MODELS OF SOCIOECONOMIC DEVELOPMENT

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Summary

A general approach to mathematical modeling of socioeconomic evolution is presented. The methodology that was developed for physic application has been extended into the field of economic applications. The main problem under investigation is how the structure of socioeconomic system depends on the economic development. The system's structure is described as frames of economic agents' behavior and interactions between them. The economy state change with time is determined by the system of balance equations describing production, distribution and consumption of goods and of balance equations describing financial assets and liabilities circulation.

The descriptions of agent's behavior and interactions close the system of balance equations and allow predicting how government's macroeconomic policy should impact on future economy evolution. This approach was applied to investigation of socioeconomic changes in Russia during 1980-1998. Many results are presented and it is shown that the approach allows getting as qualitative knowledge on interrelation between socioeconomic structures and national economy evolution as well as good quantitative estimations of government's macroeconomic impacts.

1. Introduction

The idea of sustainable development formulated in general contains an appeal to a new paradigm of humankind's evolution. However, the specific content of a problem of sustainable development depends on the level of socioeconomic development of each country. Now in the "gold billion" countries there was a rather steady social compromise based on socioeconomic structures that ensures high effectiveness in the use of resources. So in the "gold billion" countries the technological progress happens in conditions similar to a general economic equilibrium. The problem of sustainable development in these countries mainly consists in maintaining the status quo: to adapt socioeconomic structures in such way that the direction of the technological progress would be adequate to the restrictions on natural resources and would keep an unstable equilibrium of biosphere.

The problem of sustainable development is totally different for the less developed countries and for the countries with transition economy, especially for Russia. In most of these countries the socioeconomic structures do not ensure an effective utilization of resources and the social compromise is not reached yet. As a result, less developed countries and some of the countries with transition economy, such as Russia, occupy such a position in the world market that leads to dissipation of their national riches. In these countries the sustainable development problem is a problem of such reorganization of socioeconomic structures, which would make an effective utilization of resources and would create the base for steady social compromise. That is a necessary stage in transition to sustainable development for less developed countries and countries with transition economy.

The above problem also has a more general context. The global economy as a whole is far from equilibrium and the developed and less developed countries have such discrepancies that even do not allow us to speak about the social compromise on a global scale. In the nearest future the problem of sustainable development will challenge the developed countries, similar to that of the less developed countries and the countries with transition economy. It is necessary to rebuild socioeconomic structures on a global scale, to build the economic relations between the countries that would ensure the stability of the global social compromise. (See Chapters under *Systems Analysis of Global Development Processes*).

Hence, there are two actual problems:

1. Problem of study of the socioeconomic structures' evolution and the regulation mechanism for production and distribution of the goods that is generated by them.
2. Problem of a rating of the effectiveness of those regulation mechanisms of production and distribution for the economic goods, which are peculiar to socioeconomic structures originating at different periods of transition to sustainable development.

The solution of these fundamental problems gives a possibility to influence on the evolution of socioeconomic structures.

The up-to-date information technologies based on mathematical modeling should be used in solving these complicated problems. Therefore there is a problem of mathematical modeling for specificity of socioeconomic structures for different countries in conditions when socioeconomic structures are changing quickly. The essence of this problem is to develop mathematical models that would describe in an explicit form the mechanisms of the industry's regulation and the goods' distribution, distinctive to the specific socioeconomic structures for the specific countries in a specific time.

Such models are closed and they enable us to generate time series of macroeconomic indexes for economic conditions under the given scenario for the State macroeconomic policy. It gives a possibility to estimate the distant consequences of macroeconomic decisions - both real and virtual ones - by the indexes describing dynamics of a common economic condition. Under this information it is possible to judge to what degree it is possible to influence rates and proportions of economic development within the framework of the given socioeconomic structures, i.e., to judge effectiveness of these structures. By examining the limits, which the given structures put for the effectiveness of resources' use, it is possible to recommend rational directions of transformation for the socioeconomic structures influencing in this way for their evolution.

Up to now, the considered problem has not been the focus of consideration for researchers. The economic theory studies an economy of the developing countries and - in recent years - a transition economy [O. Blanchard (1997)], [A. Shleifer, D. Treisman (2000)]. However, the specificity of considered tasks of the mathematical modeling is that it is practically impossible to use the classical mathematical models of the economic theory immediately. The models of a general economic equilibrium and an optimal economic growth represent the abstract schemes, from which the common outcomes of methodological or ideological character are deduced. In these models a system of the economic goods' circulation, particularly, the credit and monetary system is described insufficiently explicitly (See chapters under *Input – Output Models and Macroeconomic Growth Models*). Therefore, as a rule, these models can not adequately reflect the specificity of socioeconomic structures of the specific countries. Econometric models describe the relations between economic indexes revealed by a statistical analysis of data about the past economic conditions, and they extrapolate the revealed tendencies into the future. It is clear, that econometric models work well while the socioeconomic structures are kept constant throughout for a sufficiently long period of time. However, it is hardly possible that they will describe well a transition economy, where structures are frequently replaced by others.

