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"Nowadays cybernetics has an increasing importance in the management of industrial and economical processes, in reducing the human effort and in increasing the special productivity of man's work, in the overall progress of mankind".

NICOLAE CEAUȘESCU

from the Message addressed by the President of Socialist Republic of Romania to the Third International Congress of Cybernetics and Systems.

Cybernetic-Economic Modelling

The achievement of the program for building up the many-sided developed socialist society is based on ensuring a powerful development of production forces and on continuous improvement of social relations, of industry increase, of agricultural and other branches of national economy, on the increase of national income and population's living standard.

The fast development of production forces is designed by the Romanian Communist Party under the conditions of an optimal proportional balanced economic growth, a sure way for mobilizing and turning to account the whole national economic-social potential and continuous increase on this base of national wealth, of population's welfare.

The policy of the Romanian Communist Party for country's economic-social development ensures the achievement of a maximum convergence of all working class efforts, of the whole people towards a fast balanced and proportional development of production sectors and branches, of counties and towns within the complex of unitary national economy. The stressing of the role of economic growth's intensive factors — the efficient use of raw materials and materials, of energy and fuels, of technologies, machines, equipments and production surfaces, of labour force, of renewal modernisation and diversification of production, the rapid increase of labour productivity, the reduction of production costs, the increase of technical level and of products and services quality, the acceleration of turning speed of all material and financial funds with a view to get an ever higher efficiency of economic activity — mean defining coordinates of growth trajectories of social product and national income, of continuous increase of people's welfare. All these

demands are fully possible under the conditions in which one of the essential features of Romanian economy is the wide opening to the contemporary technical-scientific revolution. The model of our country development mirrors the rates and proportions proper to a fast development, alongside structural changes of social production which cover more and more the characteristic features of modern economies and ensure the acceleration of Romania's economic and social progress.

Through the policy of optimal balanced and proportional growth, it is ensured the process of increasing all components of general cybernetic system of national economy on the most fitted trajectories for achieving the objectives of the Romanian Communist Party.

1. THE MODELLING METHOD – A SCIENTIFIC KNOWLEDGE INSTRUMENT OF THE MECHANISMS OF GROWTH OF THE NATIONAL ECONOMY SYSTEM COMPONENTS

The knowledge, quantification and optimum control of the phenomena and processes taking place in the national economy call for the creation of a strong symbiosis between the cybernetic analysis of the economic mechanism and the large-scale application of the cybernetic-economic modelling method.

Although "model", as a term, has but recently appeared in the current scientific language, the modelling method has been used in the social practice since ancient times. It has been extensively used in navigation, constructions, architecture and so on.

At the same time as cybernetics has emerged, the content of the model concept has been greatly enriched, witnessing a simultaneous expansion of the applicability sphere of the modelling method.

As a matter of fact, the modelling method represents one of the constituent springs of cybernetics. To illustrate this, it is worth emphasizing the fact that two years before issuing his famous book "Cybernetics or Control and Communication in the Animal and the Machine", N. Wiener together with A. Rosenblueth, was concerned with the modelling problem in the article "The Role of Models in Science", published in 1946.

The modelling method has now become a powerful instrument of knowledge and action. Once it had penetrated into various branches of the natural sciences (mechanics, pyhsics, chemistry and so on) causing a real revolution, the modelling method found a wide range of applicability within the field of social sciences as well. The whole history of science development has pointed out the strong gnoseological value of the modelling method.

An illustration of this provided by the progress of physics, in the case of which the modelling method facilitated the penetration and knowledge of a wide range of phenomena, from those which occur in the proximity of atoms and elementary particles to those regarding the movement of stars and galaxies. The decisive moment in the evolution of physics are closely conected with the improvement of the modelling instruments to be used.

Thus, Newton's deduction of the fundamental laws of physics has led to the emergence of the integral and differential calculus, Einstein's

theory of relativity in a restricted and generalized sense is closely linked with the utilization of non-Euclidean geometry and the development of quantum mechanics and physics of elementary particles has conducted to the wide-scale use of the theory of operators and infinite-dimension functional spaces.

The perfecting of the means of quantification and modelling of the natural phenomena and the social-economic ones made it possible for the representations of the real world to become more and more accurate and for the models to better and better mirror reality.

