INTER-SECTOR INTER-REGION ANALYSIS: ESTIMATING CONSEQUENCES OF REALIZATION OF LARGE INVESTMENT PROJECTS IN ENERGY SECTOR OF RUSSIAN ECONOMY

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■ Introduction

The paper discusses an approach to a long-term inter-sector and inter-regional analysis of interactions between a national economy and its energy production segment. It is based on an optimization multi-sector multi-regional model (OMMM) which includes a natural block of energy production, processing and transportation (OMMM-Energy) (Suslov et. al., 2007). The latter, in its turn, is an advanced version of the model suggested and developed by Prof. Alexander Granberg (Granberg, 1973) – a famous Soviet and Russian economist who has made a noticeable contribution to the theory of regional structure analysis. At present, this version 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.

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:

- concentration of energy-intensive productions and gasification in the South Siberia regions;
- fast development of nuclear energy in the national economy;
- a reduction of energy intensity of production in the national economy;
- wide application of heat pumps technologies in the different regions of the national economy

and many others but less significant issues.

The next section of the paper briefly describes a history of how the Soviet Union applied and later Russia continued to apply the input-output interregional analysis and OMMM, and what are their basic characteristics in comparison with IO, IRIO and MRIO approaches. The section 3 discusses both methodology and history of developing the original OMMM resulted in an OMMM-Energy version of the model. The sections 4–5 are devoted to setting and analyzing the problem of energy intensity in Russia and other world economies which we call "Energy intensity puzzle". Section 6 presents some results of our analysis conducted by applying the model, and finally, the last section presents our conclusions.

■ OMMM: Identification and History

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 the 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 first 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 (Fig. 1). 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).

