MODELING A NATIONAL ECONOMY AND THE ECONOMIC MECHANISM

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PREFACE

This paper is an attempt to link the problem of modeling to the problem of improving the economic mechanism in socialist countries.

The necessity to improve the economic mechanism is based on an analysis of its functioning under the constraints before new economic experiements in some socialist countries, as well as the new method implemented in the management of the economy. There the connection between its basic elements on the level of the economic organization--price formation, planning, credit system, incentive system, etc.--and usage of respective approaches and models for planning on a national level, is analyzed. The conclusions drawn show that using only the centralized methods for planning contradict the new principles for economic management.

The basic change in the management method requires an independence of the economic organization in decision making regarding the volume and structure of production using local criteria. Under these economic conditions, the central planning authorities have to use different, but common economic regulators in order to control local interests. On that basis a convergence between the local criteria (expressing the interest of the economic organization) and the global criteria of the economic system could be achieved. Mathematical models, which adequately reflect the process of planning at the two levels are of extreme importance for analyzing the economic mechanisms and their implementation in practice.

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Boris Mihailov

INTRODUCTION

From a practical point of view, an interaction exists between the modeling of the national economy and the economic mechanism: models have to describe the behavior of the economy as a concrete mechansim as well as to enable this concrete mechanism to be implemented in the form of adequate models for decision making. Only in this way, could the economic mechanism be improved.

This paper is based on an analysis of the relation between the models currently in practical use and the new principles and approaches to economic management. The limited framework of this report allows us only to analyze the main features of the modeling of the national economy and its connection to the economic mechanism. For that reason, the national economy is viewed at two levels only: the central level (central authorities for decision making), and the economic organizations level (as executive production units) although a variety of levels and organizational forms are used in different countries and different stages of economic experiments.

MODELING A CENTRALIZED ECONOMIC MECHANISM

Dynamic equilibrium. The use of dynamic input-output models at a central level, both for forecasting and for perspective balancing of the production links is of great importance for the centralized system of planning. As a matter of fact, these models allow the production volume and structure to be derived by some assumed conditions of balance:

$$x - Ax + Bx = Y \tag{1}$$

where

- x - n-vector of total production volume (n - number of sectors);
- A - nxn-matrix of cost coefficients (including labor);
- B - nxn-matrix of technological coefficients;
- Y - n-vector of final consumption.

Reformulating (1) in the following way:

$$x(E - A + B) = Y \tag{2}$$

where

E = identity matrix and denoting $A - B = Q$

we derive

$$x(E - Q) = Y \tag{3}$$

and $$x = (E - Q)^{-1} Y \tag{4}$$

In this balance labor is determined by the following equation:

$$\sum_{i=k}^{m} l_{ij} x_j = L_j \tag{5}$$

where:

- $i = k,\ldots,m$ - qualification groups;
- l_{ij} = labor coefficients;
- L_j = total amount of labor.

The investments are presented by:

$$K_i^{t-1} + \gamma_i^{t-1} Y_i^t = K_i^t \tag{6}$$

where

- K_i = capital investments,
- Y_i = coefficients for transforming the capital investments into production funds.

Final consumption can be forecasted as a function of personal income (R) and prices (P):

$$Y_i = f(R, P_1, P_2, \ldots, P_{n-1}, R, t) \tag{7}$$

It is not possible to achieve a real dynamic balance of an economy without the use of optimization techniques subject to natural, productive and labor constraints.

An optimization problem. This problem arises in connection with the necessity of determining different technological and territorial policy variants. Experience in modeling shows that such a secondary level of the analysis should be considered at an economic organizations level. One reason is the tremendous size of the model in case of solving it on a central level. Another reason is better knowledge of conditions of production at a secondary level. Thus the optimization problem for each economic organization could be formulated on the basis of the elements derived as a sum of (1), respectively disaggregated by products:

$$\sum_{r=1}^{\pi} p_j x_j^{\delta t} - \sum_{r=1}^{\pi} \left(\sum_{i=1}^{n} a_{ij} x_{jr}^{\delta t} + \sum_{i=k}^{m} l_{ij} e_j x_{jr}^{\delta t} + \sum_{i=1}^{n} d_{ij} x_{jr}^{\delta t} \right) = \sum_{r=1}^{\pi} m_j^{\delta t} \tag{8}$$

where

- $r = 1,2,\ldots,\pi$ - (π number of the products in sector j);
- p_j - price of product r in sector j;
- j - technological variants;
- e_j - normative wage for unit of sector j;
- d_{ij} - transportation costs coefficients;
- m_j - profit of sector j.