Modelling represents an efficient process for knowing the movement laws of the economic-cybernetic systems, for acquiring new information concerning their structure, functionality and behaviour (figure 1).

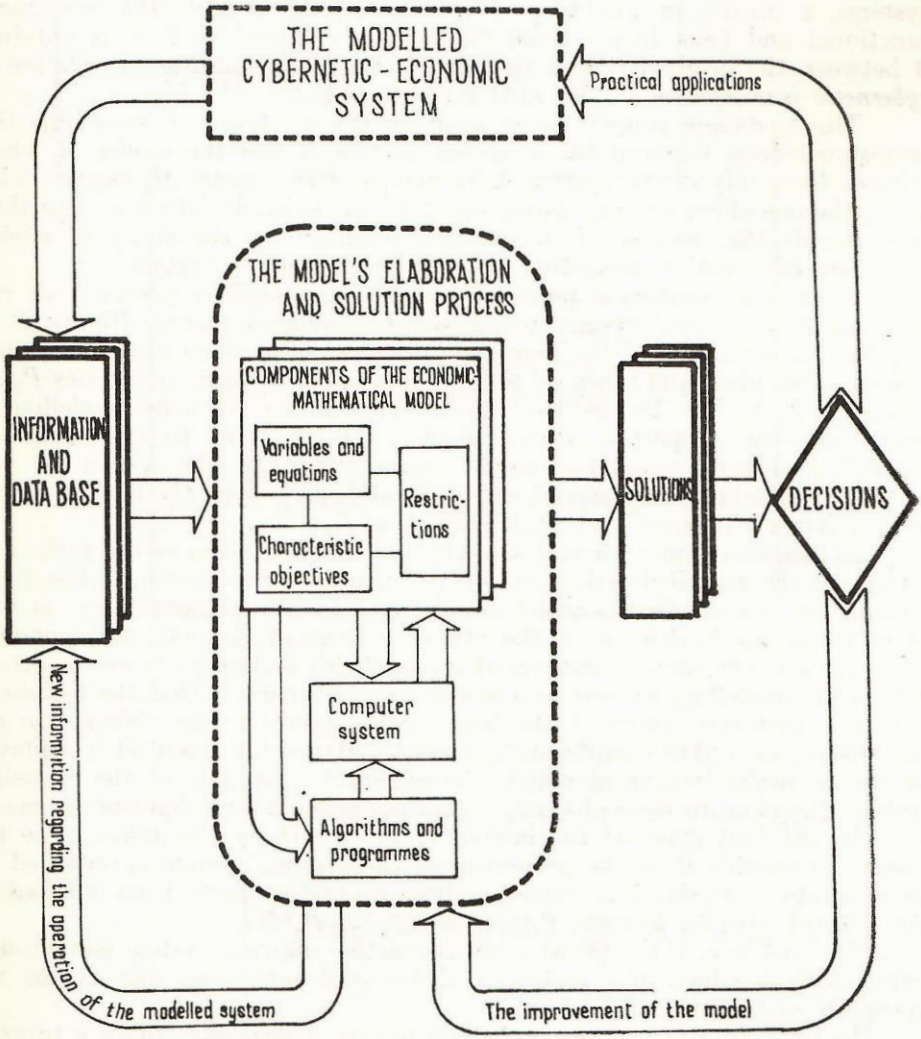

Fig. 1

The last years have witnessed a constant preoccupation for the elaboration of a general theory of modelling, for the analysis of its *gnoseological value.*

Generally, the following triplet is present in a modelling process:

$$\{\Lambda,\ S,\ M\}$$

where Λ stands for the original-system which is to be studied by subject S with the help of model M.

In order to get new information with regard to the analysed system Λ by studying the model M, it is necessary that there should exist a relation of isomorphism between M and Λ. In the case of the cybernetic-economic systems, a maximum quantity of information as regards the structural, functional and behavioural properties of the analysed system, is obtained if between the original Λ and the model M there establishes a relation of *cybernetic isomorphism* in the modelling process..

The modelling process bases itself on the existence of some objective correspondencies between the analysed system Λ and the model M which ensures the study of the system Λ by means of the model M. On the other hand, the modelling process characterised by the existence of some algorithms that permit the transfer of information obtained by the study of models into new information regarding the analysed original system.

