THE SYSTEM OF DYNAMIC INPUT-OUTPUT MODELS FOR FORECASTING THE DEVELOPMENT OF RUSSIAN ECONOMY AT THE NATIONAL AND REGIONAL LEVELS

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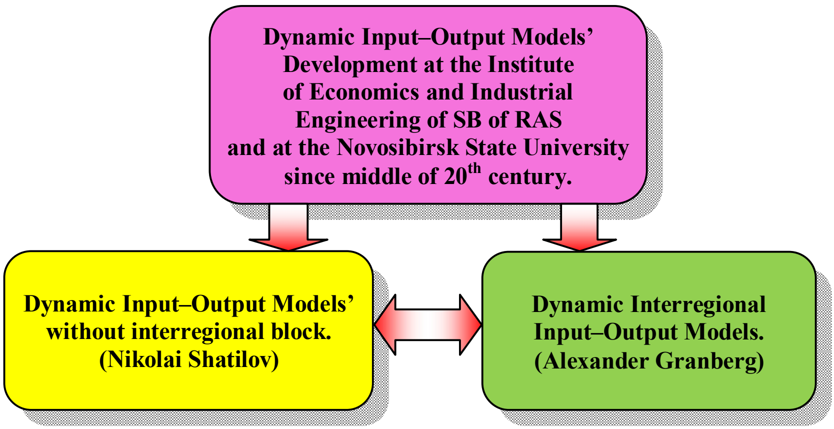
■ Introduction

In the mid-sixties of the XX century, the Institute of Economics and Organization of Production Planning of the SB RAN and Novosibirsk State University started work on developing spot dynamic input-output models and interregional dynamic input-output models. Historically, this work has been developing in two directions by two groups of researchers. The first research team lead by A.G. Granberg created an Optimization Interregional Input-output Model (OIIM) and it various modifications. The second research team created by N.F. Shatilov and later headed by V. K. Ozerov worked on developing spot dynamic input-output models and it various modifications.



Graph. 1. Two directions of research using Dynamic I-O Models at the at the Institute of Economics and Industrial Engineering of SB of RAS and at the Novosibirsk State University.

■ **KAMIN System is the system of models used for forecasting the development of the economy at the national level.**

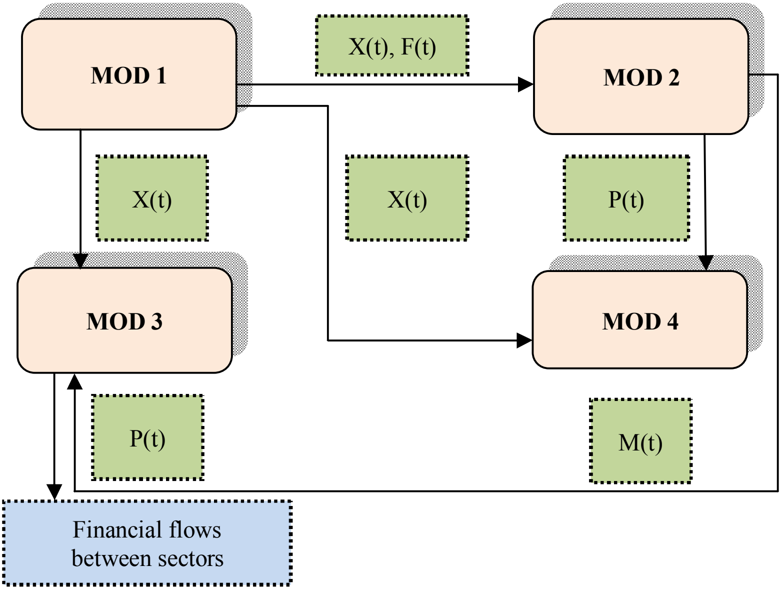
KAMIN System (the system for making a comprehensive analysis of intersectoral information) consists of the following main elements [1].

1. A dynamic input-output model for forecasting production and using the total output of the national economy with a distributed construction lag (MODI).
2. A model for prices forecasting (MOD2).
3. A Model for forecasting financial flows between financial entities /agents (MOD3).
4. A Monetary Block Model (MOD4).
5. A Model for forecasting ecological processes (MOD5).
6. A model for forecasting incomes and expenditures of the federal and consolidated budgets (MOD6).
7. A dynamic input-output model with a balance-of-payments block (MOD7).