Local optimization can be realized with different objective functions: for example minimum productive and transportation costs (c) which is the expression in the bracket:

$$\min Z = cx \tag{9}$$

or maximum profit:

$$\max Z = mx. \tag{10}$$

However, in all cases the interaction between (9) or (10) and the input-output model at a cental level (1) requires that

the sectoral production volumes and prices $P_j X_j$ have to be within some limits in the process of local optimizations:

$$p_j x_j^{min} \leq \sum_{r=1}^{\pi} p_j x_j \leq p_j x_j^{max} \qquad (11)$$

as well as constraints on total investments, labor and possibly other primary resources:

$$\sum_i k_{ij} x_j \leq K \qquad (12)$$

$$\sum_i l_{ij} x_j \leq L. \qquad (13)$$

Local optimization at the secondary level, where the choice of technological variants has been made, allow for determination of new A- and B- matrices of coefficients to be inserted in the input-output model (1) at the central level. Thus, the following iteration is possible:

- The level of prices is plannned ($\hat{P}_j$);
- optimization of some strategic alternatives for economic development which can be formulated at the central level: global production structure changes (including export and import policy); policy concerning the fraction "investments-consumption"; solving political, social, environmental problems, etc.

The most important fact in these cases is that the input-output model (1), as a tool of forecasting and balancing the economic elements, represents a basis as well as final result of the procedure described above.

The interactions between the two levels can be described in a very good form in the following scheme (Fig. 1):

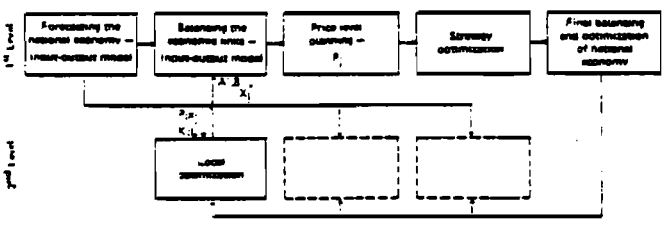


Fig. 1. Optimization scheme including two levels of national economy.

It can definitely be said that a convergence between the two planning levels is possible but very difficult and slow. This is a consequence of differences in the directions of global and local optimas as well as differences in aggregation. Multiple criteria in the balancing and optimization on a central level also contribute to a slow solution process. The relatively fast convergence in practical planning is due to the fact that many of the requirements mentioned above have not been taken into account.

There are many different proposed approaches to optimizing the national economy primarily based on some mathematical convenience. Nevertheless, the intermediate constraints coming from the first to the second level have to be connected with the volume and structure of production and with some main material resources, labor, and investments.

Stimuli and incentives. Generally, stimuli are based on the relation between the increase of wages and efficiency (or profit) of the economic organization (see (8)):

$$\nu = \frac{\Delta \sum_{r=1}^{\pi} l_{ij} e_j X_{jr}}{\Delta \sum_{r=1}^{\pi} m_j} = \frac{\Delta W_j}{\Delta M_j}, \qquad (14)$$

Hence $$\Delta W_j = \nu \Delta M_j \qquad (15)$$

where

ν = normative wage-profit co-efficient.

The problem of choice of basis for an establishment of ν requires that the dependence between the system of models (1)-(10) and stimulus mechanism is analyzed both at the stage of development and the stage of fulfillment of the plan.

Let's suppose that some ν has been prescribed by the central level for the economic organizations at the stage of development of the plan. In order to maximize profit (which is the basis of increasing the wages) each economic organization can propose changes in production volume and structure, as well as changes to the resources (including labor). But following the procedures shown in Fig. 1, after each iteration the central level will prescribe new restrictions of the production volume, prices structure and resouces until the final decision. Hence the normative coefficients ν has to change with every change of the planning targets (including labor). The main reason for this is the lack of uniformity in natural and production conditions for each economic organization, which excludes an objective basis for estimating contribution of the economic

organization to increased efficiency (profit). Thus the normative coefficients ν have to be closely connected with the prescribed planning targets, which creates real possibilities for its subjective planning.

