105.0	105.2	105.4

The results of computations demonstrate that depending on the scenario chosen the list of leading regions varies. (See Tables 1 and 2) In the case of "innovation" type of development leaders are European federal districts. The energy-oriented way of development requires for higher growth rates of investments into the economy of Asian federal districts. Our forecast shows that even under over-optimistic premises the regional differentiation strengthens, though the changes in the spatial pattern of the national economy (in the cut of large regions) remain insignificant.

The model presented provides for the national economic forecast balanced by sectors and regions, which allows focusing on more special cases as the development of a specific sector or a region. (Ershov, 2007b) Taking the constraints on productive capacities and resources into consideration, multiregional IO models enable estimating of the attainability of some forecasted indicators of economic development. Further the paper is organized as follows. Chapter1 represents results of estimating the possibility of doubling the GDP of Russia for the period of 2001-2010. Chapters 2 and 34 are focused on forecasting the perspective demand for electric energy and transportation services as possible constraints to economic growth. The problems of consistency of isolated regional long-term forecasts of economic development are discussed in Chapter 4.

1. Testing the availability of doubling the GDP in 2001-2010

In 2003, on the tide of the first progress of restoration growth a “doubling the GDP” became the more frequent phrase in the economic rhetoric. For that the former President Putin sufficed to say in his message to the Federal Assembly of 16.05.2003: “We should at the least double the gross domestic product of the country for a decade”. This phenomenon testified to strengthening the role of federal authorities in governmental regulation of the economy to the extent of formulating targets of its development.

Some analytics expressed their doubts in feasibility of the target in the given period, but their calculations did not go beyond the extraction of the tenth root of 2 so that the result was equal to 7,2% of average annual growth during 10 years. The postulate of doubling the GDP became a mandatory component of targeting in strategic documents on the federal and sectoral levels, such as the Transportation Strategy of the RF to 2025. We took part in the development of this strategy and performed calculations with the purpose of estimating consequences of the doubling of the GDP from the point of view of transportation capacities. The question was if the national transportation system was able to cope with the load of “doubling the GDP”.

The computations were performed on the base of the OMIOM on the cut of 27 industries and 8 regions for periods of 2001-2010 and 2011-2025. The procedure of forecasting implied exogenous forecasting of input-output, labour and capital ratios by recruited experts on industries, as well as forecasting the sectoral pattern of final demand.

The forecast obtained demonstrated that under the current technological level in production the GDP might raise by a factor of 1,75 to 2010, and by a factor of 1,87 to 2025. In that way it was revealed that the target of doubling the GDP produced in 10 years was not realistic. For reaching this target the experts would have to assume non-realistic parameters of the growth of labour productivity, of lowering material intensity and so on. At regional level the value added was not doubled in any federal district. The highest growth rates expected for Southern and Siberian federal districts did not exceed a factor of 1,9.

At present it is possible to test if the forecast was realistic or not. In 8 years, from 2001 to 2008, the GDP raised by a factor of 1,66. If the world crisis did not happen, the actual increase in the GDP would exceed the increase forecasted with us. But such exceed would be explained by the improvement of foreign market conditions that were not expected in 2003. Some types of economic activities, such as “Construction” and “Trade”, doubled the production of the value added by 2007 (198% and 195% to the level of 2001, correspondingly).

The “doubling” problem was studied for another indicator – the GDP used for final demand and gross investments. The computations demonstrated that this target was feasible in 10-years under some realistic hypotheses about dynamics of labour intensity, material intensity and capital intensity, about changes in the trade balance, which were previously adopted in the forecast. Now the actual size of the final demand of house holdings and of fixed investments well exceeded the forecasted sizes due to improved foreign market conditions, which allowed for increasing the final demand and gross investments at higher rates in comparison to production rates. In 2007, that is as soon as 7 years, the doubling came into reality for such components of the GDP used as expenditures of house holdings for final consumption (203% to the level of 2001) as well as gross capital accumulation (227%).

Thus, the OMIOM apparatus enabled us not only to answer the question posed about the feasibility of doubling the GDP, but to specify the statement of the question and give more qualified conclusion on this base. Now the term “doubling the GDP” is not used more in strategies of federal and sectoral level.

2. Forecasting the prospective demand for electric energy

The estimates of the prospective demand for electric energy were made as the component of the long-term forecast of the economic development of the national economy for 2020. It was performed on the base of the OMIOM in 2006 by the demand of federal authorities. The special attention on the power industry was focused due to concerns over possible energetic constraints which could impede economic growth. The specific character of the industry makes its dependence on needs of domestic market as well as the geographic gravity to consumers so that the availability of suppliers is a requirement for development of all sectors of economy.

The retrospective analysis revealed that dynamics of the GDP and of the electricity consumption has some specifics in Russia. Figure 1 demonstrates that both indicators rose at similar rates in 70-80ies. In 90ies the GDP dropped much lower than the production and consumption of electric energy while in 2000es, against a background of the rapid post-crisis growth, the opposite ratio was to be observed. So the concerns over adequacy of energetic capacities were well-grounded. [1]

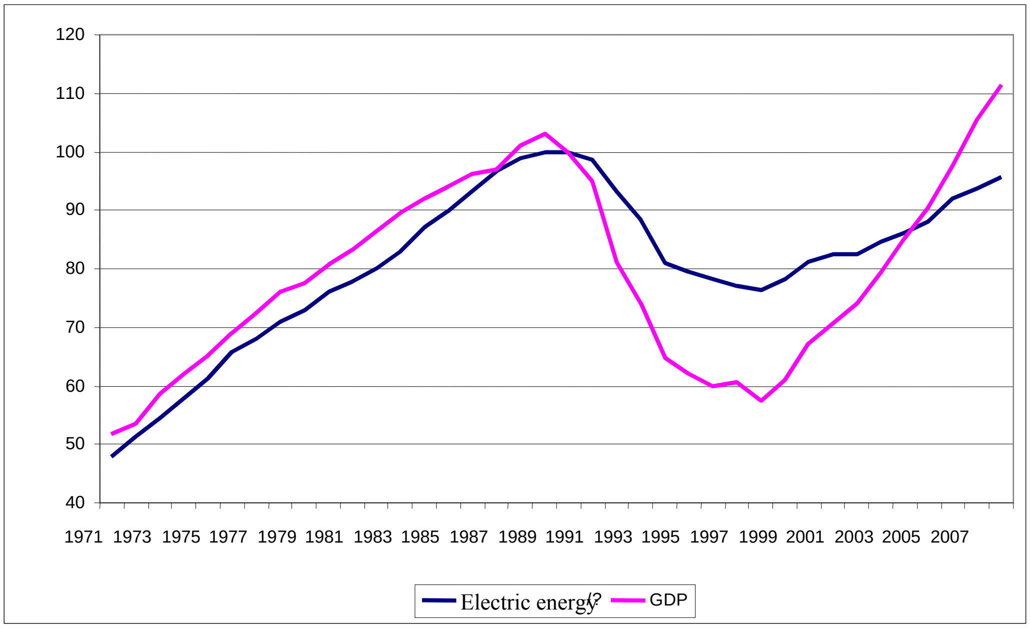

Figure 1. Dynamics of the GDP and electricity consumption in the RF in 1971-2008. (annual rates in percents; 1990=100%)

Long-term forecasts of electricity consumption appear in Energy Strategies of the RF which are regularly developed. The ministerial forecasts are elaborated in detail, providing for numerous technical parameters forecasted for power industry. At the same time, as such the sectoral strategies are used for basing requests for the governmental participation in financing the development of the industry; they reveal a tendency to over-estimating needs of the economy in the product of the industry-applicant. As a rule, such estimates are based on extrapolation of recent trends in the future. Comparing Energy Strategies of different redactions one can see the evident growth of optimism in the forecasts of electricity consumption for 2006-2020 – from the growth by a factor of 1,3-1,6 in the redaction of 2000 to the growth by a factor of 1,9-2,2 in the redaction of 2008.