All the models included into the KAMIN System can be described in terms of fuzzy sets.

It is possible to carry out macro-economic analysis and forecast the consequences of applying a particular monetary or fiscal policy applying MOD1, MOD2, MOD3 и MOD4 models. A general interaction scheme of the above-mentioned four models in the process of economic analysis and the composition of information flows in the KAMIN System can be described as follows.

Variant 1. An input-output model for forecasting economic development, which takes into account the technological capacities of a sector (MOD1), calculates the dynamics of industrial indices in comparable prices. The trajectory of changing economic indices serves as a basis for all the other models. At the input to the model, control exogenous variables characterizing the dynamics of the investment activity, dynamics of change of the technological parameters in industries and the dynamics of the number of people involved in production are set. At the output from the model, the dynamics of the output (*X(t)*) and fixed assets (*F(t)*) in each of the industries are measured in comparable prices (see Graph. 2).



Graph. 2. Calculations in KAMIN System according to Variant 1.

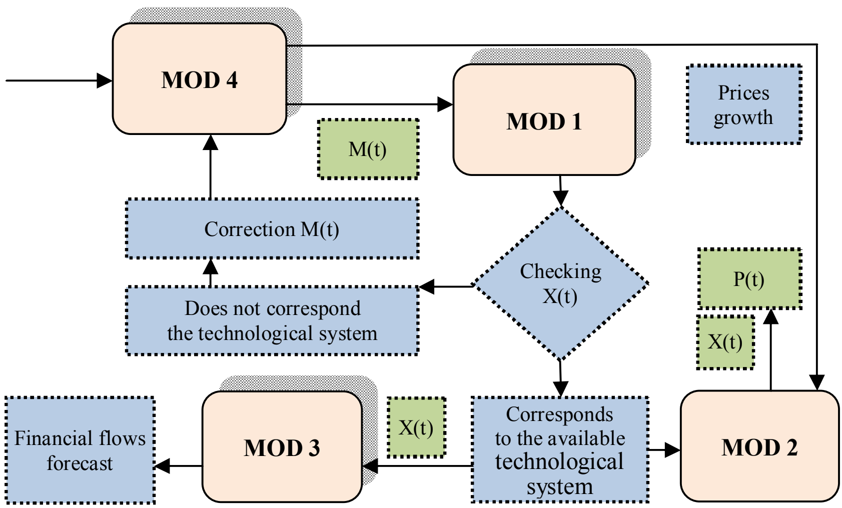
The model of calculating the dynamics of sectoral prices (MOD2) determines the trajectory of sectoral prices change rates (*P(t)*) in relation to the comparable ones. At the input to the model, along with the trajectory calculated by the first model, there are data sets that describe the dynamics of such sectoral cost indices as remuneration of labour, profit, indirect taxes, the norms of industrial wear and tear, the composition and size of material expenditures. At the output from model there is a set of industrial prices change rates of end use.

The model for calculating the dynamics of financial flows (MOD3) forms the balance of incomes and expenses for each sector of the national economy /in the nomenclature of SNA sectors (Structure of National Accounts)/ or each type of economic activity /in the nomenclature of NACE (National Classification of Economic ACTIVITIES)/ depending on the necessary degree of specification of the financial activity analysis. At the input to the model there are sets calculated in accordance within the first and the second models as well as the dynamics of the structure of the payments matrix between the entities of economic sectors or types of economic activity.

At the outcome there is a dynamics of the amount of payments matrix.

The monetary block model (MOD4) caries out a calculation of the required volume of money supply necessary for the functioning of the economy. At the input to the model there are sets calculated on the basis of the first two models. At the outcome there is a required dynamics of the volume of money supply.

Variant 2. The inclusion of the monetary block makes it possible to solve an inverse problem in the KAMIN System that consists in evaluating the consequences of changing the volume of money supply and other monetary parameters for the dynamics of both nominal and real gross output (measured in comparable prices) and the dynamics of prices (Graph. 3).