At the stage of fulfillment of the plan different potentials exist for different economic organizations. Some of them cannot fulfill their planned targets, some of them can fulfill them exactly and some of them even over-fulfill targets:

$$\frac{\prod_{r=1}^{\sum} m_j^{t_o+1}}{\prod_{r=1}^{\sum} m_j^{t_o}} \lesseqgtr 100\% \qquad (16)$$

However, the described production links formation shows an interesting fact. Each economic organization that doesn't fulfill its planned targets causes non-fulfillment of the plans of output users. At the same time, compensating excess fulfillment of their plans by some units as a rule does not lead to excess fulfillment of the plan as a whole, because of the lack of all necessary set of products and conditions for that purpose.

The lack of objective basis for comparison and estimating the results of the economic organizations forces the central level:

-To accept an actual fulfillment which is less than 100 percent as a basis for choice of stimula

$$\nu\Delta M_j^{t_o+1} < \nu\Delta M_j^{t_o} = 100\% \qquad (17)$$

-To reduce excess fulfillment to some extent in order to compensate the losses according to (17):

$$\nu\Delta M_j^{t_o+1} > \nu\Delta M_j^{t_o} \simeq 100\% \qquad (18)$$

In the two above cases the correction in ν or M_j serves as a basis for correction

This mechanism of planning creates incentives at the level of economic organizations to conceal the production potential in order to easily fulfill the plan. As a result, the feedback to the central level is not realistic which in its turn very often forces the central level to prescribe higher planning targets for the economic organizations. The latter circumstance strengthens the incentives of people to present unrealistic information to the central level. This procedure is illustrated in Figure 2:

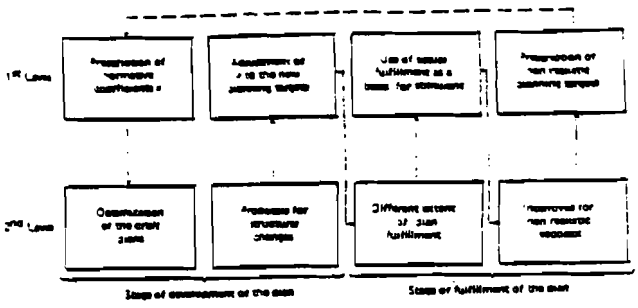


Fig. 2. Scheme of stimuli and incentives in connection with the planning mechanism.

MODELING AND THE NEW ECONOMIC REFORM

The new principles. The new principles of planning were implemented in most socialist countries since the middle of the 1960s in order to remove the shortcomings of a centralized economic mechanism. The main new principles can be formulated in the following way:

- -The economic organizations can independently take a decision concerning the total production volume and structure within some constraint;
- -Prices of some products are subject to an agreement between producers and users and are for some products bounded by certain constraints. In this way the prices to some extent express the relation between supply and demand;
- -The increase of production is implemented with the income of economic organizations and by credits;
- -The incomes of economic organizations are regulated by the central level with financial tools (regulators) which are made uniform in order to insure similarity of economic conditions as well as to serve as a long-term stimulant;
- -Wages are regulated by long-term normatives and the wages increase is connected with increase of income in the economic organization.

Modeling and the new principles. Analyzing the new principles from the point of view of the modeling of the national economy at two levels, we can answer the question of whether these principles are realistic or not. The analysis is based on the assumption that models for centralized planning of type (1)-(7) are applied in practice at the central level. As far as the economic organization level is concerned, there is no problem to apply the model for optimizing income (or profit) influenced by adequate economic

regulators in terms of the new principles mentioned above. This model will appear in the following general form:

$$\left\{ \sum_{r=1}^{r} \left[(P_j^r + S_j^r) - (x_j^r + W_j^r + T_j^r + C_j^r) \right] x_j^r \right\} = \sum_{r=1}^{H} M_j^r - \max \qquad (19)$$

where

P_j = price of j-th sector, which can be bounded as follows:

$$P_j \geq \underline{P}_j \; ; \; P_j \leq \bar{P}_j \; ;$$

S_j = subsidy which can be given in a percentage of unit of production: $S_j = \alpha X_j$;

E_j = current production expenditures;

W_j = wages connected with the profit (or income) in such a way that $W_j = \nu M_j$;

T_j = taxes on the budget, usually connected with the profit (or income): $T_j = \theta M_j$;

C_j = payment of interest for credit, as a percentage of the amount of credit: $C_j = \beta C$.