From a gnoseological point of view, in a modelling process, one can distinguish 3 different stages, which will be analysed further (figure 2).

In the first stage of the modelling process the analysis of the Λ original system takes place and based on this the identification of its properties $P_1(\Lambda)$, $P_2(\Lambda)$, ..., $P_n(\Lambda)$. As far as the cybernetic-economic systems modelling is concerned, the properties $P_1(\Lambda)$, $P_2(\Lambda)$, ..., $P_n(\Lambda)$ refer to the technical, technological and financial-economic characteristics of the system, as well as to the availability of material resources and manpower, the level of labour productivity, efficiency and profitability, and so on.

At the same time, there takes place an identification of the tasks pertaining to the modelled system within the economic mechanism, of the direct connections and feedbacks which are formed among its subsytems, as well as of those established with the other systems of the national economy.

The stage of concrete analysis of the modelled system plays an important role in the modelling process as a whole, as it is within it that the technical-economic premises laying at the basis of the model under elaboration are established, as well as its informational basis. Hence the essential role played by *the scientific level* from which the cybernetic analysis of the modelled system, the identification of tasks within the economic mechanism are made.

In the first stage of the modelling process there also takes place the transfer to model M of the properties of the original system Λ obtained by its concrete analysis. The corresponding properties have been marked in the scheme at Fig. 2 with $P_1(M)$, $P_2(M)$, ..., $P_n(M)$.

For instance, if the growth process of the analysed system can be described with the help of a system of differential equations, this will be the model M of the original system.

In the first stage of the modelling process there takes place a transfer to the system of differential equations (model M) of the information obtained

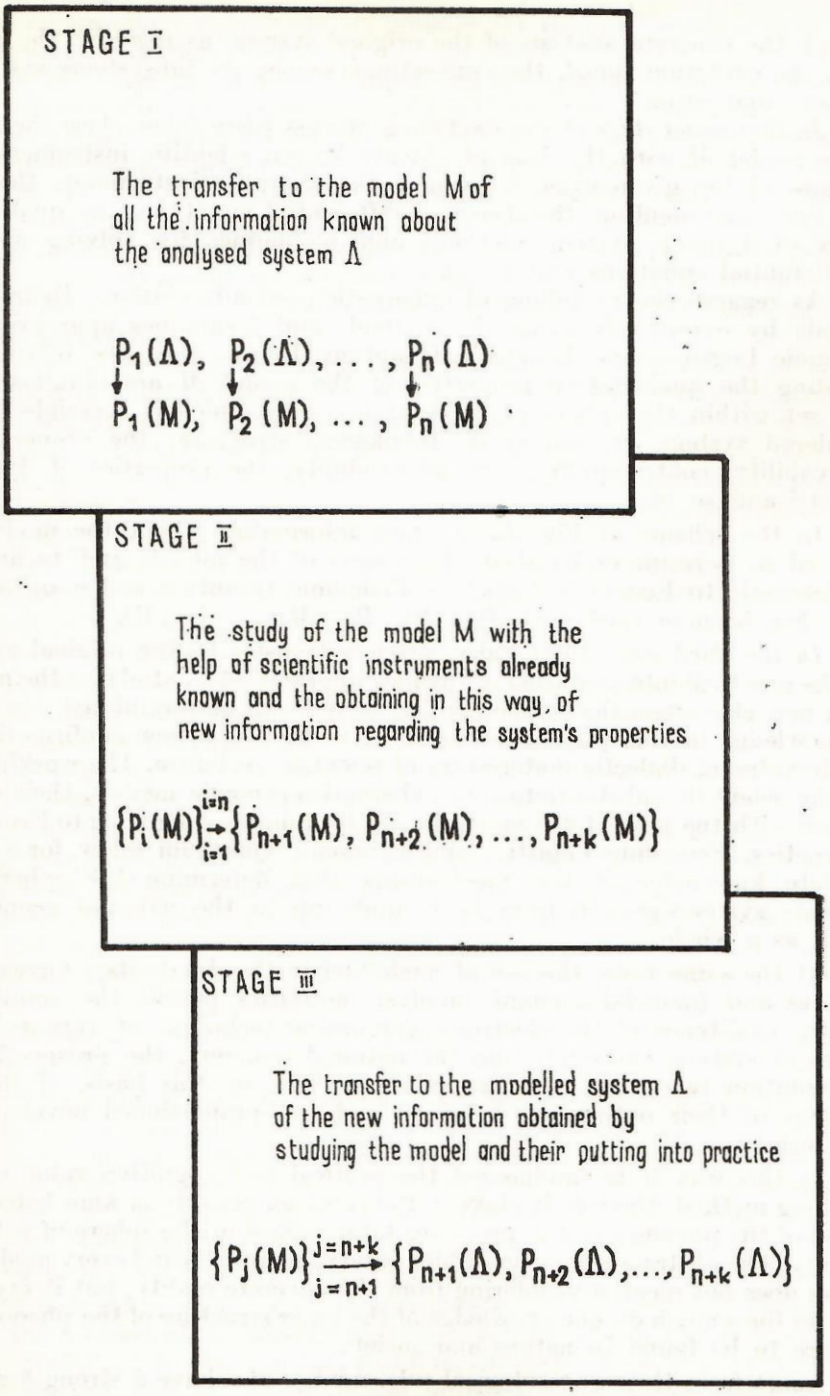
STAGE I
The transfer to the model M of all the information known about the analysed system Λ
$P_1(\Lambda), P_2(\Lambda), \ldots, P_n(\Lambda)$
$P_1(M), P_2(M), \ldots, P_n(M)$
STAGE II
The study of the model M with the help of scientific instruments already known and the obtaining in this way, of new information regarding the system's properties
$\{P_i(M)\}_{i=1}^{i=n} \rightarrow \{P_{n+1}(M), P_{n+2}(M), \ldots, P_{n+k}(M)\}$
STAGE III
The transfer to the modelled system Λ of the new information obtained by studying the model and their putting into practice
$\{P_j(M)\}_{j=n+1}^{j=n+k} \rightarrow \{P_{n+1}(\Lambda), P_{n+2}(\Lambda), \ldots, P_{n+k}(\Lambda)\}$