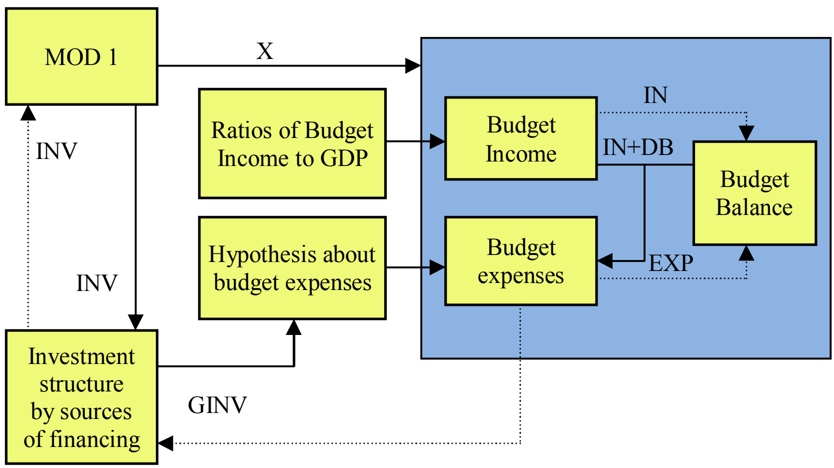


Graph. 3. KAMIN System calculations based on Variant 2

The anticipated dynamics of gross output in target prices that would correspond to the condition of a simultaneous equilibrium in the markets of money and goods is calculated within MOD4 model, with the dynamics of the volume of money supply, exchange rate of ruble to US dollar and interest rate in the forecasting period specified exogenously. This calculation is carried out with the help of regression equations, verified by retrospective information, that describe the connection between the gross output and the variation of monetary and other factors specified exogenously. MOD1 model makes it possible to carry out an industry “sweep” of the gross output in comparable prices and test the validity of the received value of gross output from the point of view of the possibility of realizing its dynamics calculated within MOD 4 in the framework of the existing technological system and considering its changes in the forecasting period. For example, receiving the gross output growth rates calculated within MOD4 would require an unrealistic increase of the size of fixed assets and labour resources in the forecasting period. MOD2 model makes it possible to “expand the vector” calculated within MOD4 according to the elements of the cost structure and to describe the price dynamics in the forecasting period.

MOD3 forecasts the size of financial flows between the sectors of the national economy (or types of economic activity) based on the results received within MOD4 and MOD1.

The interaction of KAMIN System models with the budget block is illustrated in Graph. 4.



Graph. 4. The interrelation of the budget block
and the dynamic input-output model

The construction of the dynamic input-output model budget block gives additional opportunities for the practical application of this type of models for forecasting the development of the national economy. State government bodies receive an opportunity to justify consolidated and expanded budgets more thoroughly. The income part of the budget can be estimated on the basis of projections of the dynamics of gross output of national economy sectors and their cost structures. On the other hand, an opportunity arises to assess the impact of different variants of state expenditures on the economic development dynamics at the macro and sectoral levels.

On the basis of the parameters calculated within the dynamic input-output interregional model and accepted standards, the income part of the budget block is calculated. After that, on the basis of the implicit hypothesis related to the composition of expenses of the expanded budget, the expenditure budget is estimated that includes the size of investments into fixed assets financed from the budget *GINV* (as the main parameter in the dynamic input-output model within the budget block).

Moreover, the redistributive operations fulfilled within the expanded budget increase total expenses on final consumption and change the composition of aggregate demand and, consequently, are reflected in the composition of gross output of the national economy. The consideration of this factor will make it possible to fully reflect all the connections (both direct and reverse ones) between the budget of the expanded government and gross output. For this purpose, the following parts can be singled out in the budget expenditure block:

1. Investments into fixed capital: *GINV(t)* financed from the budget.

2. Expenses connected with servicing state debt, *D(t)*.

3. Expenses connected with organizing socio-cultural events: *SOC(t)*. This part is supposed to be covered out of non-budgetary funds and expenditures of the consolidated budget on socio-cultural events.

4. Other expenses:

$$OEXP(t)=EXP(t)-GINV(t)-D(t)-SOC(t),\ t = 0, \dots, T \tag{1}$$

where *EXP(t)* is the total volume of expenses of the expanded budget.