In this way, the rest of the profit M'_j can be used for investments.

It is supposed that all economic regulators ($\bar{P}_j$, $\underline{P}_j$, $\alpha, \nu, \vartheta, \beta$ etc.) are prescribed in a common way to all economic organizations at the stage of developing the plan. Keeping the above requirements, a temporary dynamic equilibrium can be achieved, expressed by the prices $P_1^t, \ldots, P_n^t$ in

$$\begin{aligned} s_1^t(p_1^t, p_2^t, \ldots p_{1n}^t) &= D_1^t(p_1^t, p_2^t, \ldots p_{1n}^t) \\ s_1^t(p_1^t, p_2^t, \ldots p_{2n}^t) &= D_2^t(p_1^t, p_2^t, \ldots p_{2n}^t) \\ s_n^t(p_1^t, p_2^t, \ldots p_{mn}^t) &= D_n^t(p_1^t, p_2^t, \ldots p_{mn}^t) \end{aligned} \qquad (20)$$

where S_i = supply of i-th sector,

D_i = demand of i-th sector.

On the other hand, it is apparent that the central level can use the models (1)-(7) only with the following production volume and structure balance:

$$x^{t'} - Ax^{t'} + Bx^{t'} = Y^{t'} \qquad (21)$$

and a relative equilibrium of the prices (let us call it state 2):

$$P_j^{t'} = \sum_{i=1}^{n} a_{ij} P_i^{t'} + W_j^{t'} + M_j^{t'} \qquad (22)$$

$(j = 1, 2, \ldots n)$

The above two states of economic dedevlopment differ from each other on one hand because of the redistribution of volume and structure of production in terms of the prices in state 1 in comparison with state 2 where the production volume and structure are directly derived at a central level. On the other hand, due to the well-known fact that the sum of local optimums (2nd level) is never equal to the global optimum (1st level). However, the prices in state 2 have to be consistent with the production expenditures in order to better express the efficiency at a central level in which case expansion of production should be achieved from centrally distributed capital investments, independent prices.

Looking upon state 1 we can claim that it is not optimal with respect to state 2; moreover it could contain disadvantageous consequences as for example unemployment, insufficient social utility, environmental pollution, etc. Hence this state must be adjusted to state 2, which is optimal from the national (global) point of view.

If the central level would like to change the level of economic regulators, it should have models which adequately describe the behavior of economic organizations at every change of state 1. However, the central level does not yet use such models because they have not been elaborated for practical use. That is why the only reaction of the central level to the discrepancy between the two states can be to discard locally developed plans. This can be shown by describing the interactions between the two levels in the planning procedure. At the stage of development of the plan:

- The central level prescribes the volume and structure of production to the economic organizations, which are derived centrally as a response to each proposal to change their plans in the economic organizations:

$$\sum_{i=1}^{n} X_j = \sum_{j=1}^{n} X_i \; , \qquad (23)$$

Thus the local autonomy as a new accepted principle for decision making cannot be achieved in this case. Each proposal to change the plan of one economic organization lead to an imbalance in all other economic organizations from the point of view of the elaborated plan at the central level. This was, however, the reason why an economic independence was admitted at the very beginning of the new economic reform, but immediately after

that this independence was taken away.

-Simultaneously with the production volume and structure, the volume and structure of labor and financial resources are also balanced at a central level (22) which are to be prescribed to the economic organizations. As for the economic regulators (19.1 - 19.5), applied in optimizing (19), they will always lead to differences in the amount of resources required according to (22). For the separate economic organization, these differences will appear as follows:

According to the wage level:

$$\nu M_j^t \leq \sum_{i=k}^{m} l_{ij} e_j x_j^t \qquad (24)$$

According to capital investments:

$$\hat{M}_j^t \geq p_j^{t'} - \left(\sum_{i=1}^{n} a_{ij} p_i^{t'} + W_j^{t'} \right) \qquad (25)$$

where the right side is derived from (22).