These forecasts displayed a common limitation of the forecasting procedure and instruments, namely econometric models with a small number of parameters, –over-reaction to changes in electricity consumption that took place in the last 1-2 years before the development of the forecast. In our opinion, more adequate methods should be based on the IO analysis, on the retrospective studies of electricity consumption in the cut of industries, on formulating well-

[1] In 1999 the RAO "UES of Russia" published the forecast of production and consumption of electricity. On the graph presented the falling curve of production crossed with the rising line of consumption in 2005. This graph became popular in economic press under the name “Chubais’ cross”.

grounded hypotheses about prospective trends in demand, and on the imposition of the forecasted rates of electricity intensity by industries on the forecasted outputs and growth rates of specific industries.

The problem of forecasting electricity demand and of finding required rates of the power industry development should be considered as the set of relatively independent regional problems because electric energy cannot be reserved while the needs in electricity cannot be satisfied with interregional supplies from energy-abundant regions at long distances. In the multiregional IO model the growth rates of power industry are determined depending directly on the growth rates of demand on regional markets.

The procedure of forecasting implied, first of all, the realization of the multiregional IO model under conditions of the following macroeconomic scenario: during the whole period of 2006-2020 economic growth rates slow down, and in 2011-2020 growth rates of the GDP begin to exceed rates of house holdings' consumption.

As the result, the preliminary estimate of expected rates of electricity generation was obtained (102,7% in 2006-2010 and 103,2% in 2011-2020). In other words, it was forecasted that growth rates of demand for electricity would increase while growth rates of the GDP would decrease. The forecast was measured in value terms (in ruble prices of 2005); hence, sector proportions were influenced with differential tariffs applied for different groups of consumers. The forecast given was to be converted into natural terms (kilowatt-hours).

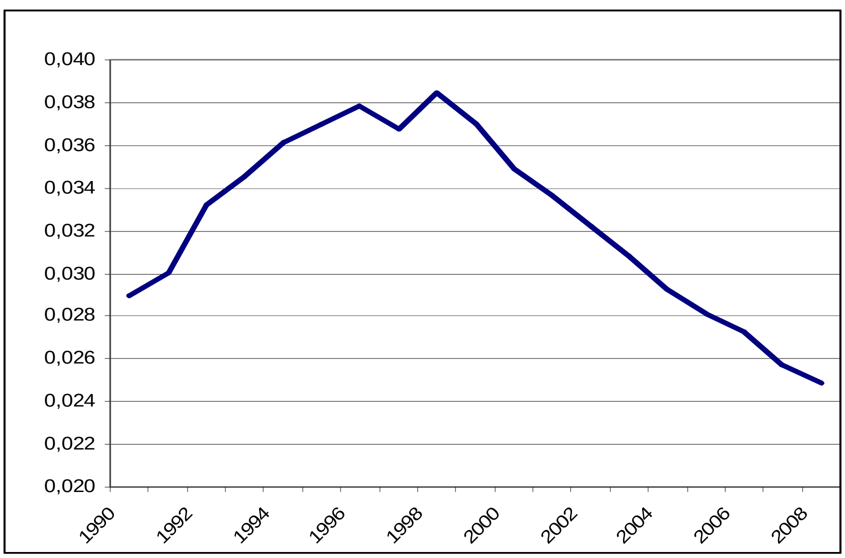

Figure 2. Dynamics of electricity intensity of the GDP in the RF in 1991-2008.
(kilowatt-hour/ ruble in prices of 2008)

With this purpose we have analyzed the retrospective data of electricity consumption for the period of 1997-2004 as well as for earlier periods. As it is shown on Figure 2, since early 2000es the production of value added in Russian economy is distinguished with falling electricity intensity. Since as some revolutionary changes in technologies were not observed at that time, then one should search for the reason in the change in industrial pattern of production. So we performed the retrospective analysis by industries focusing on indicators of electricity intensity and levels of the use of productive capacities. The special attention was given to the analysis of some expert estimates of prospective changes in electricity intensity because the technological progress may result both in a decline and in a rise of electricity intensity in specific industries.[2]

Table 3

Average annual rates of electricity intensity changes (in factors)

	2006/2010	2011/2020
Power energy	1	0.995
Oil extraction	1.015	1.03
Oil processing	1.018	1.02
Gas industry	1.01	1.01
Coal and other fuelso	0.98	1.01
Ferrous metallurgy	0.98	0.97
Non-ferrous metallurgy	0.98	0.985
Chemical and petrochemical industry	0.99	1
Machinery	0.93	0.96
Logging and wood industry	0.97	0.99
Pulp and paper industry	1.01	1.015
Building materials	0.995	0.995
Light industry	0.96	0.97
Food industry	0.97	0.99
Other industries	0.98	0.99
Construction	0.95	0.98
Agriculture	0.99	1.02
Transport	1.01	1.01
Housing and communal services	0.98	0.99
Other activities	0.96	0.98
Losses in networks	1	0.995
Population		
rural	1.015	1.023
urban	1.017	1.025

Prospective indicators of electricity consumption were calculated in natural units on the basis of the hypotheses formulated for specific industries. Additionally, we estimated the most probable changes in the more detailed sectoral pattern of output; the distribution of the total electricity consumption between technological needs and indirect costs. The forecasted rates of changes in electricity intensity are displayed in Table 3. Most industries are characterized with

[2] Electricity intensity increases in such industries as oil extraction (because of increasing degree of oil extraction from deposits), transport (as a result of continuing electrification of railways and development of undergrounds), gas-main transport (due to shift to “electric traction”), and agriculture (due to increasing share of mechanized processes).

lower rates of decrease in electricity intensity in relation to the retrospective period, the rates slow down to the end of prospective period. The explanation is that the post-crisis stage of restoration growth was over to 2006 so that the factor of loading free capacities exhausted. The increase of electricity intercity is evident mostly in extracting industries due to worsening conditions of extraction.

Further_the procedure of breaking down the aggregate demand for electricity into sector components was used for estimating the demand for electricity in more details under conditions of inertial", "mild-optimistic" and "innovation" scenarios formulated by the Ministry of economic Development and Trade. We have elaborated prospective fuel and energy balances in the cut of industries and regions

Some indicators of dynamics of electricity consumption according to "mild-optimistic" scenario are displayed in Table 4. For Russia as whole electricity consumption in 2010 will not exceed the level of 1990. So, it is possible to avoid of the general deficit of electric power even if new capacities would not be putted into operation, especially since the aggregate capacity of electric power stations now exceeds the same of 1990. The greatest relative increase in electricity consumption is forecasted for Southern and North-Western federal districts. The lack of electric power in Urals Federal District may be compensated with supplies from Volga district; generating supplies of Central Federal District will suffice for covering the deficit in North-Western and Southern federal districts. Siberian Federal District will face the most serious problem of covering the deficit of supplies because the production of value added is characterized with the highest electricity intensity due to the high share of metallurgy and to the development of oil extraction. Reaching the forecasted indicators of electricity consumption requires for putting new power units into operation in this region. After 2010 putting new power stations will be necessary in all regions excluding Central Federal District.

The special character of the forecast lies in the following. Under all scenarios the growth rates of the GDP and of electricity consumption converge, though during all forecast period the latter will lag behind of the former. At the same time growth rates of the GDP decrease while the growth rates of electricity generation required for providing the GDP forecasted, quite contrary, increase. This is caused by gradual transition from one model of growth to another, from the economy with higher growth rates of consumption to the economy with higher growth rates of production, which is necessary for providing higher rates of gross investments

Table 4

Forecasted dynamics of electricity consumption in the cut of regions
(in percents)

	RF	CFD	NWFD	SoFD	VFD	UFD	SiFD	FEFD
Increase of electricity consumption for 2006–2010	114,0	111,7	117,3	115,7	115,5	112,7	113,6	113,0
Increase of electricity consumption for 2011–2020	132,6	129,0	138,5	141,4	135,2	129,2	130,1	132,5
Increase of electricity consumption for 2006–2020	151,1	144,1	162,6	163,5	156,1	145,7	147,8	149,8
Ratio of electricity consumption in 2010 to the level of generation in 1990	99,8	87,5	111,0	103,1	95,6	104,2	108,1	95,4
Ratio of electricity consumption in 2020 to the level of generation in 1990	132,0	112,9	153,8	145,7	129,2	134,7	140,6	126,4

The forecast was developed without taking some extreme projects into consideration, such as, for instance, prospective supplies of 50-100 billions of kilowatt-hours from Far East to China. Our forecast revealed that the problem of controlling over probable shortages in generating capacities for domestic needs is of primary importance. In the case of realization of the project economic resources would be distracted from the more urgent problem – the liquidation of deficit of power capacities after 2010.