Fig. 2

through the concrete analysis of the original system, as regards: the initial state, the evolution speed, the connections among its subsystems and their intensity and so on.

In the second stage of the modelling process there takes place the study of the model M with the help of already known scientific instruments. In the case of the given example, among the scientific instruments that are used, one could mention: the theory of differential equations, the qualitative theory of dynamic system, methods and techniques for solving systems of differential equations and so on.

As regards the modelling of cybernetic-economic systems, their study is made by extensively using the methods and techniques appropriate to Economic Logistics and Economic Quantum. In this way new information regarding the quantitative properties of the model M are obtained: the state set within the sphere of national economy which is accesible to the considered system, as well as its topological structure, the properties of observability, controllability, and adjustability, the properties of dynamic stability and so on.

In the scheme at Fig. 2., the new information about the model M, obtained as a result of its study by means of the models and techniques characteristic to Economic Logistics, Economic Quantum and so on and so forth, has been marked with $P_{n+1}(M)$, $P_{n+2}(M)$, ..., $P_{n+k}(M)$.

In the third stage there takes place a transfer to the original system and the practical interpretation of the new information by studying the model. Thus, new characteristics of the studied system can be formulated, enriching its knowledge in this way. The modelling method is a new confirmation of gnostic value of dialectic materialism of scientific socialism. The working-out and the scientific substantiation of cybernetic-economic models, their investigation with the help of the methods and techniques pertaining to Economic Cybernetics, Economic Logistics and Economic Quantum allow for a more complete knowledge of the mechanisms that determine the cybernetic-economic systems'growth from basic units up to the national economy's system as a whole.

At the same time, the use of modelling in the day-to-day forecasting, planning and financial-economic analysis activities permit the simulation with the assistance of the electronic computing technique of various alternatives of systems growth within the national economy, the prospecting of the evolution tendencies and the substantiation, on this basis, of the coordinates of their optiumum, balanced and well-proportioned development trajectories.