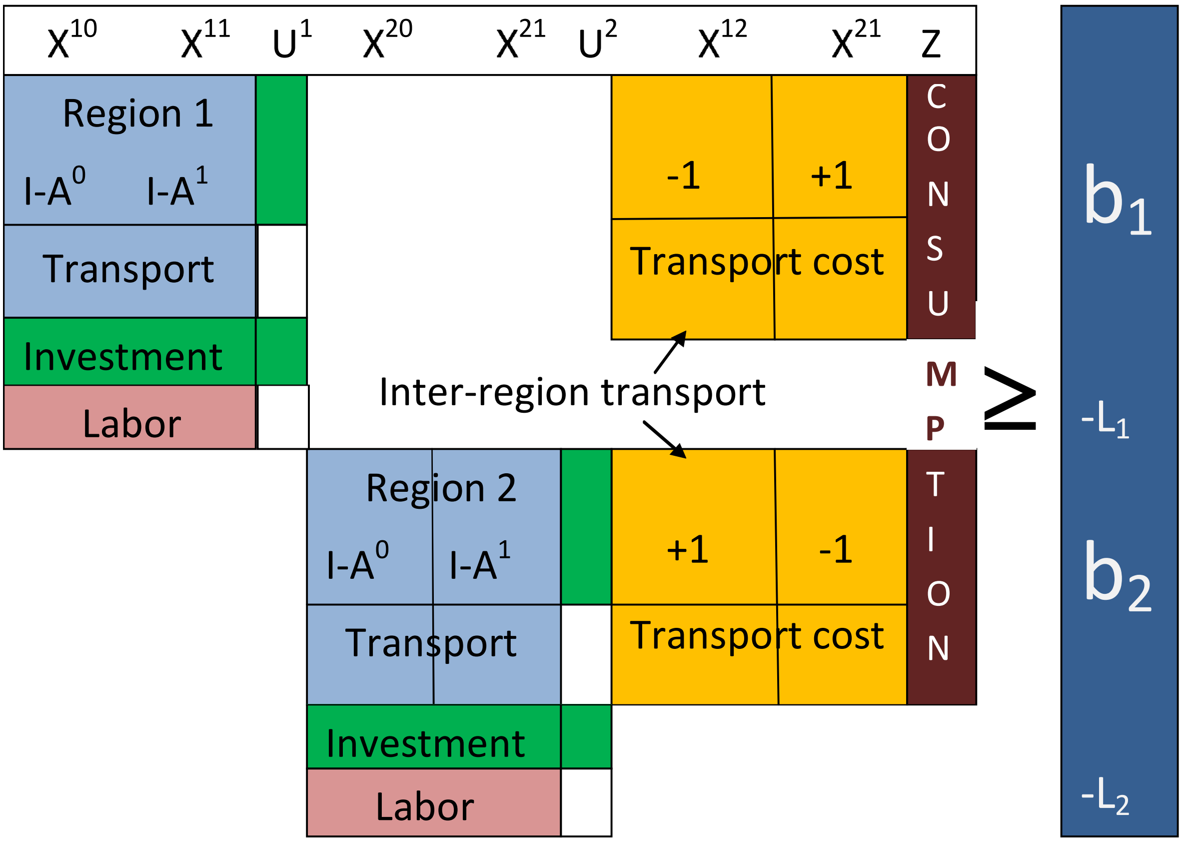

Fig. 1. A Principle structure of OMMM for 2 regions:
Intra-regional IO matrixes for all identified regions
are the basis of the OMMM.

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.

$$x_i^{r0} + x_i^{r1} - \sum_{j=1}^{n} a_{ij}^{r0} \cdot x_j^{r0} - \sum_{j=1}^{n} a_{ij}^{r1} \cdot x_j^{r1} - u_i^{r1} - \alpha_i^r \cdot Z -$$

$$\sum_{\tau=1}^{T} \sum_{s \neq r} x_i^{rs} + \sum_{\tau=1}^{T} \sum_{s \neq r} x_i^{sr} - NEX_i^r \geq b_i^r, \quad i = 1, \ldots, n \tag{1}$$

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

$$\tau = 1, \ldots T \tag{2}$$

$$\sum_{j=1}^{n} l_j^{r0} \cdot x_j^{r0} + \sum_{j=1}^{n} l_j^{r1} \cdot x_j^{r1} + \sum_{\tau=1}^{T} l_\tau^{r0} \cdot x_\tau^{r0} + \sum_{\tau=1}^{T} l_\tau^{r1} \cdot x_\tau^{r1} \leq L^r, \tag{3}$$

$$\sum_{j=1}^{n} k_{gj}^{r0} \cdot x_j^{r0} + \sum_{j=1}^{n} k_{gj}^{r1} \cdot x_j^{r1} + \sum_{\tau=1}^{T} k_{g\tau}^{r0} \cdot x_\tau^{r0} + \sum_{\tau=1}^{T} k_{g\tau}^{r1} \cdot x_\tau^{r1} - f(u_g^{r0}, u_g^{r1}) \leq 0, g \in G \tag{4}$$

$$\xi_i^{r0} \leq x_i^{r0} \leq \zeta_i^{r0}, \quad \xi_i^{r1} \leq x_i^{r1} \leq \zeta_i^{r1}, \; i = 1, \ldots, n \tag{5}$$

$$\max Z \tag{6}$$

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 a_{ij}^{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_τ^{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:

- 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 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.

■ OMMM-Energy

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 percent 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, 1976, 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. el., 1995, Wade, 2003). 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:

- specific reproduction of capacities in the oil-and-gas sector;
- 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;
- complementary outputs of different energy technologies (e.g. oil and associated gas, or gas and condensed fluid);
- specific transportation of oil and gas (a pipeline system);

- 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. 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.

■ Energy Intensity Puzzle

Before the energy crisis of 1970s, the main trends in energy consumption especially evident in the countries with average income were increased per capita energy consumption and growing energy intensity. Thus, we observe that the average per capita consumption of commercially produced energy had practically doubled in today's OECD countries from 1960s to 1973, out of which in Japan, Portugal, and Spain this growth was 2.5–3 times, and in Greece the increase was almost 5 times. Accordingly, the energy intensity of the income produced grew too. The average growth index of energy intensity for OECD countries over this period was 120%.