3. Forecasting perspective demand for transportation services

The sector of transport is similar to the power industry in the sense that its outputs practically cannot be replaced with imports and is determined with needs of domestic demand. The lack of transportation services may impede economic growth, in part, to cause cancellations of new projects. This aspect was stressed in ministerial strategies of transport sector development (Transportnaya, 2008) So federal authorities required for the analysis and the long-term forecast of demand for transportation services in the cut of regions. This work was carried out with the use of the OMIOM apparatus in 2003 as a component of the long-term forecast for development of the national economy.

First, the retrospective analysis for 1997-2004 was performed. It revealed the long-term tendency to decreasing a share of transport in gross outputs and in the GDP resulted from lagging the growth rates of demand for transportation services behind of the growth rates of the above-named indicators. It is evident from Figure 3 that this tendency keeps for the aggregated sector of transportations and communications as well, despite of rapid development of the communication sector.

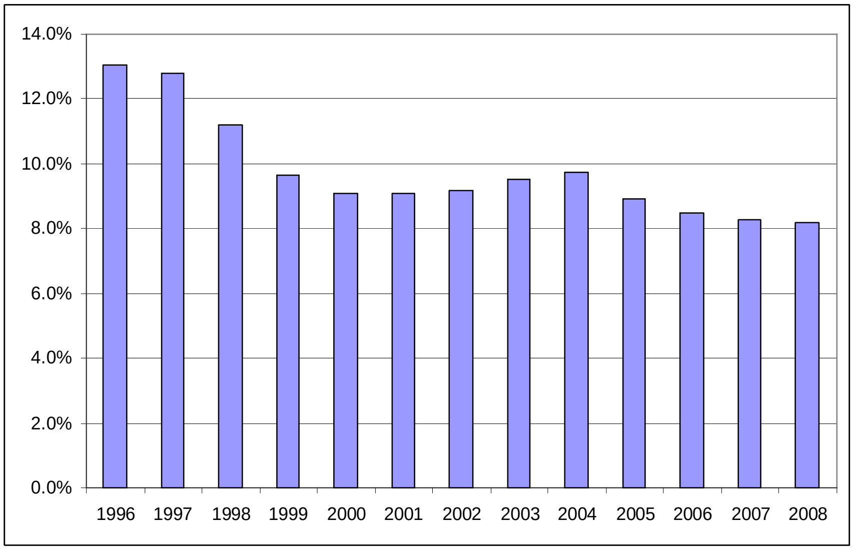

Figure 3. Dynamic of a share of the aggregate sector of transportation and communication in the GDP for 1996-2008 (in percents of the GDP)

The trend displayed on Figure 3 is explained with long-term, short-term and specific factors. The long-term factors relate to industrial structure of outputs. In the case of freight transportation one may observe a long-term trend to decreasing a share of extraction industries in the total output (in fixed prices). Passenger transportation exhibits a tendency to increasing self-services and replacing personal travels with electronic communication services. Short-term factors relate to foreign market conditions of 2000es, that is the growth of world prices for Russian exports. At that period the rapid increase in imports was possible under rather low physical volume indices of exports while the goods imported were characterized with low transport intensity of production. Specific factors are the following: the rapid growth of stock of personal cars (not accounted with statistics in outputs of transport); stagnation of transport communication between Russia and former soviet republics; rapid development and relative reduction of Internet prices; and the leading growth of transport tariffs. All these factors contribute to downward trend of demand on transportation services.

The formulation of the problem for the base year (2005) required, first of all, for estimating territorial and sectoral patterns of distribution of transport services because the modern statistics does not account these data in full size and in the sectoral nomenclature required for our model. The spatial pattern of transportation services is determined with domestic demand4 so, it is close enough to the pattern of the gross regional product. The estimating of sectoral pattern of transport services was based on tables of the use of goods and services in Russian economy for 2003. These tables are constructed in basic prices and contain information about transport margins for products of industries. Initially the base sectoral pattern corresponded to the data of the last detailed IO table of 1997. But current IO tables distribute about a half of the total transport margin by industries. So the data available were compared with transport statistics in natural units (turnover of goods, freight traffic). Then the volumes of transportation services were adjusted according to changes in their "mode pattern", that is changes in shares of different modes of transport in the total volume of transportation services. As the result, we obtained the estimate of distribution of services of pipelines, railways and other transports by 14 sectors-producers of transportables.

As the calculations revealed, the largest consumer of transportation services is a fuel industry that loads 62% of freight transports, as well as the industry of building materials (9,7%) and ferrous metallurgy (8,4%). Hence, dynamics of production in these industries will strongly influence on changes in the performance of freight transport.

The analysis of the sectoral pattern of freight transport enabled us to predict lowering contribution of pipelines in the total volume of freight transportation services because no economic forecast assumed keeping up such high growth rates in the oil and gas industry as they were in the last decade. The same factor will determine lagging growth rates of freight transport services behind the GDP rates. Only in long future prospect, in the course of decreasing the shares of fuel and raw materials industries in the total volume of industrial production, the link between the demand for services of freight transport and industrial growth will become stronger.

Further the multiregional IO model was realized on the database developed under conditions of the above-described "inertial", "energy-raw materials" and "innovation" scenarios. The results obtained reveal that in the perspective covered the physical volume indices of transport sector outputs will significantly lag behind the indices of the gross output and the GDP. (See Tables 5 and 6) In the next future, at least till 2015, the carrying capacity of Russian transport system will not seriously impede the economic growth. There are more urgent problems, such as high degree of wear and tear, problems of traffic in large cities as well as limited capacities of ports and frontier admission points.

Table 5

Average annual growth rates of demand for freight transport services in Russian regions2008-2020; "energy-raw materials " scenario (in percents)

	RF	CFD	NWFD	SoFD	VFD	UFD-T	Tyu	SiFD	FEFD
Gross output	104.9	104.9	105.2	105.3	104.9	104.9	103.8	105.1	105.1
Freight transport	104.0	103.8	104.2	104.4	103.6	103.8	102.8	104.6	105.3
including									
pipelines	101.6	100.9	102.1	101.9	101.3	100.8	101.6	104.1	109.6
railway	103.4	102.8	103.3	103.4	103.2	103.1	104.3	103.8	104.2
other transports	105.2	104.7	105.6	105.9	105.2	104.9	105.4	105.7	106.4

Table 6

Average annual growth rates of demand for freight transport services in Russian regions2008-2020; "innovation " scenario (in percents)

	RF	CFD	NWFD	SoFD	VFD	UFD-T	Tyu	SiFD	FEFD
Gross output	105.7	105.8	106.0	106.1	105.9	105.7	104.2	105.7	105.7
Freight transport	104.3	104.2	104.6	104.7	103.9	104.2	102.8	105.0	105.7
including									
pipelines	101.4	100.7	101.9	101.7	101.1	100.6	101.4	103.9	109.6
railway	103.6	103.0	103.4	103.6	103.3	103.2	104.5	103.9	104.3
other transports	105.7	105.2	106.1	106.5	105.7	105.4	105.9	106.2	106.9

The studies have discovered only one potential bottleneck in interregional transportations. This is a railroad system connecting Siberian federal district with western regions of the country. It approaches to the limit of its carrying capacity. For enlarging the capacity different projects compete: construction of North-Siberian railway; reconstruction of Trans-Siberian Railway (that is construction of the third line on the most over-loaded distances); shifting a part of freight traffic on transit railways connecting through Kazakhstan. The choice of the specific project cannot be based on the level of multiregional IO models.

The results of forecasting the demand for transportation services demonstrated a decrease of "transport intensity" of the GDP as a consequence of changes in sectoral pattern of outputs due to lower growth rates of outputs in those industries that provided for higher loading for transportation sector. (See Table 7) The "transport intensity" decreased in Central and Volga federal districts more rapidly while in Far East this indicator did not change. The switch from "energy-raw materials" to "innovation" scenario increased the total volume of transportation services because the role of imports in the GDP growth reduced into favor of domestic market determining the loading of transports.