In a context of the problem of transition to sustainable development the following approach to modeling of socioeconomic development is offered.

- Systems analysis of the specific socioeconomic structures is carried out and as a result of the analysis a system of hypotheses concerning behavior and interactions of the basic economic agents is formulated.
- Within the framework of the formulated hypotheses general principles of the economic theory and the dynamic systems' theory are applied to develop mathematical models of socioeconomic structures and to join them in the closed

model of a national economy or region.

- Computing experiments with the model are carried out within different scenarios of macroeconomic policy of administration with the purpose, firstly, to adjust the model to specific conditions of the country or region, and secondly, to obtain the initial information for a rating of effectiveness of socioeconomic structures and recommendations on how to influence them.

The structure of a socioeconomic development model is defined by a set of economic agents. The economic agent is a stable macrostructure assigned by the definite economic function (production, consumption of the goods and resources, trade of the goods, credit and monetary operations, redistribution of the incomes). The state of the economic agents is described by sets of their material and financial assets and liabilities. The stores of the assets and liabilities for all agents give economic conditions. The stores of the agents' assets and liabilities vary according to the equations for the material and financial balances that have been written out for each of the agents. Right side terms of the equations set amount of assets and liabilities that economic agents create, destroy, or transmit to each other. The models of behavior and interactions of the economic agents define these values.

The behavior of the agent is described by dependence of flows of assets and liabilities that it creates and transmits out, and flows, that it receives from the outside, from its state and from information variables. The last ones are defined by descriptions of the agents' interactions and they coordinate the flows of transmitted and obtained resources. A widely known example of the information variables is prices, and an example of the description for interactions is of the conditions for equation of demand and supply, that define the equilibrium prices which balance demand and supply in the model of a completely competitive equilibrium market.

The description of the economic agent behavior is usually derived from the optimality principle for the use of the limited resources, that an agent has or which it receives externally. The statement of the appropriate optimization problem contains restrictions on feasible actions of the agent that consist of exogenously given exogenous flows and informational variables. The decision of the optimization problem describes rational behavior of the economic agent - plan of its activity under the given conditions of knowledge concerning exogenous streams and the given information variables. Such a description corresponds to the principle of rational expectations. The description of the economic agent, which might be termed administration, is an exception. Its behavior cannot be derived from a rationality principle, and the scenario states it.

The scenario of the administration behavior, description of behavior of other agents and the interactions' descriptions form a closed system of equations for material and financial balances. The economic model so constructed can be explained in the following way. It is supposed that the economically active agents adapt their behavior for new external conditions quicker, relative to the variations of these conditions. Restrictions of optimization problems that set the behavior of the agents, and also set of information variables and descriptions of interactions describe the external conditions for the economic agents. It simulates real socioeconomic structures within the framework of the formulated hypotheses. They define a real choice for each agent, so it

is supposed that the economic agents have time to adapt to any changes, but within the framework of the overall socioeconomic structures. It can be noted that non-equilibrium processes in economy are simulated at a microlevel by equilibrium processes of changing within the framework of the given socioeconomic structures.

Such approach gives good outcomes. Since 1986 it was regularly used for modeling and analyzing the evolution of socioeconomic structures at first in the USSR, and then in Russia.

2. A general approach for modeling the socioeconomic development

The economy is considered as a self-developing complex system subjected to actions on the side of the governmental administration and the monopolies of equal strength. The response of the economy on their decisions and actions frequently takes place in an unexpected way, since it is determined by its peculiarity as a complex system. The economic activity is carried out by lots of relatively independent natural and legal persons or, as it is accepted, the economic subjects. Each economic agent has its interests, the majority of them arrange the rather limited resources, but it is enough for them to work in the existing conditions pursuing their own interests.

What are those existing conditions? It is a system of restrictions on the activities of the subject that arises because its interests do not coincide with the interests of other, similar, subjects or even contradict them and also because the administration and the monopolies establish rules restricting its operation.