During the decade following the energy crisis break-up, the energy consumption trends were reversed in most countries. By 1983, the average reduction index of GDP energy intensity for OECD countries was 10%, and by the end of the century this index dropped by further 4%. At the same time, however, in such OECD member countries as Australia, Belgium, Denmark, Italy, Japan, Great Britain, and USA, the reduction in the GDP energy intensity exceeded 20% over the first post-crisis decade and 30–40% – before the end of the century (see Fig. 2). Obviously, such a striking improvement of the energy consumption efficiency in the above-mentioned countries should be attributed not only to the skyrocketing energy prices in the efficient markets but also to the special measures of government policy aimed at better energy conservation.

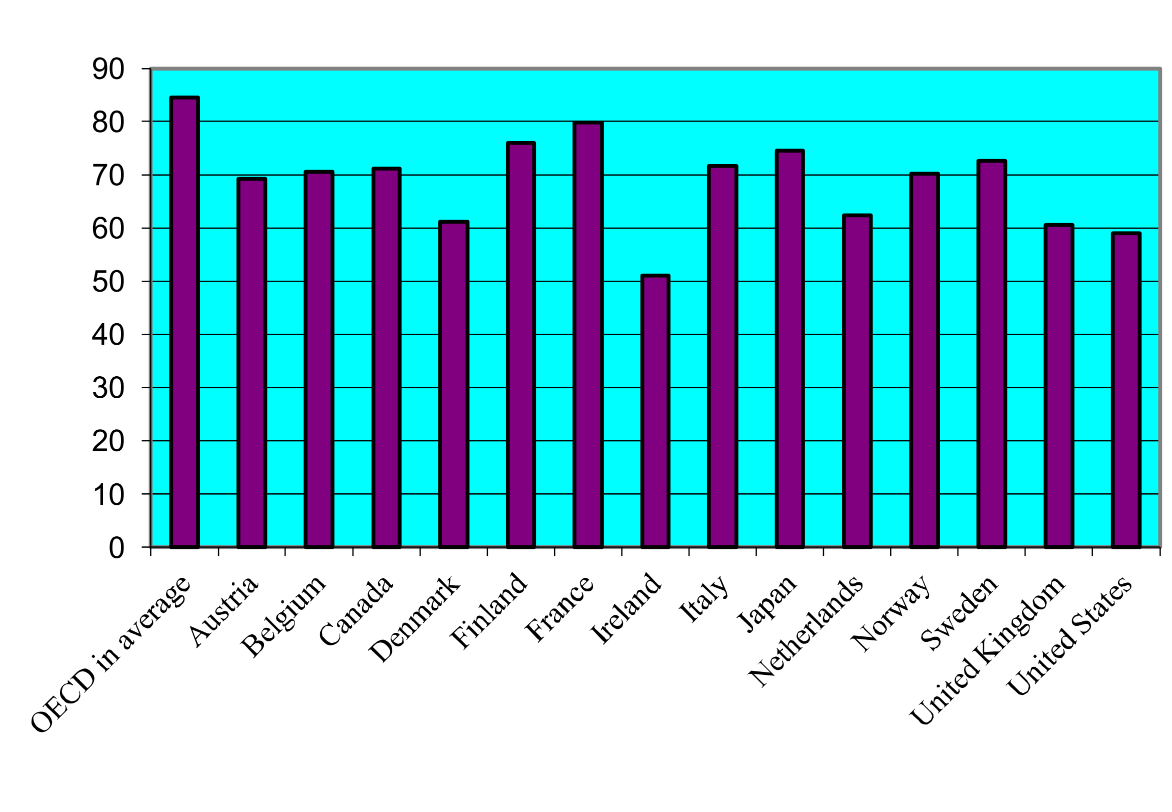

Fig. 2. Change in the GDP Energy Intensity in Selected OECD Economies: 2000 to 1973, %