Table 7

Changes in the forecasted "transport intensity" of production on Russian regions in 2007-2030 (volume of transportation services in percents of the gross outputs)

	RF	CFD	NWFD	SoFD	VFD	UFD-T	Tyu	SiFD	FEFD
2007 год	6.7	6.8	7.1	8.4	5.7	5.0	6.6	6.8	7.6
"energy-raw materials " variant, 2030	5.0	4.8	5.3	6.3	3.9	3.6	5.0	5.7	7.2
"innovation " variant, 2030	4.6	4.5	4.9	5.9	3.5	3.3	4.6	5.4	7.0

4. Testing the consistency of isolated regional strategic forecasts

At present some large regions of Russia develop their strategies of socio-economic development. We took part in the development of Strategy of Development of Siberia to 2020 (Siberian Strategy) providing for the long-term forecast of development of Siberian Federal District consistently with other districts' forecasts. The forecast was based on the OMIOM apparatus.

In the course of development of Siberian Strategy it was necessary to take account of interests of regions-subjects of Siberian Federal district that were expressed in their local strategies of development – in strategies of republics, of krais, of oblasts. We have analyzed long-term forecasts that were included in 11 regional strategies with different time horizons (from 2017 to 2028). The analysis revealed that local forecasts were based on deep knowledge about regional economy, on reliable information about existing and prospective investment projects, on careful estimates of all resources and potentialities of a region. But, having no special economic-mathematical instruments, it is impossible to allow for all resource constraints that appear after the consideration of inter-industry and inter-regional links by production and exchange of products. So, the questions have arisen as to whether regional strategies are adequately provided for resources, or, whether isolated regional forecast may be verified. With such purposes we performed a comparison of the aggregate forecast as a sum of available regional forecast with our forecast produced with the use of the optimization multiregional IO model of the economy of Russia in the cut of federal districts with isolated Tyumen oblast.

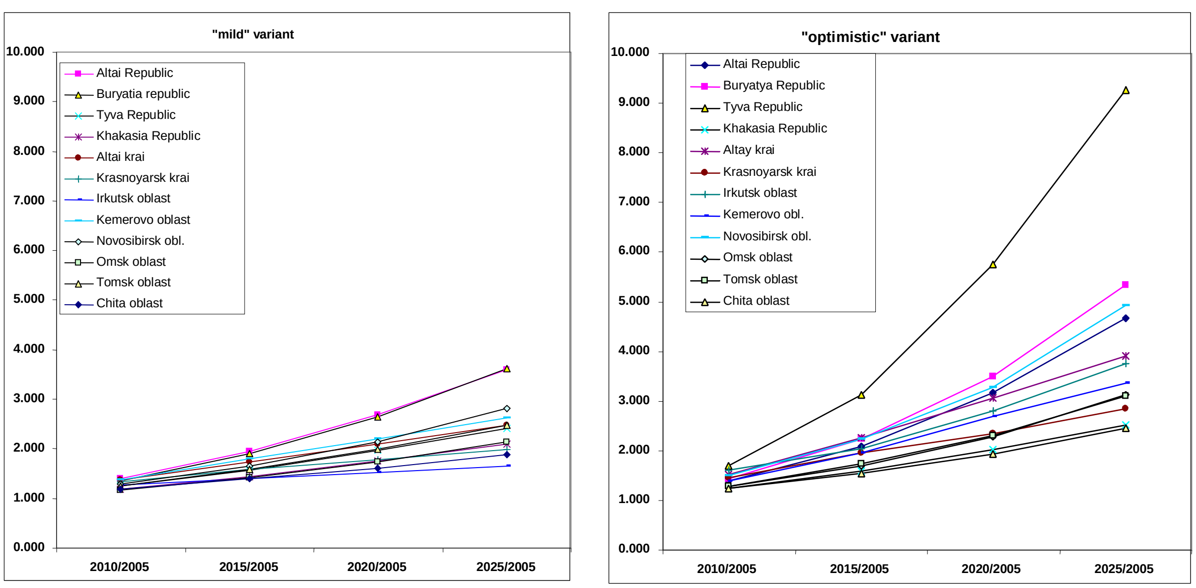

Figure 4. Forecasted growth rates of the gross regional product in regions-subjects of Siberian Federal District in 2010-2025 (in factors; 2005=1)

The consolidation of regional forecast required for a special procedure of converting targeted figures into compatible form of average annual growth rates because different strategies used different time horizons. Various types of scenarios of development formulated in different strategies were generalized and reduced to “inertial” (more probable) and “optimistic” (targeted) scenarios. As it is evident on Figure 4, “inertial” and “optimistic” variants of regional strategies significantly differ. Optimistic expectations cause the rapid growth of regional differentiation. Republics of Tyva and Buryatia, as well as Novosibirsk oblast are distinguished with especially high expectations. Nevertheless, the spatial pattern of the gross regional product (the GRP) of Siberian Federal District remained stable and changed incidentally.

So, it became possible to estimate appropriateness of expectations expressed in the strategies of regions-subjects of Siberian Federal District. As Table 8 demonstrates, in the case of “inertial” scenario” the authors of local strategies extrapolated existing trends in the future so that the results do not deviate too much of the forecast based on the OMIOM – by 0,5 percentage points. At the same time, the mere aggregate of local forecasts yields in higher growth rates even under conditions of “inertial” scenario, that is in the absence of any regional policy.

The comparison of “optimistic” variants evidently reveals the over-estimation of probable positive effects of realization of local strategies caused and, as a consequence, inadequate taking resource constraints into account. The aggregated growth rates of the sum of Siberian regions appear to be much higher even in comparison with the most optimistic, “innovation” scenario of our spatial forecast, exceeding the last by 1 percentage point. This implies that The total gross regional product of Siberian regions increases by a factor of 3,25 for the period of 2006-2020 while after consideration of interregional interactions and inter-industry links, it cannot rise more than by a factor of 2.5 even under the most favourable circumstances and successful realization of regional policy.

Table 8

Forecasts of average annual growth rates of the GRP of Siberian federal District in 2006-2020 (in percents)

	Scenarios		
	Inertial	Energy-raw materials	Innovation
Forecast on the base of the OMIOM	5,3%	6,3%	7,2%
	Inertial	Optimistic	
The aggregate of isolated regional forecasts	5,8%	8,2%	

The same procedure of compilation was performed for forecasted estimates of volumes of fixed investments. The aggregated growth rates of investments in the sum of isolated forecasts of Siberian subjects of the RF turned out to be much higher – by 2 percentage points - in relation to the complex forecast based on the use of multiregional IO model (See Table 9)

Table 9

Forecasts of average annual growth rates of fixed investments of Siberian federal District in 2006-2020 (in percents)

	Варианты прогноза		
	Inertial	Energy-raw materials	Innovation
Forecast on the base of the OMIOM	10,2%	12,1	13,4%
	Inertial	Optimistic	
The aggregate of isolated regional forecasts	12,3%	14,3%	

The result obtained confirms our supposition about insufficient validity of investment plans of regional administrations. They are formulated in terms of realization of regional potential on the assumption of investment inflows from outside, especially from the federal government. But for the national economy as a whole such “external” investment resources are internal. According to the calculations on the base of the OMIOM, the national economy of the RF will not be able to provide the volume of investments declared in local forecasts.

Nevertheless, local forecasts appear to be consistent with the national forecast at least in one aspect: they require for exceeding growth rates of investments over growth rates of production. Now strategies of the subjects of Russian Federation are used as additional tools for lobbying regional interests in the federal center, and from this point of view the development of regional strategies certainly improves the culture of investment decision-making on all federative levels.

So, the existing practice of developing local forecast in isolation of the national forecast of spatial economic development results in their inconsistency, that is exceeding the aggregate demand for external resources over available size of national resources including foreign investments. Improving quality of regional forecasts would be possible if the national spatial forecast were the initial point in the procedure of development of local strategic documents. Our experience in testing 11 regional forecasts proved that the same procedure for 70-80 strategies will be much more complicated process, which requires for the use of multiregional IO modeling.

Conclusion

This paper reported about some results of the use the apparatus of optimization multiregional IO models in forecasting national economy and in solving applied problems.

The first experience concerned to 2003 when our model enabled us not only to answer the question about probability of doubling the GDP in 10 years, but to specify the problem and to make more reasoned conclusion. It turned out to be that doubling the GDP used for final demand of house holdings and gross investments was a quite realistic target. Current statistical data proved the validity of the forecast.