The above differences concern the most important elements of the economic mechanism. The wages are closely connected with the stimulus and incentives and the capital investments ensure expansion of production. In this sense, to reduce the labor wages and capital investments to those required by the centrally developed plan, the central level should change the price level or the economic regulators' level at each iteration. Changing the price level as a rule is not enough because increasing the price level for the producers in order to expand their production at the same time can provoke increases of the expenditures among users which can cause a contraction of the production. The easiest way to reach the above purpose is to recalculate the magnitude of the economic regulators (L, β, θ, ν, etc.).

The normative coefficient (14) for example, will then be:

$$\nu' = \frac{\sum_{r=1}^{\pi} l_{ij} e_j x'_{jr}}{\sum_{r=1}^{\pi} m'_j} \qquad (26)$$

In this way the economic regulators must be explicitly and individually determined in accordance with both requirements of the national plan and the lack of uniformity in natural and production conditions. Therefore, at the development stage of the plan, the final version of the individual regulators shows that they allow a subjective estimate of the economic organizations' contribution to increased efficiency. That is why the economic organizations, in the centralized economic mechanism, are interested in concealing their production potential.

<u>During fulfillment of the plan</u>. The economic organizations do not have equal potential to fulfill their prescribed planned targets. A sharp contradiction exists between the large number of all types of products required at the executive level and the need to balance and optimize with the use of aggregate models at the centralized planning level. Besides unequal potentials to fulfill the plan exist because of the subjective estimates of the economic organizations from the central level. As a result, different extents of fulfillment of the plan by different economic organizations usually appear:

-At any stage of application of the plan, it is impossible to change the plan targets by creating a balance in the range of goods produced within one economic organization independently of the centrally balanced plan, because a partial balance within one organization can lead to an imbalance in all the others.

-The central level must correct each plan target that is not fulfilled due to insufficient production volumes by relative suppliers. This situation is analogous to (16)-(18) by the centralized mechanism but in condition of the new economic reform it requires that all economic regulators have to be corrected in order to meet the corrected plan targets. This destroys their role as stimulators because they cannot serve as long-term regulators.

The analysis of the relationship between the new principles of the economic reform and the models (or the approaches of planning) used in practice shows that the economic regulators are a passive reflection of the plan but they cannot play a regulatory role as a device for development and fulfillment of the plan. In this way, the economic reform is a modification of the centralized planning mechanism. This can be shown in Figure 3 as a modification of Figure 2:

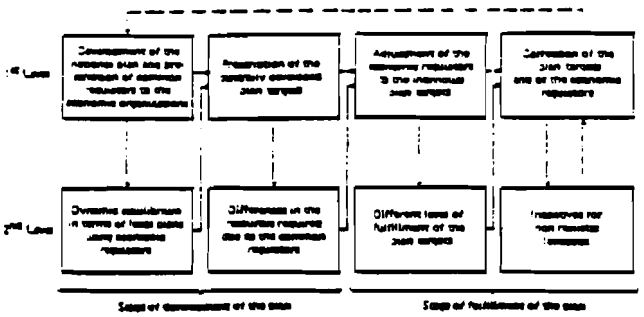


Fig. 3. Scheme of the stimuli and incentives in connection with the new economic reform.

The analysis made has been explicitly conformed in practice. It also shows that volume and structure of production as well as the volume of resource use are the actual tools for control of the national economy but not the economic regulators described above.

Therefore it is necessary to use applied models for planning on a central level which would allow the economic regulators to be used as an active device and stimulant for development and fulfillment of the national plan.

NEW DIRECTIONS IN MODELING A NATIONAL ECONOMY

Basic assumptions. The only alternative to direct interaction between economic organizations and the central level is a direct interaction between the economic organizations themselves and their indirect regulation from the side of the central level. Practice shows that nothing else can substitute the incantives which are provoked by competition between economic organizations when they have equal possibilities. On the other hand, practice shows that a normal (and more desirable or optimal) development is impossible without an active regulative role of some central authority. In this sense adequate models have to be developed for the two levels under analysis. These models have to describe the real planning procedures and not to depend on mathematical convenience only.

The limited framework of this paper allows us only to outline main features of the planning procedures and of the models which are to be developed and used in practice.