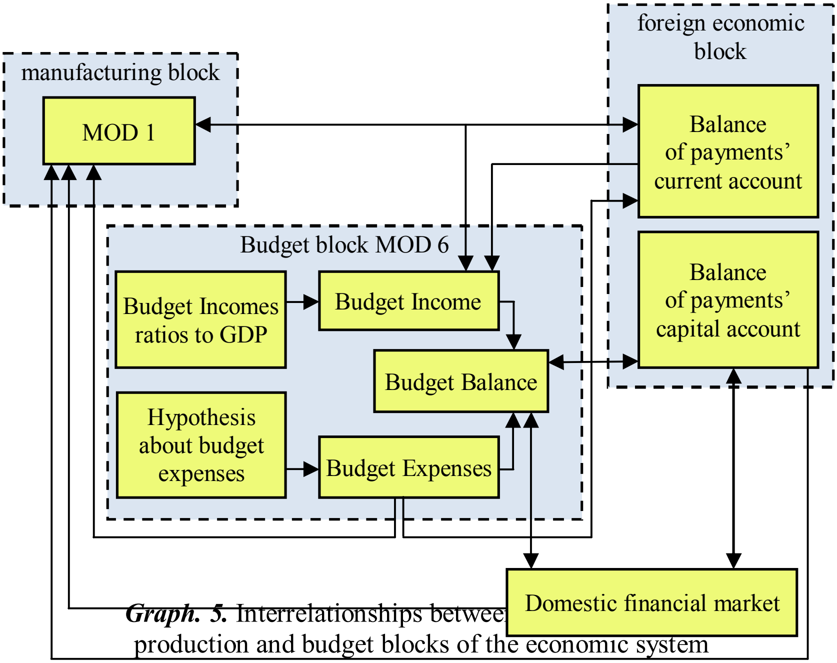
In this setting, the parameters of the dynamic input-output model in the budget block are controlled only by the size of investments into fixed capital financed from the budget.

At the input to the dynamic input-output model, the value of cumulative investments into fixed capital is introduced. It is calculated from the following equation:

$$INV(t) = GINV(t) \,/\, dgi(t)\,, \qquad t = 0, \ldots, T, \tag{2}$$

where *dgi(t)* is the share of investments into fixed capital financed from the budget in cumulative investments per year *t* (specified exogenously).

Graph 5 schematically illustrates the interrelationship between production, budget, and the rest of the world (foreign economic block) in the economy.



Graph. 5. Interrelationships between production and budget blocks of the economic system

Let us now focus our attention on the influence of external economic shocks on the budgetary subsystem and the development of the economy.

The variation of export arising due to a change in demand and/or prices on exported goods and services of a particular country in the world market leads to changes in budget earnings. For example, the reduction of export leads to a decrease of export duty receipts (see the arrow connecting the current capital account of the balance of payments and the expanded budget incomes, graph. 5). In its turn, the reduction of export is likely to lead to a decrease of production primarily in export-led industries (see the arrow from the foreign economic block to the production one). The latter will result in the reduction of VAT receipts in the budget, the reduction of profits tax, reduction of income tax paid to the employees of exporting enterprises and so on. As a consequence, there may be a growth of budget deficit or a reduction of budget surplus. If there is a growth in export, the reverse processes are observed.

Let us turn to capital account of balance of payments financial instruments. Direct investments affect production, contribute to its growth and provide growth of budget earnings (see the arrow going from capital accounts and financial instruments directly to the production block).

The influence of external shocks on the budgetary system connected with the movement of speculative capital has a more complicated character. The inflow of capital through the financial market (portfolio investments) increases the capacity of enterprises to finance their development and promotes economic growth (see the arrow pointing from the capital account of operations and financial instruments to the financial market and further to the production block). As a result, production grows and tax revenues in the budget increase.