In self organization, divisions of characteristic roles of social labor are formed, each of executing a set of the subjects. The subjects have the same type in the sense that their economic interests are brought up, i.e., are reduced in correspondence with those by roles, which they execute in economy. The subjects who were not managed to adjust their interests to roles, which have developed in the given system of the division of labor, simply disappear from the economy due to competition.

The generalized typical subject (more exactly, a set of subjects of the same type), with its interests adapted to the role, operating in the given social system of labor division, is called an economic agent. It is a basic concept for macroeconomic model of economy. The economic agent is not a legal person; and is also not a physical person. A macroeconomic structure, to which a certain function in the studied economy can be assigned, hides under the term ‘economic agent’. In all theories of political economy the concept of the economic agent as «a typical producer,» «a typical customer,» or «a subject operating in normal, average conditions of public reproduction» is used explicitly or implicitly.

Therefore they say about «knowledge,» about the «behavior» of the economic agent, about "interactions" of the economic agents. Though it is no more than convenient language, as it is usual, partly hides an entity of matter. Essentially, the economic agent is known as a rather stable (hence, equilibrium or quasi-equilibrium) open macroeconomic structure. The agent’s behavior is described by dependence of resource streams (in the most common sense) that the appropriate macrostructure creates and/or

transmits out and of the resource flows that it receives from outside influencng its state and information variables determined as a result of the agents' interactions and coordinated flows of the transmitted and obtained resources. A model of a completely competitive equilibrium market is widely used as an example of such description. The dependence among the outside flows and between the outside flows and the state variables and the information variables is represented in terms of supply and demand functions of the agents (customers and producers). Non-negativity constraints of stocks or of stocks' increases for goods, money etc. give the feasible states of the agents. The information variables are prices of goods and resources, on which supply and demand depend. Interactions are the conditions for equality of demand and supply that determine the equilibrium prices balancing demand and supply.

Usually, the description of the economic agent behavior is derived from an optimality principle of use of the limited resources, which are arranged by the agent or which the agent receives from outside. The statement of the appropriate optimization problem contains restrictions on admissible operations of the agent. The given exogenous streams and the information variables enter into these restrictions. The solution of the optimization task describes rational behavior of the economic agent - plan of the agent's activity under the given conditions of knowledge concerning streams from outside and given information variables. In economics such description corresponds to the principle of rational expectations.

However, it can have another explanation. From mechanics and thermodynamics it is known that the equilibrium systems can be described on the basis of the variational principle. The connection of such description with the theory of dynamic systems is described by the well-known A.N. Tikhonov's theorem about asymptotic description of dynamic systems depending on "fast" and "slow" time [Petrov A.A., Shananin A.A. (1989)]. It was shown that if the system is asymptotically steady in "fast" time it is possible to approximately replace it by a system depending only on "slow" time. The "fast" variables are replaced in it by their equilibrium dependence on "slow" variables. In other words, it is possible to consider with an adequate accuracy, that in conditions of the Tikhonov's theorem «fast" processes have time to relax (to come to an equilibrium, which is described by a variational principle) before the «slow» variables essentially vary. With reference to the description of an economic agent it means the following. It is supposed that the economically active subjects in a mass adapt their behavior to new external conditions more quickly than the variation of these conditions. Restrictions of the optimization problem as was already told describe the external conditions, and also by the set of information variables and descriptions of the economic agents' interactions.

It is important to note that the descriptions of the agents' behavior and of their interactions are built on the basis of hypotheses, that are formulated as the result of the system analysis of the real socioeconomic structures existed in the given country or region in the given period of time (See chapters under *Systems Analysis of Social and Political Development Processes*). Therefore within the framework of the accepted hypotheses for description of the agents' behavior and their interactions they simulate regulation mechanisms of production and distribution of the goods that have real socioeconomic structures. Thus, descriptions of regulation mechanisms of production and the distribution of the goods, which determine a real choice of the economic agents,

are based on the suggestion that the economic subjects have time to adapt to any modifications, but within the framework of the overall socioeconomic structures. For example, the non-equilibrium processes in a transition economy are simulated in equilibrium at a microlevel by processes of modifications within the framework of the given socioeconomic structures. After essential changes of the socioeconomic structures it is necessary to pass to a new model, because so far there is no mathematical theory of evolution for socioeconomic structures.