The forecast of long-term demand for electric power revealed a deficiency of current ministerial forecasts that overweighted the influence of short-term factors in electricity consumption. The use of normative methods based on the IO analysis allowed to decline concerns about high probability of general shortage of electric power as well as to reveal potentially energy-scarce regions.

In the similar way, the forecast of demand for transportation services proved that this sector should be developed in full consistency with domestic market needs, not orienting on exports. The potential bottleneck was revealed – carrying capacity of Trans-Siberian Railway.

The experience of coordination of isolated forecasts of development of 11 Siberian regions revealed their inconsistency with available national investment resources. Testing the consistency of local forecast id possible only on the base of national forecast of spatial economic development in the cut of large regions based on the optimization multiregional IO model

References

Ershov, Yu. S., Ibragimov, N. M., Melnikova L. V. 'Sovremennye postanovki modeli prikladnyh meghregional'nyh meghotraslevyh modelei', in Suslov, V. I. (ed.) (2007a) *Issledovaniya mnogoregional'nyh ekonomicheskih system: opyt primeneniyz optimizatcionnyh meghregional'nyh meghotraslevyh system* (Novosibirsk, IEOPP), pp.29-59

Ershov, Yu. S., Ibragimov, N. M., Melnikova L. V. 'Meghregional'nye meghotraslevye modeli v prikladnyh issledovaniyah novoi ekonomiki Rossii', in Suslov, V. I. (ed.) (2007b) *Issledovaniya mnogoregional'nyh ekonomicheskih system: opyt primeneniyz optimizatcionnyh meghregional'nyh meghotraslevyh system* (Novosibirsk, IEOPP), pp.60-94

Kontceptcia dolgosrochnogo sotcial'no-ekonomicheskogo razvitia Rossiiskoi Federatcii na period do 2020 goda. (2008) Moscow. www.economy.gov.ru

Transportnaya strategia Rossiiskoi Federatcii na period do 2030 goda (2008) Moscow. www.mintrans.ru

Supplement 1

List of sectors

№	Types of economic activities
1	Agriculture
2	Hunting and forestry
3	Fishing, fish-farming
4	Extraction of solid fuel
5	Oil extraction
6	Gas extraction
7	Ferrous ore extraction
8	Non-ferrous ore extraction
9	Other minerals extraction
10	Food industry
11	Light industry
12	Wood industry
13	Pulp and paper industry
14	Publishing and printing
15	Coke
16	Oil products
17	Chemical products
18	Other non-metallic mineral products
19	Ferrous metals
20	Non-ferrous metals
21	Fabricated metal products
22	Machinery
23	Other industries
24	Generating and distributing electric energy
25	Generating and distributing heat energy
26	Production and distribution of gas fuel
27	Gathering and distributing water
28	Construction
29	Trade, repair of vehicles and others
30	Hotels and catering
31	Railway transport
32	Pipeline transportation
33	Other transportation and auxiliary activity
34	Communication
35	Financial activities
36	Операции с недвижимостью, аренда и услуги
37	Public administration and military protection, mandatory social insurance
38	Education
39	Health and social services
40	Other public, social and personal utilities

Supplement 2

Formal statement of optimization input-output dynamic model of the Russia's economy

Balances of production and distribution of products
for 2010:

$$x_i^0 + x_i^1 - \sum_{j=1}^{n} a_{ij}^{01} x_j^0 - \sum_{j=1}^{n} a_{ij}^{11} x_j^1 - \alpha_i^1 z^1 - v_i^1 + w_i^1 \geq b_i^1;\ i = 1,\ldots,n; \quad (1)$$

for 2015:

$$x_i^0 + x_i^1 + x_i^2 - \sum_{j=1}^{n} a_{ij}^{02} x_j^0 - \sum_{j=1}^{n} a_{ij}^{12} x_j^1 - \sum_{j=1}^{n} a_{ij}^{22} x_j^2 - \alpha_i^2 z^2 - v_i^2 + w_i^2 \geq b_i^2;\ i = 1,\ldots,n; \quad (2)$$

for 2020:

$$x_i^0 + x_i^1 + x_i^2 + x_i^3 - \sum_{j=1}^{n} a_{ij}^{03} x_j^0 - \sum_{j=1}^{n} a_{ij}^{13} x_j^1 - \sum_{j=1}^{n} a_{ij}^{23} x_j^2 - \sum_{j=1}^{n} a_{ij}^{33} x_j^3 - \alpha_i^3 z^3 - v_i^3 + w_i^3 \geq b_i^3;\ i = 1,\ldots,n; \quad (3)$$

for 2030:

$$x_i^0 + x_i^1 + x_i^2 + x_i^3 + x_i^4 - \sum_{j=1}^{n} a_{ij}^{04} x_j^0 - \sum_{j=1}^{n} a_{ij}^{14} x_j^1 - \sum_{j=1}^{n} a_{ij}^{24} x_j^2 - \sum_{j=1}^{n} a_{ij}^{34} x_j^3 - \sum_{j=1}^{n} a_{ij}^{44} x_j^4 - \alpha_i^4 z^4$$
$$-v_i^4 + w_i^4 \geq b_i^4;\ i = 1,\ldots,m; \quad (4)$$

corresponding restrictions for capital-forming sectors:

$$x_g^0 + x_g^1 - \sum_{j=1}^{n} a_{gj}^{01} x_j^0 - \sum_{j=1}^{n} a_{gj}^{11} x_j^1 - u_g^1 - \alpha_g^1 z^1 - v_g^1 + w_g^1 \geq b_g^1;\ g \in G; \quad (5)$$

$$x_g^0 + x_g^1 + x_g^2 - \sum_{j=1}^{n} a_{gj}^{02} x_j^0 - \sum_{j=1}^{n} a_{gj}^{12} x_j^1 - \sum_{j=1}^{n} a_{gj}^{22} x_j^2 - u_g^2 - \alpha_g^2 z^2 - v_g^2 + w_g^2 \geq b_g^2;\ g \in G; \quad (6)$$

$$x_g^0 + x_g^1 + x_g^2 + x_g^3 - \sum_{j=1}^{n} a_{gj}^{03} x_j^0 - \sum_{j=1}^{n} a_{gj}^{13} x_j^1 - \sum_{j=1}^{n} a_{gj}^{23} x_j^2 - \sum_{j=1}^{n} a_{gj}^{33} x_j^3 - u_g^3 - \alpha_g^3 z^3$$
$$-v_g^3 + w_g^3 \geq b_g^3;\ g \in G; \quad (7)$$

$$x_g^0 + x_g^1 + x_g^2 + x_g^3 + x_g^4 - \sum_{j=1}^{n} a_{gj}^{04} x_j^0 - \sum_{j=1}^{n} a_{gj}^{14} x_j^1 - \sum_{j=1}^{n} a_{gj}^{24} x_j^2 - \sum_{j=1}^{n} a_{gj}^{34} x_j^3 - \sum_{j=1}^{n} a_{gj}^{44} x_j^4 - u_g^4 - \alpha_g^4 z^4$$
$$-v_g^4 + w_g^4 \geq b_g^4;\ g \in G; \quad (8)$$

corresponding restrictions for the sector of transport ($i = \tau$):

$$x_\tau^0 + x_\tau^1 - \sum_{j=1}^{n} a_{\tau j}^{01} x_j^0 - \sum_{j=1}^{n} a_{\tau j}^{11} x_j^1 - \alpha_\tau^1 z^1 - \sum_{j=1}^{n} c_{\tau j}^{v1} v_j^1 - \sum_{j=1}^{n} c_{\tau j}^{w1} w_j^1 \geq b_\tau^1; \quad (9)$$

$$x_\tau^0 + x_\tau^1 + x_\tau^2 - \sum_{j=1}^{n} a_{\tau j}^{02} x_j^0 - \sum_{j=1}^{n} a_{\tau j}^{12} x_j^1 - \sum_{j=1}^{n} a_{\tau j}^{22} x_j^2 - \alpha_\tau^2 z^2 - \sum_{j=1}^{n} c_{\tau j}^{v2} v_j^2 - \sum_{j=1}^{n} c_{\tau j}^{w2} w_j^2 \geq b_\tau^2; \quad (10)$$