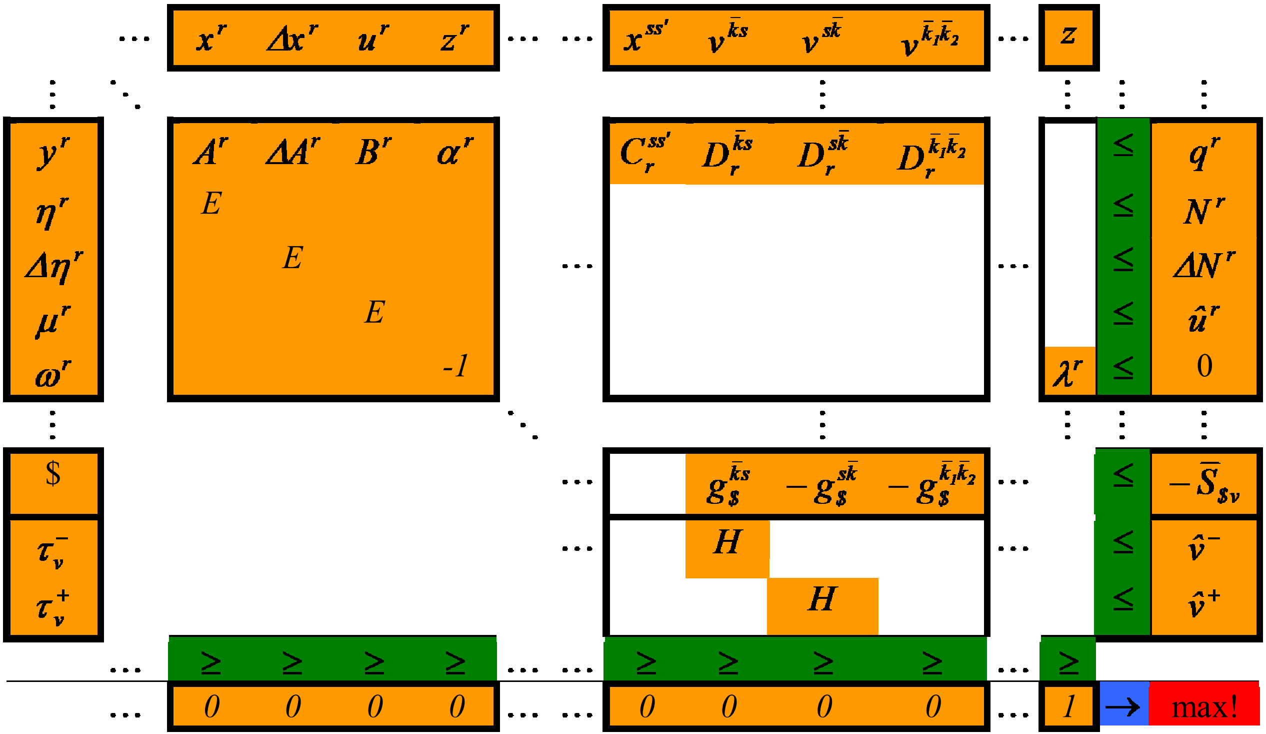
Moreover, when foreign portfolio investors buy state bonds in the financial market, they partly carry out debt financing of the state budget deficit. Sudden changes in the world financial markets that lead, for example, to a mass sale of corporate and state securities of a particular country contribute to the increase of interest rates and a decrease of the exchange rate of the national currency. Both the impacts have the opposite effect on production. The growth of interest rates decreases the economic activity, while the devaluation of national currency stimulates export, reduces import and, in the long run, promotes the growth of net export. The ultimate result of the impact of such external shocks on production depends on the correlation of the above-mentioned consequences.

■ Optimization interregional input-output model and its modifications

Optimization multi-regional input-output models (OMIOM) were proposed by A.G. Granberg in the sixties of the XX century. In more than 40 years of their existence and application, their structure and application methods in the theoretical and applied analysis they have significantly changed. However, their essence has remained unchanged: regional input-output models are united into linear-programming constructions with the help of interregional relations (of the transportation problem type) and conditions for equalizing regional consumption levels of the population and state (scalarizing vector of regional goals).

In some separate segments, these constructions linearize non-linear dependencies. In this way, in modern modifications of the models, the dependence of the investments made in the last year of the forecasting period on total investments into fixed capital, the dependence of investments on production capacity growth, the dependence of world market prices on the size of export and import and some other dependencies are non-linear. (It is natural for Russia as an important country on a world scale).

The limitations of the direct problems (in order of their presentation in Graph 6) are: the balances of production and resources (labour and investment ones), restrictions of available production capacities, of the growth of production capacity, restrictions of investment growth, of the territorial structure of non-production consumption, foreign trade balance, restrictions of export-import quotas. The limitations of the dual problem are: conditions of break-even production under the available capacities and under the available capacity growth, break-even of investments, non-production consumption, interregional product transportation, export-import delivery, and international transit.