It is necessary to explain what means "the equilibrium of the processes at a microlevel." According to the mathematical modeling of socioeconomic development it was established that most flexible, reliable, and unambiguously interpretive descriptions of economic agents turn out in the case, when the initial microdescription for a set of the same type of economic subjects, connections and mutual relations, modeling is carried out by constructing initial microindices by strict aggregation. Examples of this are the production functions constructed on distribution of capacities on technologies by virtue of the given relations of production [Petrov A.A., Shananin A.A. (1993)], or aggregated description of consumer demand [Petrov A.A., Shananin A.A. (1997)]. It is not always possible to obtain such descriptions of the economic agents, and it is necessary to use phenomenological descriptions, formulating an optimality principle for some generalized typical subject [Pospelov I.G. (1995)]. Therefore it is necessary to develop microdescriptions of socioeconomic structures and to develop aggregation methods for microdescriptions. This direction of studies also suggests an approach to the problems of validation of socioeconomic development models, of establishment of limits of their applicability, and, thereby of construction of systems of the models.

Till now in classical mathematical economics selection of the economic agents is considered as a formal operation. The researchers try to obtain general results that are correct for any number of the economic agents. However, the selection of the economic agents is not a formal operation. The selection of the economic agents determines the aggregation level of the model and its structure. The state of the economic agent is described by a set of its material and money assets (stocks of basic and circulating capitals, stocks of raw material and final products, amount of cash, residuals of settlement, deposit or correspondent nostro accounts in banks) and liabilities (obligations to supply the goods, debts of cash, residuals of the credit accounts and correspondent loro accounts in banks). Therefore selection of the economic agents, as a rule, is connected with the aggregation description of the material and money assets and liabilities.

The combination of the variables for material and money assets and liabilities of the economic agents, which are entered into model, sets the state variables for the model of socioeconomic development; they belong to its state space or phase space, as it is referred to in physics (See chapters under *Mathematical Modeling of Physical Phenomena*). The changes of the state variables in time are subject to the equations of material and financial balances, that describe the creation and demolition of assets and liabilities and also feasible transmissions of assets and liabilities from one agent to another (See chapters under *Systems Analysis of Financial Processes and Financial Markets*). The flows are determined by the coordinated plans of the economic agents. Hence, the system of equations of material and money balances is closed by the

descriptions of behavior and interactions between the agents.

The suggested approach allows construction of mathematical models, which describe economy as a complex system with those basic peculiarities, intrinsic to it, which were discussed in the beginning of this section. Formally such a model represents a system of the differential or finite difference equations (See chapters under *Differential Equation Models*), which is closed upon the condition that the scenario of decisions for either activities of the State administration or the monopolists is constructed.

State administration or large monopolists are the legal or physical persons arranging resources, which give them a possibility to dominate the remaining mass of the subjects in the economy. It is clear, that it is impossible to describe the behavior of the legal or physical person arranging such resources and its influence, according to any principles of rationality, that work well at description of macroeconomic structures - outcomes of activity of masses of the subjects of the same type of the economy arranging limited resources. Therefore it is necessary to develop the scenarios of possible behavior of either programs of the administration activities or the large monopolists' activities. After the scenario defines their activities, the model enables us to calculate the coordinated time series of macroeconomic indexes describing the state of the economy at any moment of time. It is a good initial material for a rating of consequences of realization of the accepted scenario. The calculation of a time series collection appropriate to the different scenarios, gives an initial material for the analysis of peculiarities of regulation mechanism of industry and reversion and for a rating of possibilities of the State macroeconomic policy in conditions of the given socioeconomic structures. This information is enough to estimate the effectiveness of the given socioeconomic structure, to reveal its shortages and to recommend rational directions for its reorganization. Effective numerical methods and software packages are developed to carry out such studies [Kamenev G.K., Kondratiev D.L. (1992)].

To sum up, it is necessary to underline the principal ideas. Models that will be described below demonstrate adequacy of the common approach to mathematical modeling of socioeconomic development. All models are based on a complete system of equations of material and financial balances. In all models the system of equations of balances becomes isolated in descriptions of regulation mechanism of industry and distribution of the goods. The descriptions of mechanisms are based on a few independent hypotheses, which by an explicit image are formulated as outcomes of system analysis of the existing real socioeconomic structures. Therefore consequences, which are deduced with the help of these models, are correct and are well interpreted within the framework of the initial hypotheses. The models reflect dynamics of reproduction as a whole and enable us to estimate the consequences of macroeconomic policy. It is verified by special studies that the models correctly reproduce the collection of the basic qualitative peculiarities of evolution of economy, and models, which were developed for practical applications, give good quantitative ratings. The equations of even the primary model do not lend themselves to a formal description. Therefore all models will be described verbally: specificity of those socioeconomic structures, which are simulated, and principal outcomes of the researches which have been carried out with the help of these models. Under the links it is possible to get acquainted with all details of models and more detailed outcomes.

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