The available data for the countries with socialist economy show that there too was a certain reduction in the output energy intensity in 1970s and 1980s, although is already universally recognized that the official statistics in socialist countries overestimated the output growth indices, and, consequently, the data on the energy intensity dynamics lack reliability. In the early 1990s when the economic reforms were launched, the GDP energy intensity in transitional economies significantly – as often as not several fold – exceeded the levels of market economies, and the situation has not changed significantly since that time (see Fig. 3). The initial transformation period in former socialist countries was characterized by increasing energy intensity of production resulting from the shrinking output. After this, however, in most of the above-mentioned countries energy intensity of production decreased fairly fast, although not everywhere it approached the pre-crisis levels. As was shown in (Suslov and Ageeva, 2005), the reduction in the energy intensity of production over the above-named period was little related to the increase in the energy prices, and was rather a "byproduct" of increase in the production and capacity utilization.

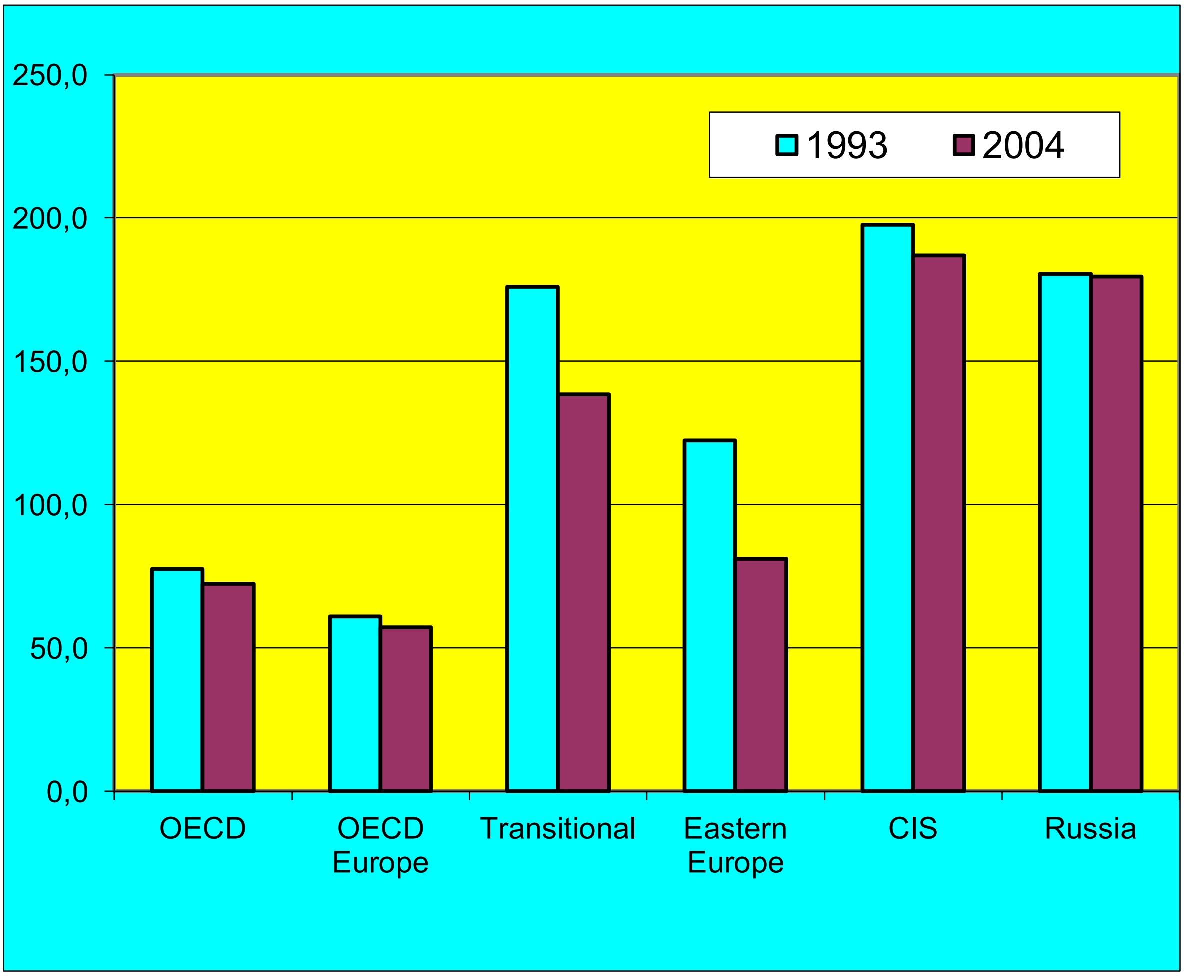

Fig. 3. Energy Intensity of GDP in World Economies and Groups of Economies, USA in 1993=100%

Higher energy inputs in former socialist countries may partially be attributed to the inclement climatic conditions: in this part of the East Europe and the Asian part of the former Soviet Union average annual temperatures are significantly lower and the amplitude of seasonal variations is much higher than in, say, Western Europe. However, as our analysis showed (Suslov and Ageeva, 2005), this factor fails to account for the entire difference in the levels of energy intensity. This suggests that a significant factor affecting the levels of specific energy consumption is the quality of economic institutions determining the key aspects of economic system performance mechanism. Our hypothesis is that weak institutional development can lower the incentives for economic agent to take energy conservation measures, including the implementation of investment projects aimed at energy saving.

We use the following specification:

$$\ln(e) = \beta_0 + \beta_1 \cdot DISTE + \beta_2 \cdot INST \cdot \ln\left(\frac{P}{p_E}\right) +$$

$$+ \beta_3 \cdot \ln\left(\frac{P}{p_E}\right) + \varepsilon \tag{7}$$

though the variable *INST* may designate different institutional variables from their total list presented in the section 4.1. We used in our analysis both several individual variables and their combinations but present in our paper the most satisfactory version of this variable being a sum of two institutional indices – Government Effectiveness and Control of Corruption:

$$INST = GE + CC \tag{8}$$

The variable of a combined influence of the real energy price and institutions $INST \cdot \ln\left(\frac{P}{p_E}\right)$ is called the interaction term, which we use following Polterovich and Popov (Polterovich and Popov, 2004). If it proves significant, one could suggest that the institutions affect energy intensity through the price system. On the other hand, a simple transformation in (7) helps to see that the value $\beta_2 \cdot INST + \beta_3$ is the price elasticity of output energy intensity as a function of the institutional strength index, which fit our theoretical model.

■ Estimation Results: What are the Main Reasons for High Transaction Cost?

We estimated the model (7) keeping (8) for 5 years: 2002 trough 2006. The reason why we omitted the year of 2001 is absence of institutional indices for it in the World Bank databases. The main results are presented in the Tab. 1.

Using in the regression a variable of seasonal temperature fluctuation which we consider a good reflection of climate severity rather than a mean annual temperature one is caused by the fact that the first indicator works better in all the regressor's combinations we tried. We address this phenomenon to two things. First, it represents better technologic specifics brought about by the climatic conditions in the country: equipment should fit to both low and high temperature regimes; on the other hand more enduring technologies are more energy intensive. Secondly, the variable of seasonal temperature fluctuation is at the same time a measure for a geographical continentality of the countries taking into account that the economies located more distantly from the sea shores incur additional (energy) cost of the world economic integration.