Graph. 6. The model regional block

This is a new presentation of the optimization interregional input-output model. Along with ordinary variables (size of production, capital investments, non-production consumption, interregional transportation, export, import, international transit) and limitations of the direct problem (balance of products and resources, production capacity, foreign balances and quotas), special role is given to variables (prices of production and resources, tax rates on profit and turnover, exchange rates, export-import duties) and limitations of the dual problem (financial balances of current and investment activity, household and state consumption, interregional and foreign trade transportation).

The possibility of "price" interpretation of so-called unbiased appraisals of product balance (dual variables) is connected with the fact that in the model with open foreign trade (at present it is the main variant of the model) internal prices (dual assessment of production, i.e. the same unbiased appraisals of production balance) differ from the external or world ones by the size of export-import duties (due to which they are "tangible in content"): for exported goods they are lower than the external ones by the size of export duty, for imported goods they are higher by the size of import duty. At the same time, external prices in the model are "semi-exogenous): they are given but they are somewhat elastic to the volumes of Russian export-import.

As a result, the variables and limitations of the direct and dual problem of the optimization interregional input-output model create an integral theoretical-methodological concept of national spatial economy within the system of world economic relations. An important role in it is played by macro-financial aggregates that depend on variables of both direct and dual character and that create macro-financial balances. The latter show the dependence between "investments" of particular regions into national consumption and actual regional consumption. These dependencies are balanced by surplus macro-aggregates of interregional and foreign trade exchange. The realization of these macro-financial balances is guaranteed by the characteristic of complementary non-rigidity of optimal designs of linear-programming problems.

Unfortunately, in essence, these models are "subjectless", they represent the field of possibilities for economic games, but not the economic games themselves. In fact, they (the models) consist of strict limitations, i.e. "laws of economic matter conservation": in the region it is impossible to use more (products, services, resources) than are available and all that is available should be somehow used (loss is also viewed as a form of use).

One the directions of applying the models under study is building scenarios for socio-economic development of spatial economy (of the world economy, the economy of the USSR, Russia, and Siberia in applied works). In recent years, serious attempts have been made to increase the adequacy of applying the models to this and other problems (by introducing non-linearity into the dependencies of introducing production capacity on investment size and dependencies of world market prices on the volume of Russian export and import). Due to this, models begin to represent a real border of the area of acceptable states, and a change from one scenario to another is fulfilled by changing a small number of parameters rather than by a full rearrangement of many hundreds of borders into separate variables.

In constructing development scenarios, the main meaningful role in carrying out calculations is played by a group of experts in industrial and structural-functional problems. Expert teams have their own ideas about a possible course of events in their area, as they have expert information, local forecasts expressed in terms of variables both at the input to and output from the model. One of the tasks facing "model implementators" is to transform expert data into information to be fed into the model and, after the problem is solved, to transform the model output information into the formats that would be understandable for experts. However, experts and "implementators" usually use interface models of different types: models of direct calculation, imitational, economic, network models, etc.

Experts and their teams, proceeding from the set goal and scenario conditions (aims, problems, concepts, threats and challenges) and expert data, formulate an input to the optimization interregional input-output model. If the model solution transformed into expert data formats does not contradict initial goals and scenario conditions of none of the experts, the forecast is considered to have been formulated. The scenario reconciles the views of all the experts involved, i.e. local forecasts.

In reality, such a coordinated forecast is a result of long work in the course of which the experts adjust (coordinate) their opinions (set goals and scenario conditions, i.e. local forecasts), while the model represented by the group of specialists "leading it" plays the role of some central expert council. In order to get coordinated decisions on the central scenario, the optimization input-output model is made up several thousand times, and dozens of expert brainstorming meetings of the "leading team" and "exploiters" are held.

In 2009–2010, research on medium-term and long-term post-crisis development of Siberia and the whole of Russia was carried out. As a result, scenario conditions researched to varying degrees were prepared with the help of the optimization input-output model. To the full, model calculations were fulfilled for the central variant of development – the inertial scenario.

The ideas about a post-crisis world organization are still very vague. As the history of Genoese, Bretton-Woods and Jamaica agreements shows, the new order will be determined in five to ten years of post-crisis development, i. e. by the end of the 10^s – beginning of the 20^s of the XXI century. Oversimplifying the situation, all the multitude of possible development scenarios can be concentrated into two extreme ones:

A scenario – the world will resume its "normal course";

B scenario – the world will become totally different.