$$x_\tau^0 + x_\tau^1 + x_\tau^2 + x_\tau^3 - \sum_{j=1}^{n} a_{\tau j}^{03} x_j^0 - \sum_{j=1}^{n} a_{\tau j}^{13} x_j^1 - \sum_{j=1}^{n} a_{\tau j}^{23} x_j^2 - \sum_{j=1}^{n} a_{\tau j}^{33} x_j^3 - \alpha_\tau^3 z^3 -$$
$$\sum_{j=1}^{n} c_{\tau j}^{v3} v_j^3 - \sum_{j=1}^{n} c_{\tau j}^{w3} w_j^3 \geq b_\tau^3; \quad (11)$$

$$x_\tau^0 + x_\tau^1 + x_\tau^2 + x_\tau^3 + x_\tau^4 - \sum_{j=1}^{n} a_{\tau j}^{04} x_j^0 - \sum_{j=1}^{n} a_{\tau j}^{14} x_j^1 - \sum_{j=1}^{n} a_{\tau j}^{24} x_j^2 - \sum_{j=1}^{n} a_{\tau j}^{34} x_j^3 - \sum_{j=1}^{n} a_{\tau j}^{44} x_j^4 - \alpha_\tau^4 z^4 -$$
$$\sum_{j=1}^{n} c_{\tau j}^{v4} v_j^4 - \sum_{j=1}^{n} c_{\tau j}^{w4} w_j^4 \geq b_\tau^4; \quad (12)$$

Balances of labor resources:

for 2010:

$$\sum_{j=1}^{n} t_j^{01} x_j^0 + \sum_{j=1}^{n} t_j^{11} x_j^1 \le T_1; \tag{13}$$

for 2015:

$$\sum_{j=1}^{n} t_j^{02} x_j^0 + \sum_{j=1}^{n} t_j^{12} x_j^1 + \sum_{j=1}^{n} t_j^{22} x_j^2 \le T_2; \tag{14}$$

for 2020:

$$\sum_{j=1}^{n} t_j^{03} x_j^0 + \sum_{j=1}^{n} t_j^{13} x_j^1 + \sum_{j=1}^{n} t_j^{23} x_j^2 + \sum_{j=1}^{n} t_j^{33} x_j^3 \le T_3; \tag{15}$$

for 2030:

$$\sum_{j=1}^{n} t_j^{04} x_j^0 + \sum_{j=1}^{n} t_j^{14} x_j^1 + \sum_{j=1}^{n} t_j^{24} x_j^2 + \sum_{j=1}^{n} t_j^{34} x_j^3 + \sum_{j=1}^{n} t_j^{44} \le T_4; \tag{16}$$

Balances of investments:

at period 1 (2006-2010):

$$\sum_{j=1}^{n} k_{gj}^{01} x_j^0 + \sum_{j=1}^{n} k_{gj}^{11} x_j^1 - f_1(u_g^0, u_g^1) \le 0;\ g \in G; \tag{17}$$

at period 2 (2011-2020):

$$\sum_{j=1}^{n} k_{gj}^{02} x_j^0 + \sum_{j=1}^{n} k_{gj}^{12} x_j^1 + \sum_{j=1}^{n} k_{gj}^{22} x_j^2 - f_2(u_g^1, u_g^2) \le 0;\ g \in G; \tag{18}$$

at period 3 (2016-2020):

$$\sum_{j=1}^{n} k_{gj}^{03} x_j^0 + \sum_{j=1}^{n} k_{gj}^{13} x_j^1 + \sum_{j=1}^{n} k_{gj}^{23} x_j^3 + \sum_{j=1}^{n} k_{gj}^{33} x_j^3 - f_3(u_g^2, u_g^3) \le 0;\ g \in G; \tag{19}$$

at period 4 (2021-2030):

$$\sum_{j=1}^{n} k_{gj}^{04} x_j^0 + \sum_{j=1}^{n} k_{gj}^{14} x_j^1 + \sum_{j=1}^{n} k_{gj}^{24} x_j^2 + \sum_{j=1}^{n} k_{gj}^{34} x_j^3 + \sum_{j=1}^{n} k_{gj}^{44} x_j^4 - f_4(u_g^3, u_g^4) \le 0;\ g \in G; \tag{20}$$

Foreign trade balances:

for 2010:

$$\sum_{j=1}^{n} \beta_j^1 v_j^1 - \sum_{j=1}^{n} \gamma_j^1 w_j^1 \ge Q_1; \tag{21}$$

for 2015:

$$\sum_{j=1}^{n} \beta_j^2 v_j^2 - \sum_{j=1}^{n} \gamma_j^2 w_j^2 \ge Q_2; \tag{22}$$

for 2020:

$$\sum_{j=1}^{n} \beta_j^3 v_j^3 - \sum_{j=1}^{n} \gamma_j^3 w^3 \ge Q^3; \tag{23}$$

for 2030:

$$\sum_{j=1}^{n} \beta_j^4 v_j^4 - \sum_{j=1}^{n} \gamma_j^4 w^4 \ge Q^4; \tag{24}$$

Restrictions on outputs and increases in outputs:

$$x_j^0 \le d_j^0; x_j^1 \le d_j^1; x_j^2 \le d_j^2; x_j^3 \le d_j^3; x_j^4 \le d_j^4;\ j = 1, \dots, n; \tag{25}$$

Restrictions on maximum and minimum exports and imports:

$$\begin{aligned} &q_j^1 \le v_j^1 \le \overline{q}_j^1; q_j^2 \le v_j^2 \le \overline{q}_j^2; x_j^3 \le d_j^3;\ x_j^4 \le d_j^4;\ p_j^1 \le w_j^1 \le \overline{p}_j^1;\ p_j^2 \le w_j^2 \le \overline{p}_j^2; \\ &p_j^3 \le w_j^3 \le \overline{p}_j^3; p_j^4 \le w_j^4 \le \overline{p}_j^4;\ j = 1, \dots, n; \end{aligned} \tag{26}$$

Objective function:

$z^1 + \delta^1 z^2 + \delta^2 z^3 + \delta^3 z^4 \to \max;$

List of symbols:

Variables:

x_i^0 - base output in sector *i* (as of 2005);

x_i^1 - increase in output of sector *i* over a period 1 (2006 – 2010);

x_i^2 - increase in output of sector *i* over a period 2 (2011 – 2015);

x_i^3 - increase in output of sector *i* over a period 3 (2016 – 2020);

x_i^4 - increase in output of sector *i* over a period 4 (2021 – 2030);

z^1 - value of maximized part of final demand in 2010;

z^2 - value of maximized part of final demand in 2015;

z^3 - value of maximized part of final demand in 2020;

z^4 - value of maximized part of final demand in 2030;

v_i^1 - export of products of sector *i* in 2010;

v_i^2 - export of products of sector *i* in 2015;

v_i^3 - export of products of sector *i* in 2020;

v_i^4 - export of products of sector *i* in 2030;

w_i^1 - import of products of sector *i* in в 2010;

w_i^2 - import of products of sector *i* in 2015;

w_i^3 - import of products of sector *i* in 2020;

w_i^4 - import of products of sector *i* in 2030;

u_g^1 - gross fixed investments in 2010 (in the part of capital-forming sector g);

u_g^2 - fixed investments in 2015 (in the part of capital-forming sector g);

u_g^3 - fixed investments in 2020 (in the part of capital-forming sector g);

u_g^4 - fixed investments in 2030 (in the part of capital-forming sector g);