Forecasting at the central level. The main purpose of these forecasts is to describe the expected future state of the development of the national economy under the conditions of independence of the economic organizations. This implies flexible price formation and a production volume and structure based on their marginal value, when supply is equal to demand. The following models can be used:

- -Consumption functions for the final consumption in dependence on the main production factors, as for example:

$$Y_t = \mu(L_t^{k_{1t}}, K_t^{k_{2t}}, N_t^{k_{3t}}, e^{nt})\psi \quad (27)$$

where

L = labor;
K = production funds;
N = environmental factors:
k_1, k_2, k_3 = density of the personal income, profit and rent;
e^{nt} = technological progress;
μ, ψ = parameters.

The final consumption as a function of personal income and prices can be forecasted in terms of (7) also.

- -Input-output models which allow the technological production links to be forecasted on the basis of forecasted final consumption:

$$X_t = (I - A)^{-1}Y_t + (I - A)^{-1}B\Delta K \quad (28)$$

A consistent forecasted state of the national economy which has its equilibrium is a result of the linkage of the above different models and can be represented by the following price equations:

$$p_j^t = \sum_{i=1}^{n} a_{ij}p_i^t + W_j^t + M_j^t \quad (j=1,2,\ldots,n) \quad (29)$$

More general price equations can easily be derived from general production functions.

Forecasting and optimizing at an economic organizations level. These procedures have to be realized simultaneously because the development of each economic organization can be optimized on the basis of forecasted trends in the national economic development, of the technological (and social) progress and of the behavior of competitors. However, it is not only possible but necessary to exchange information between the central level and the economic organizations to help forecasting at both levels.

Optimization of development in an individual economic organization generally has to be realized in terms of maximization of (8). This will, in aggregating over all economic organizations, be consistent with the forecasted state of the national economy, developed at the central level (29).

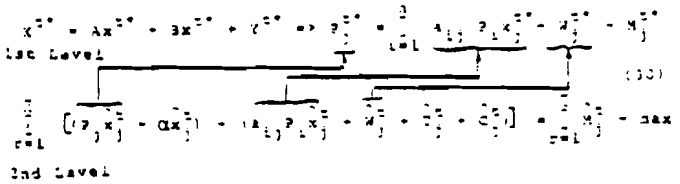
Optimization of the national economy development at the central level. Central optimization is absolutely

necessary because the forecasted state of the national development as a result of local optimization cannot be optimal from the point of view of reasonable global criteria. Optimization at a central level can be realized in terms of the already described scheme (Figure 1) for the centralized economic mechanism and formulae (1)-(13). A substantial feature here is that the optimization within the economic organizations is realized by the central level but not by the economic organizations. Besides, the optimal state of the economic development in this case represents a desirable state but not a state to be prescribed in a direct way to the economic organizations.

This procedure allows the forecasted state of economic development (29) and the desirable optimal state (1)-(13) to be compared, using the main commensurable elements: production volume and structure and different kind of resources.

Indirect reduction of the forecasted state to the optimal state of economic development. This procedure can be made if one knows the direction of influence on behavior of the economic organizations from each economic regulator. In this sense, the central level prescribes in a common way different levels of economic regulators and after each iteration changes this amount until a convergence between the two states can be reached. The economic organizations react by optimizing their development using objective function (19) but subject to the prescribed regulators (19.1)-(19.5).

In a very general form, the above procedure could be represented as follows:



where

* = optimized state of economic development at a central level

^ = forecasted state of economic development at a central level

The economic regulators could be implemented by the central level at the very beginning of the forecasting procedure. We, however, want to show a pure example of forescasting in which the regulators could be corrected at the next iteration. The procedure of planning analyzed and the models adequate for this procedure can be illustrated with Fig. 4:

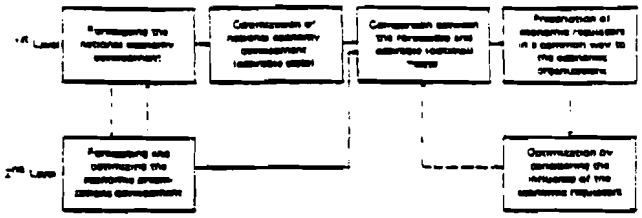


Fig.4. Scheme of the general planning procedures and modeling.

It is obvious that the use of economic regulators by the central level does not preclude local independence. Instead it provokes positive incentives among the economic organizations due to the common way of application of the regulators as well as to the competition among themselves. At the same time the economic regulators ensure an optimal development of the national economy which is the real advantage of the efforts to develop a set of adequate models to the described economic mechanism.

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