The world order is determined by four major characteristics: the role of the dollar, oil, state and innovations. The "normal course" is: dollar is (almost) world currency, oil is the main good "managing" world financial flows, state is liberal, innovations are insufficient because decision makers focus on current momentary tasks.

The Russian development scenario within the framework of world scenario ***A*** can be called inertial or energy and raw materials-dependent, but with lower growth rates than under the energy and raw materials-dependent scenario of *the Concept of Long-term Development of Russia by 2020* (CLD) made by the Ministry for Economic Development, a little higher than for world economic development on the average. The share of the extracting sector in the total output will slightly decrease; the share of Siberia will continue to fall, with a symbolic increase of the Far East share.

This scenario will be carried out under the passive position of the Russian government that has existed until the present time: words about economic growth, innovations and development of the eastern part of the country are not supported with real actions.

Under this scenario, the economic development of Russia and Siberia assume a stable inertial character. In the long term, Russia will keep its position of an "average" country and will continue losing its national sovereignty. However, it can be assumed that, given a radical activization of state policy in this situation, an innovational scenario could be realized.

The situation would be quite different under scenario ***B.*** Russia would appear in an unstable position. If adequate measures are not taken, in the long term it will "slide down" to destruction and disintegration (a catastrophic development scenario). The main reasons for this will be a considerable fall in demand for natural resources and acceleration of world economic development based on high and research-intensive technologies. However, given Russia undertakes serious steps, the prospects for its development can be more than favourable (innovational scenario).

Under the catastrophic scenario, growth rates would fall and appear lower than the world average ones, macroeconomic rates would be suspended and the share of Siberia in total output would markedly decrease, with the share of the Far East being unchanged.

The hope for Russia to become one of the world leaders would be lost forever. The Russian state, which in the XVI–XVII centuries expanded from the Volga to the Pacific Ocean and farther, can return to its previous size only in 20 to 40 years giving rise to a whole multitude of pseudo-states, which would, to varying degrees, depend on developed countries and transnational capital.

The opportunity for realizing the innovational scenario will appear only in case the Russian government comes from slogans to real actions that will stimulate:

1) economic growth as a result of which the share of accumulation in GDP will grow from the present 18–19% to a minimum of 25–30% (in China this figure exceeds 40%);

2) research and development including corporate and technological update and innovations that would increase expenditures on research and development in relation to GDP up to 3–4% (4–5 times), the share of high technology research-intensive production, innovative enterprises in the range of 25–40%;

3) economic development and improvement of Asian and Arctic territories of Russia.

There is nothing unexpected or new in the list of required actions: adequate laws, prioritization, direct public financing, and tax incentives. They are well-known and are easily implemented provided there is political will and tangible success in anti-corruption and anti-monopoly policy.

Under this scenario, in 10–12 years the GDP will double, the share of the extractive sector will markedly decrease, and the share of Siberia and Far East will grow. The spatial architecture of Russia will change drastically: Russia will get a new foothold – South-East Asia. In late 20s, according to the scale of its economy, Russia will become one of the five (or even four) leading countries by the level of its economic development measured by GDP per capita and will rise to the upper quartile in the list of countries.

This innovational scenario is more optimistic than the one in the *Concept of Long-Term Development of Russia* developed by the Ministry of Economic Development.

The models can also be applied for analyzing interregional economic relations. The analysis is based on two parts of mathematical economics: the theory of economic equilibrium and the theory of cooperative games. The first one (Valrus equilibrium) concerns an ordinary commodity-money market and equivalent interregional exchange, the second one (Nash equilibrium, the nucleus of the system) concerns contract market and mutually beneficial exchange. If these approaches are taken, it is necessary to introduce "subjectivity" into the ideology of modeling. The "subjects" are regions represented by some government bodies – the bearers of regional goals (the increase of household and state consumption) and decision-making instruments (plans for economic development including foreign economic relations).

According to Valrus market conception, each "subject" of the market (region) determines its demand and supply (export-import of products) by maximizing their target function under budget restriction in the current exchange prices. Meanwhile, s/he does not care about partners or any common goals. At the same time, the markets operate under the law of supply and demand: the price grows if the aggregate demand (import) exceeds aggregate supply (export) and vice versa. The market subjects review their plans adjusting to new prices. It goes on until equilibrium is reached.

An equilibrium with zero budget balance is the condition of equivalent interregional exchange.