Parameters:

a_{ij}^{01} - input-output coefficients providing a value of output of sector *j* in 2010 not exceeding a base value;

a_{ij}^{02} - input-output coefficients providing a value of output of sector *j* in 2015 not exceeding a base value;

a_{ij}^{03} - input-output coefficients providing a value of output of sector *j* in 2020 not exceeding a base value;

a_{ij}^{04} - input-output coefficients providing a value of output of sector *j* in 2030 not exceeding a base value;

a_{ij}^{11} - input-output coefficients for 2010 that provide an increase in output in 2006-2010 ;

a_{ij}^{12} - input-output coefficients for 2015 that provide an increase in the output attained over a period 1;

a_{ij}^{13} - input-output coefficients for 2020 that provide an increase in the output attained over a period 1;

a_{ij}^{14} - input-output coefficients for 2030 that provide an increase in the output attained over a period 1;

a_{ij}^{22} - input-output coefficients for 2015 that provide an increase in output of sector *j* in 2011-2015;
a_{ij}^{23} - input-output coefficients for 2020 that provide an increase in the output attained over a period 2;
a_{ij}^{24} - input-output coefficients for 2030 that provide an increase in the output attained over a period 2;
a_{ij}^{33} - input-output coefficients for 2020 that provide an increase in output of sector *j* in 2016-2020;
a_{ij}^{34} - input-output coefficients for 2030 that provide an increase in output of sector *j* in 2016-2020;
a_{ij}^{44} - input-output coefficients for 2030 that provide an increase in output of sector *j* in 2021-2030;
$\alpha_i^1, \alpha_i^2, \alpha_i^3$ - a share of products of sector *i* in the maximized part of final demand (correspondingly, in 2010, 2015 and 2020);
$c_{\tau j}^{v1}$ - transport costs of exporting a product unit of sector *j* in 2010;
$c_{\tau j}^{w1}$ - transport costs of importing a product unit of sector *j* in 2010;
$c_{\tau j}^{v2}$ - transport costs of exporting a product unit of sector *j* in 2015;
$c_{\tau j}^{w2}$ - transport costs of importing a product unit of sector *j* in 2015;
$c_{\tau j}^{v3}$ - transport costs of exporting a product unit of sector *j* in 2020;
$c_{\tau j}^{w3}$ - transport costs of importing a product unit of sector *j* in 2020;
$c_{\tau j}^{v4}$ - transport costs of exporting a product unit of sector *j* in 2030;
$c_{\tau j}^{w4}$ - transport costs of importing a product unit of sector *j* in 2030;
t_j^{01} - labour coefficients providing a value of output of sector *j* in 2010 not exceeding a base value;
t_j^{02} - labour coefficients providing a value of output of sector *j* in 2015 not exceeding a base value;
t_j^{03} - labour coefficients providing a value of output of sector *j* in 2020 not exceeding a base value;
t_j^{04} - labour coefficients providing a value of output of sector *j* in 2030 not exceeding a base value;
t_j^{11} - labour coefficients for 2010 that provide an increase in output in 2006-2010 ;

t_j^{12} - labour coefficients for 2015 that provide an increase in the output attained over a period 1;
t_j^{13} - labour coefficients for 2020 that provide an increase in the output attained over a period 1;
t_j^{14} - labour coefficients for 2030 that provide an increase in the output attained over a period 1;
t_i^{22} - labour coefficients for 2015 that provide an increase in output of sector *j* in 2011-2015;
t_j^{23} - labour coefficients for 2020 that provide an increase in the output attained over a period 2;
t_j^{24} - labour coefficients for 2030 that provide an increase in the output attained over a period 2;
t_i^{33} - labour coefficients for 2020 that provide an increase in output of sector *j* in 2016-2020;
t_i^{34} - labour coefficients for 2030 that provide an increase in output of sector *j* in 2016-2020;

t_i^{44} - labour coefficients for 2030 that provide an increase in output of sector j in 2021-2030;

k_{gj}^{01} - capital coefficients that maintain an output of sector j on the base level in 2006-2010 (in the part of costs of capital-forming sector g);

k_{gj}^{02} - capital coefficients that maintain an output of sector j on the base level in 2006-2015 (in the part of costs of capital-forming sector g);

k_{gj}^{03} - capital coefficients that maintain an output of sector j on the base level in 2006-2020 (in the part of costs of capital-forming sector g);

k_{gj}^{04} - capital coefficients that maintain an output of sector j on the base level in 2006-2030 (in the part of costs of capital-forming sector g);

k_{gj}^{11} - capital coefficients that provide an increase in output of sector j in 2006-2010 (in the part of costs of capital-forming sector g);

k_{gj}^{12} - capital coefficients that provide an increase in output of sector j in 2006-2010 and maintain the increase in 2006-2015 (in the part of costs of capital-forming sector g);

k_{gj}^{13} - capital coefficients that provide an increase in output of sector j in 2006-2010 and maintain the increase in 2006-2020 (in the part of costs of capital-forming sector g);

k_{gj}^{14} - capital coefficients that provide an increase in output of sector j in 2006-2010 and maintain the increase in 2006-2030 (in the part of costs of capital-forming sector g);

k_{gj}^{22} - capital coefficients that provide an increase in output of sector j in 2011-2015 (in the part of costs of capital-forming sector g);

k_{gj}^{23} - capital coefficients that provide an increase in output of sector j in 2011-2015 and maintain the increase in 2011-2020 (in the part of costs of capital-forming sector g);

k_{gj}^{24} - capital coefficients that provide an increase in output of sector j in 2011-2015 and maintain the increase in 2011-2030 (in the part of costs of capital-forming sector g);

k_{gj}^{33} - capital coefficients that provide an increase in output of sector j in 2016-2020 (in the part of costs of capital-forming sector g);

k_{gj}^{34} - capital coefficients that provide an increase in output of sector j in 2016-2020 and maintain the increase in 2021-2030 (in the part of costs of capital-forming sector g);

k_{gj}^{44} - capital coefficients that provide an increase in output of sector j in 2021-2030 (in the part of costs of capital-forming sector g);

u_g^0 - a base value (2005) of investments (in the part of costs of capital-forming sector g);

$f_1(u_g^0, u_g^1)$ - a dependence function of total investments for period 1 on their base values and on their values attained in the last year of period 1 (for a given law of growth);

$f_2(u_g^1, u_g^2)$ - a dependence function of total investments for period 2 on their values attained in the last year of period 1 and on their values attained in the last year of period 2 (for a given law of growth);

$f_3(u_g^2, u_g^3)$ - a dependence function of total investments for period 3 on their values attained in the last year of period 2 and on their values attained in the last year of period 3 (for a given law of growth);

$f_4(u_g^3, u_g^4)$ - a dependence function of total investments for period 4 on their values attained in the last year of period 3 and on their values attained in the last year of period 4 (for a given law of growth);

β_j^1 - coefficients converting domestic basic prices (in rubles) into foreign market prices (in dollars) for exported products of sector j in 2010;

γ_j^1 - coefficients converting domestic basic prices (in rubles) into foreign market prices (in dollars) for imported products of sector j in 2010;
β_j^2 - coefficients converting domestic basic prices (in rubles) into foreign market prices (in dollars) for exported products of sector j in 2015;
γ_j^2 - coefficients converting domestic basic prices (in rubles) into foreign market prices (in dollars) for imported products of sector j in 2015;
β_j^3 - coefficients converting domestic basic prices (in rubles) into foreign market prices (in dollars) for exported products of sector j in 2020;
γ_j^3 - coefficients converting domestic basic prices (in rubles) into foreign market prices (in dollars) for imported products of sector j in 2020;
β_j^4 - coefficients converting domestic basic prices (in rubles) into foreign market prices (in dollars) for exported products of sector j in 2030;
γ_j^4 - coefficients converting domestic basic prices (in rubles) into foreign market prices (in dollars) for imported products of sector j in 2030;
$d_j^0, d_j^1, d_j^2, d_j^3, d_j^4$ - restrictions on variables of output of sector j (increases in outputs);
Q^1, Q^2, Q^3, Q^4 - restrictions on values of trade balances (correspondingly, in 2010, 2015, 2020 and 2030);
T^1, T^2, T^3, T^4 - expected employment (correspondingly. in 2010, 2015, 2020 and 2030);
$q_j^1, q_j^2, q_j^3, q_j^4, \overline{q}_j^1, \overline{q}_j^2, \overline{q}_j^3, \overline{q}_j^4$ - maximum and minimum exports of products of sector j (in 2010, 2015, 2020 and 2030);
$p_j^1, p_j^2, p_j^3, p_j^4, \overline{p}_j^1, \overline{p}_j^2, \overline{p}_j^3, \overline{p}_j^4$ - maximum and minimum imports of products of sector j (in 2010, 2015, 2020 and 2030);
$\delta^1, \delta^2, \delta^3$ - discounting coefficients for final demand, $0 < \delta^i \le 1, i = 1,3$