Table 1

Estimated Energy Intensity of Production in the World Countries (dependent variable: ln[Energy Consumption in production sphere per a unit of GDP PPP], White covariance matrix method)

Variables	2002, 75 observ.	2003, 77 observ.	2004, 74 observ.	2005, 75 observ.	2006, 77 observ.
Constant term	–.1718 *t*–Value= –1.30	–.1665 *t*–Value= –1.25	–.1511 *t*–Value= –1.26	–.2771 *t*–Value= –2.30	–.2872 *t*–Value= –2.49
Variable of climate conditions: *DISTE*	.0025 *t*–Value =4.84	.0023 *t*–Value= 4.30	.0019 *t*–Value= 3.97	.0021 *t*–Value= 4.48	.0022 *t*–Value= 4.15
Real energy price for previous year: $\ln(P/p_E)_{-1}$	.5155 *t*–Value= 5.13	.4592 *t*–Value= 4.95	.4429 *t*–Value= 4.94	.2536 *t*–Value= 2.56	.2841 *t*–Value= 2.67
Interaction term: $\ln(P/p_E)_{-1} \cdot INST^{*}$	.1153 *t*–Value= 3.29	.1005 *t*–Value= 2.49	.1133 *t*–Value= 2.76	.1124 *t*–Value= 2.96	.1239 *t*–Value= 2.54
R-squared	0.4835	0.4231	0.3979	0.3189	0.3343
F-value	19.75	18.90	16.40	10.96	8.73
Root MSE	.38297	.39872	.36507	.36192	.37684
Hausman test, Chi2**	0.00, Prob>chi2= 0. 0.9999	0.03, Prob>chi2= 0.9984	0.76, Prob>chi2= 0.8582	0.27, Prob>chi2= 0.9661	0.90, Prob>chi2= 0.8246

* Combination of Government Effectiveness and Control of Corruption indices.

** Instrumental variables are logarithm of import cost of oil in the previous year for the real energy price variable and in addition a combination of latitude degree and infant mortality variables for the interaction term; IVS and OLS models are compared for the samples of economies for which is the data on import cost of oil accessible.

Endogeneity of regressors problem is expected to be present with respect of use in the regression of both the institutional and energy price variables which could be affected with the energy intensity one. Trying to soften it for the real price of energy factor we used in the regression a variable for the previous year rather than for current one: $\ln\left(\frac{P}{p_E}\right)_{-1}$ instead of $\ln\left(\frac{P}{p_E}\right)$. Besides this a proper method to treat the problem of endogeneity is application of IVLS estimator in addition to OLS employing Hausman test. A serious difficulty here is existence of consistent instrumental variables for energy price. The only possible one which we could imagine was crude oil import cost for corresponding economies. We applied the data from IEA database containing statistics on only 25 OECD countries. Thus the sample used to test the problem was of only this dimension what, of cause reduced the reliability of the estimates which we obtained. Nevertheless we present the results of Hausman test suggesting that the effective model should be preferred. Institutional index was instrumented with the help of latitude degree and infant mortality variables.

As it could be seen, significance of institutional variables is still well preserved and for the services sector proves o be even higher than for overall energy intensity. However, transaction term visibly loses its explanation power in the regressions for the goods production sector. This fact has a transparent explanation: share small and medium-sized enterprises in services sector is essentially higher than in goods producing one. At the same time small and medium-sized business, at least in economies with not good enough institutions, suffer from overregulation and corruption considerably higher than large enterprises. Thus, the implicit transaction cost burden for it is higher as well.

We provide our calculations of price elasticity of production energy intensity both by the groups of the economies (Tab. 2) and for each country from the sample (Tab. A1 in Appendix). One can see that these results confirm our theoretical assumption: the better the institutions the stronger consumption of per output unit responds to changes in real energy price. Particularly, in CIS countries, adjustment of energy demand to changes in real energy prices is to be regarded as weak:

the absolute value of average price elasticity coefficient of energy intensity is about one third of that in OECD countries; in the East European and Baltic countries this value is also visibly lower than in the developed countries though not so crucially (it is "only" one half of the OECD level). This fact means weak incentives of firms for energy conservation and, thus, serves an important reason for the higher energy intensity of production.