According to Nash, the principal notion of the market mechanism is an agreement or contract, consensus. The market mechanism is a negotiation process where the market subjects (regions in this case) conclude agreements on cooperation, that is, enter into coalitions. The subjects focus on their own interests and leave old agreements or coalitions if they see more promising partners. The equilibrium according to Nash is reached when none of the subjects and none of the subjects' coalitions is able to improve their position by changing the composition of partners.

One of the main results of the corporate games theory is that in the situation of equilibrium, all the subjects of the market enter into interaction and, if a subjects' coalition leaves the full system, it loses. The multitude of such equilibrium states is called the nucleus of the system. This is a specific multitude – the multitude of mutually beneficial interregional exchange.

In 2012, Sheply and Rot received the Nobel Prize for investigating these problems in the cooperative games theory.

For about thirty years, the theory of economic equilibrium and cooperative games has been successfully used in the applied analysis of multi-regional economic systems applying optimization multiregional input-output models (OMIM) However, it is only recently that rigorous proof has been received of the existence of Valrus and Nash equilibriums (as well as Edgeworth, fuzzy nucleus) in the economic systems presented by the models of OMIM type. The research was made in the framework of the integration project of the Presidium of the Siberian Branch of the Russian Academy of Sciences and carried out by researchers of the Institute of Economics and Industrial Planning and the Institute of Mathematics of SB RAS. The proof was found by V.F. Vasilyev.

As an example of the applied analysis of interregional economic interrelation we will give the results of calculations for the system of the Soviet republics made before the disintegration of the Soviet Union. Such calculations are also carried out for the macro-regions for Russia, but they are not very demonstrative yet, and the conclusions made are too general in nature, for example: "Siberia plays approximately the same role in Russia as Russia played in the USSR".

First, let us focus on the results of coalition analysis, calculations for all the possible coalitions of the former 15 Soviet republics. The share of the emergent (synergy) effect in the total final consumption by the Soviet republics accounted for about 55%. Only Russia, in the situation of total autarchy, could manage to keep the value of its target index at a rather high level. Moreover, the contribution of Russia into the total consumption of the system exceeded its own consumption, the balance of inter-republican interaction being positive. At the same time, the balance of the Ukraine was "indecently" negative.

A somewhat different picture was presented by the results of the equilibrium analysis (according to Valrus and Nash). The zone of the nucleus is strongly stretched in the direction of the increase of the share of Russia in the total non-production consumption of the system. It means that the non-production consumption of Russia could have been considerably increased at the expense of the other republics, but the inter-republican exchange would have still remained mutually beneficial because the coalitions of republics would have consumed less without Russia.

At the same time, the actual share of non-production consumption of Russia was higher than its share in the situation of an equivalent exchange because its consumption was overstated in comparison with that which would have existed under equivalent inter-republican exchange.

The same situation, but to a greater degree, was true for Kazakhstan and Central Asia, while the consumption of the Ukraine, Transcaucasia, the Baltic Republics and especially Byelorussia was understated in comparison with the equilibrium equivalent one.

To develop interregional input-output models of space economy further it is planned a) to go beyond the borders of the paradigm of perfect competition and take into account innovational monopolism (such an attempt based on Shtackleberg's equilibrium concept was made by V.L. Beresnev within the above-mentioned framework of the integration project of the Presidium of SB RAS and the Institute of Mathematics); b) to find a reasonable compromise between the continua and agent-oriented (subject) approaches including large investment projects as special subjects (along with large corporations, municipalities, cities and households) into the simulation; c) geo-informational and state-of-the-art computational technologies should be used together with traditional methods of mathematical programming, statistics, econometrics, simulation control and normative regulation.

Another direction for further research is harmonizing input-output models used in the Institute of Economics and Production Planning of SB RAS. At present, several spot and multiregional models of different specializations are being applied, each of them exploited in isolation from each other. This is an absolutely abnormal situation that leads to a dissipation and irrational use of research resources. A task to coordinate the models has been posed and is beginning to be solved in three areas: informational (oriented to creating a common data base), simulational-methodological (making a "construction" of different models out of a small number of model units connected by formalized "adapters"), software and mathematical (creating a common software platform – the language of model construction). In other words, here we have some kind of a "mild variant of reincarnation" of the idea of coordinating a system of territorial and industrial planning models created in the 60s of the last century

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