Supplement 3

List of regions and abbreviatures

1. Central Federal District (CFD)
2. North-Western Federal District (NWFD)
3. Southern Federal District (SoFD)
4. Volga Federal District (VFD)
5. Urals Federal District excluding Tyumen oblast (UFD-T)
6. Tyumen oblast (Tyu)
7. Siberian Federal District (SiFD)
8. Far Eastern Federal District (FEFD)

Formal statement of optimization multiregional input-output model of Russia's economy

Regional blocks of the model

Balances of production and distribution of products

$$x_i^{r0} + x_i^{r1} - \sum_{j=1}^{n} a_{ij}^{r0} x_j^0 - \sum_{j=1}^{n} a_{ij}^{r1} x_j^1 - \alpha_i^r z^r - \sum_{s \neq r} x_i^{rs} + \sum_{s \neq r} x_i^{sr} - \sum_{h=1}^{3} v_i^{rh} + \sum_{h=1}^{3} w_i^{rh} \geq b_i^r ; i = 1,...,n; \quad (1)$$

corresponding restrictions for capital-forming sectors:

$$x_g^{r0} + x_g^{r1} - \sum_{j=1}^{n} a_{gj}^{r0} x_j^0 - \sum_{j=1}^{n} a_{gj}^{r1} x_j^1 - u_g^{r1} - \alpha_g^r z^r - \sum_{s \neq r} x_g^{rs} + \sum_{s \neq r} x_g^{sr} - \sum_{h=1}^{3} v_g^{rh} + \sum_{h=1}^{3} w_g^{rh} \geq b_g^r ; g \in G; \quad (2)$$

corresponding restrictions for the sector of transport ($i = \tau$):

$$x_\tau^{r0} + x_\tau^{r1} - \sum_{j=1}^{n} a_{\tau j}^{r0} x_j^0 - \sum_{j=1}^{n} a_{\tau j}^{r1} x_j^1 - \alpha_\tau^r z^r - \sum_{k,s:k \neq s} \sum_{j=1}^{n} a_{\tau rj}^{ks} x_j^{ks} - \sum_{h=1}^{3} \sum_{j=1}^{n} c_{\tau j}^{rvh} v_j^{rh} - \sum_{h=1}^{3} \sum_{j=1}^{n} c_{\tau j}^{rwh} w_j^{rh} \geq b_\tau^r ; \quad (3)$$

Balances of labor resources:

$$\sum_{j=1}^{n} t_j^{r0} x_j^0 + \sum_{j=1}^{n} t_j^{r1} x_j^1 \leq T^r ; \quad (4)$$

Balances of investments:

$$\sum_{j=1}^{n} k_{gj}^{r0} x_j^0 + \sum_{j=1}^{n} k_{ji}^{r1} x_i^1 - f_1 (u_g^{r0} , u_g^{r1}) \leq 0; g \in G ; \quad (5)$$

Regional foreign trade balances:

$$\sum_{j=1}^{n} \beta_j^r v_j^r - \sum_{j=1}^{n} \gamma_j^r w_j^r \geq Q^r ; \quad (6)$$

Restrictions on outputs and increases in outputs:

$$x_j^{r0} \leq d_j^{r0} ; x_j^{r1} \leq d_j^{r1} ; \ j = 1,...,n; \quad (7)$$

Restrictions on maximum and minimum exports and imports (quotas on imports and exports):

$$q_j \leq \sum_r v_j^r \leq \overline{q}_j ; \ p_j \leq \sum_r w_j^r \leq \overline{p}_j ; \ j = 1,...,n; \quad (8)$$

System-wide restrictions

Restrictions on territorial pattern of final demand

$$z^r - \alpha^r z \geq 0; \ r = 1,...,R \quad (9)$$

Restrictions on maximum and minimum exports and imports:

$$\sum_{r=1}^{R} \sum_{j=1}^{n} \beta_j^r v_j^r - \sum_{r=1}^{R} \sum_{j=1}^{n} \gamma_j^r w_j^r \geq Q; ; \quad (10)$$

Objective function:

$$z \rightarrow max \quad (11)$$

List of symbols:

Variables:

x_i^{r0} - output of sector *i* of region *r* produced in the last year of forecasting period on production facilities that worked at the beginning of the period;

x_i^{r1} - increase in output of sector *i* in region *r* for the period;

x_i^{rs} - transportation of products of sector *i* from region *r* to region *s* in the last year of forecasting period;

x_i^{sr} - transportation of products of sector *i* from region *s* to region *r* in the last year of forecasting period;

z^r - value of final demand of region *r* in the last year of forecasting period;

v_i^{rh} - export of products of sector *i* of region *r* in the last year of forecasting period in direction *h*;

w_i^{rh} - import of products of sector *i* of region *r* in the last year of forecasting period in direction *h*;

u_g^{r1} - gross investment of region *r* in the last year of the period (in the part of capital-forming sector *g*) that are calculated as a sum of investments in the base year u_g^{r0} and increases in investments $\sum_{k=1}^{T} \Delta u_g^{r0}(k)$ (T - length of the period);

z - a value of maximized part of final demand in the last year of the period;

α^r - a share of region *r* in maximized part of final demand in the last year of the period.

Parameters:

a_{ij}^{r0} - input-output coefficients providing a value of output of sector *j* of region *r* in the last year of the period not exceeding a base value;

a_{ij}^{r1} - input-output coefficients providing an increase in output of sector *j* of region *r* over the period;

α_i^r - a share of products (services) of sector *i* of region *r* in maximized part of final demand in the last year of the period;

$a_{\tau rj}^{ks}$ - transport costs of region *r* for transportation of a product unit of sector *j* from region *k* to region *s* in the last year of the period;

b_i^r - fixed part of final demand of sector *i* of region *r* in the last year of the period;

$c_{\tau j}^{rvh}$ - transport costs of exporting a product unit of sector *j* of region *r* in the last year of the period by direction *h*;

$c_{\tau j}^{rwh}$ - transport costs of importing a product unit of sector *j* of region *r* in the last year of the period by direction *h*;

t_i^{r0} - labour coefficients providing a value of output of sector *i* of region *r* in the last year of the period not exceeding a base value;

t_i^{r1} - labour coefficients in the last year of the period providing an increase in output of sector *i* of region *r* over the period;

k_{gi}^{r0} - capital coefficients maintaining output of sector *i* of region *r* over the period on the level attained in the base year (in the part of costs of capital-forming sector *g*);

k_{gi}^{r1} - capital coefficients providing an increase in output of sector *i* of regiona *r* for the period (in the part of costs of capital-forming sector *g*);

u_g^{r0} - base value of investment in the part of costs of capital-forming sector *g* of region *r*;

$f(u_g^{r0}, u_g^{r1})$ - dependence function of total investment of region *r* for the period on its base value and its value attained in the last year of the period (for a given law of growth);

β_i^r - coefficients converting domestic basic prices (in rubles) into foreign market prices (in dollars) for products of sector *i* exported from region *r* in the last year of the period;

γ_i^r - coefficients converting domestic basic prices (in rubles) into foreign market prices (in dollars) for products of sector *i* imported by region *r* in the last year of the period;

T^r - restrictions on number of labour resources of region *r* in the last year of the period;
Q^r - restrictions on trade balance of region *r* in the last year of the period;
d_i^{r0}, d_i^{r1}, - restrictions on values of output variables and on increases in outputs of region r in the last year of the period;
$q_i, \overline{q}_i$ - maximum and minimum exports of products of sector *i* in the last year of the period;
$p_i, \overline{p}_i$ - maximum and minimum imports of products of sector *i* in the last year of the period;
Q - restriction on value of national trade balance in the last year of the period.

Scheme of optimization multiregional input-output model (on the example of 3 regions)

	Restriction N	Region 1						Region 2						Region 3								Right hand
		$x^{(1)}$	$x^{(12)}$	$x^{(13)}$	$v^{(1)}$	$w^{(1)}$	$z^{(1)}$	$x^{(2)}$	$x^{(21)}$	$x^{(23)}$	$v^{(2)}$	$w^{(2)}$	$z^{(2)}$	$x^{(3)}$	$x^{(31)}$	$x^{(32)}$	$v^{(3)}$	$w^{(3)}$	$z^{(3)}$	Z		
Region 1	**1-8**																					
Region 2	**1-8**																					
Region 3	**1-8**																					
Regional pattern of	**9**																					
Foreign trade balance	**10**																					
Functional	**11**																					