Table 2

Coefficients of Price Elasticity of Production Energy Intensity by the Economies and the Groups Economies of the World

	2002	2003	2004	2005	2006	In average
World in Average, 118 economies	–0,546	–0,519	–0,506	–0,278	–0,317	–0,433
OECD, 26 economies*	–0,889	–0,838	–0,910	–0,596	–0,666	–0,780
Former Socialist, 27 economies	–0,451	–0,436	–0,406	–0,212	–0,243	–0,349
East Europe and Baltic, 14 economies	–0,559	–0,540	–0,551	–0,322	–0,362	–0,467
CIS, 11 economies	–0,318	–0,308	–0,234	–0,082	–0,102	–0,209
Russian Federation	–0,374	–0,374	–0,320	–0,124	–0,128	–0,264

* Without new members.

■ Application of OMMM-Energy: Some Results

Using econometrical analysis to explain both the values of energy input coefficients and factors influencing them. This information could be further used to calculate future energy input coefficients for forecasting model. But this analysis by itself is not sufficient for estimation of economic efficiency of measures to reduce energy intensity of the economy. In this the roles we consider to be appropriate just the OMMM-energy.

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:

- concentration of energy-intensive productions and gasification in the South Siberia regions;
- fast development of nuclear energy in the national economy;
- a reduction of energy intensity of production in the national economy;
- wide application of heat pumps technologies in the different regions of the national economy;

and many others but less significant issues.

To illustrate what can be obtained by applying such models, we present the results of our analysis concerning the efficiency of different arrangements undertaken to widen application of heat pump technologies in Russia and Russian regions. For this purpose we applied a previous OMMM-Energy covering 1999–2010 which is practically analogous to the above model.

Annual market for compression heat pumps in Russia was estimated to be 40–55 million of coal equivalent. According to the results of the calculations conducted with the help of OMMM-Energy, spreading compression heat pump can bring about a significant reduction in energy intensity, forcing out fossil fuels combusted at traditional heat plants. At the same time, an increase in capital intensity of national economy takes place. It happens because, first, heat pumps are more expensive as compared to traditional heat producing engines; second, additional electricity generation capacity is needed since compression heat pumps are highly electricity intensive; third, additional gas pipelines could be needed.

Our calculations suggest that heat pumps are efficient in Siberia under the transformation coefficient[1] of level 4, while in European regions of Russia – under the transformation coefficient of level 5. This difference is explained by the fact that electricity which is essentially cheaper in Siberia than in the Western part of Russia is the main production resource to run the heat pump technology.

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[1] Transformation coefficient is a technical characteristic of *compression* heat pump technology showing a ratio of heat provided by an engine to the electricity consumed to run it; both of them measured in comparable units.

Another calculation series was conducted to estimate economic consequences of heat conservation in the regions of Russia. To do this we incorporated into our model additional technologies producing output for each region which included only output components. Their contents were providing gratuities heat energy which could be utilized through improving organization and management systems. The purpose of this analysis was to determine just the efficiency of use of additional energy: either will it result in reductions of heat provided by heat plants, or will it be recycled to produce additional goods and with what economic outcomes? So, we run calculations for each region of the model in order to see responds of the total national economy to providing additional heat just in a certain region. After that we looked at the change of energy output in total and of some macroeconomic indicators.

Speaking in general, in different regions both the shares of energy recycled to produce additional goods in its total additional output and the levels of economic efficiency of these events were different. For instance in Western Siberia almost all the additional heat was used to increase production outputs in industry, on the contrary in European Russia it was used instead of energy provided by the heat plants. In turn this reduction of production resulted in further reduction of energy consumption at the transport and industrial enterprises and, thus, in decreasing the total energy output. Finally total energy consumption reduction per a unit of heat additionally provided in Western Siberia equaled one unit while in European Russia – about 3,5 units (see right box of Fig. 4). However, increase of GDP per unit of additional heat (as measured in tones of coal equivalent) was higher in Western Siberia (see left box of Fig. 4). The reason was that in Siberia the conditions to develop the energy intensive products are more favorable than in European part of Russia. So, additional energy can be used with higher economic output.

The latest calculations carried out on the basis of OMMM-Energy were aimed at identifying permissible and economically justified cost limits of installed electricity generation facilities using RES. We have found out that such a cost limit for the regions included in the model equals to USD 2100 per 1 kW, which means that, given the estimated long-run *average* conditions, production technologies of electric energy from RES requiring additional investments above the specified level, do not seem to be economically justified and feasible. At the same time, the obtained assessment of marginal cost of power appeared to be slightly lower than the average expected price on electricity generation from RES which in the State Program of the Russian Federation "Energy efficiency and energy development" is established at the level of RUB 75 thousand per 1 kW. This fact proves that RES development in Russia requires special attention and support from the government.

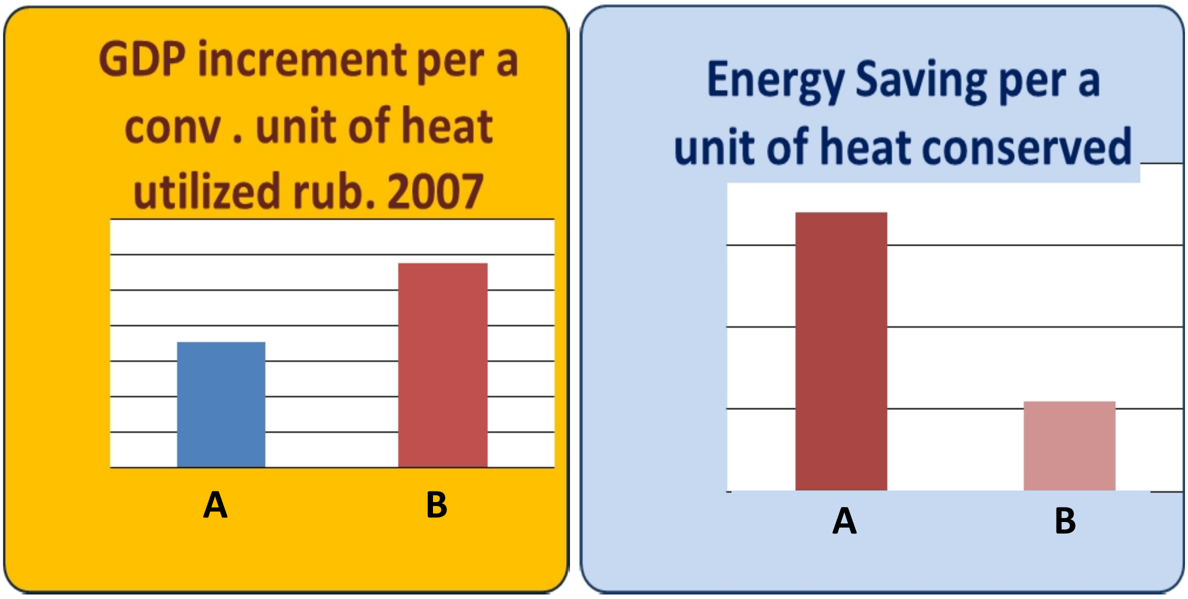

Fig. 4. Effects of heat recycling in Western Siberia (B) and European Russia (A) compared

■ Conclusion Remarks

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 in the section 2 of this paper. 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.

This model has been applying in IEIE SB RAS since the middle of 1980ths. 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.

Further use of this model is associated with conducting scenario analysis of energy sector and national economy interactions within the future period up to 2030.

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