In this way it is emphasized the pratical and cognitive value of the modelling method, the role it plays in the complex activity of knowledge and control of the phenomena and processes taking place in the sphere of national economy. The abstracting process which intervenes in each and every modelling process does not mean a wandering from the concrete reality, but it lays the premises for a much deeper knowledge of the inner structure of the phenomena that are to be found in nature and society.

Apart from their gnoseological role, models also have a strong *heuristic function.* Synthesizing the knowledge acquired up to a certain moment,

modelling simultaneously makes it possible for the knowledge process to be re-taken on a higher level.

A new stage in the field of modelling is represented by the *cybernetic-economic modelling* which stresses and quantifies the connections and interferences formed among the components of the national economy system by bringing into relief various aspects of the phenomena and processes that take place in the national economy. At present, cybernetic-economic modelling has become a most powerful scientific instrument in the study of the objective laws governing economy, in a more solid substantiation of the programmes of social and economic development ensuring an ever more efficient intervention on man's behalf in the phenomena going on, in the speeding of the general progress.

The model of a cybernetic-economic system reflects, in equational form, its structure, behaviour and functionality within the economic mechanism, its specific evolution within the space of national economy. This is why, within the cybernetic-economic modelling, an important part is played by the instrument of modern mathematics. In this way, it is proved the prevision made by Karl Marx according to which a science attains its perfection when it succeeds to use the mathematical methods on a large scale.

Paul Lafargue outlined that: in "Higher Mathematics", Karl Marx has found the dialectic movement in its most logic and at the same time its most simple shape; according to his opinion, a science is fully developed only when it reaches to use mathematics.

An important aspect of the gnoseological function of modelling in general, and of cybernetic-economic modelling in particular, refers to the fact that this investigation method allows for the utilization of the entire treasury of knowledge acquired by humanity along centuries, of the methods and technics elaborated by mathematics.

Cybernetic-economic modelling involves an iterative process of elaborating ever more perfected models that permit the faithful mirroring of the phenomena and processes taking place in the economic sphere. As the study of the results obtained by solving the model, of their comparison with the objective reality progresses, the power of reflection and the validity of the hypotheses made on the occasion of its elaboration are verified.

This way, the model becomes a bridge between the theoretical knowledge and the economic practice. This function manifests itself in two ways: from reality to theory and from theory to concrete practice.

Within the general framework of science progress, of its ever stronger assertion as a main factor of progress and civilization, cybernetic modelling is regarded as an important instrument of knowledge and control of the phenomena and processes that take place in economy. At the same time cybernetic economic modelling is a factor of action, its applications in the field of economic phenomena management being a telling example of the ceaseless turning of science into a productive force.

Cybernetic-economic modelling facilitates the knowledge of the objective laws, the forecast of the social-economic development; it brings an outstanding contribution to the technical and scientific revolution, to the development of automation and the techniques of optimising the production process, to

the rise of labour productivity, of the efficiency of all the activities characterizing national economy, in general, to the progress of productive forces.

Practice has confirmed that cybernetic-economic modelling has become an efficient means for the analysis and interpretation of the various problems regarding economic growth and social development. *The gnoseological function of cybernetic-economic modelling* is achieved because it points in a qualitative-quantitative form the interaction of various compartments of the economic mechanism, its organization and management, its optimal articulation with a view to increase the material production, the labour productivity, the efficiency of all economic activities and based on this to rise the national income, the country's general wealth, the population's material and cultural living standard.

As the material production develops and its complexity grows, there becomes more obvious the necessity for a cybernetic-economic modelling of the processes and phenomena which take place in the economic sphere in order to rapidly ensure some decisions and steps of maximum economic efficiency.

The fast development of socialism technical-material basis, the ever complex character of mutual connections among the various branches of national economy, the demands related to the proportional and balanced development of economy implies the continuous improvement of the methods of cybernetic-economic modelling, of planning methods based on operative and very exact calculations, which to ensure the efficient utilization of society's material and human resources, of all components of national wealth.

An ever greater number of requirements are connected with the application of cybernetic-economic modelling methods in the production process in order to simulate, substantiate and design *the optimal solutions and variants* from an economic point of view. Thus, it is stressed the strong symbiosis that is born in the economic practice between the techniques of cybernetic-economic modelling and those of simulating and optimizing economic processe (Fig. 3).

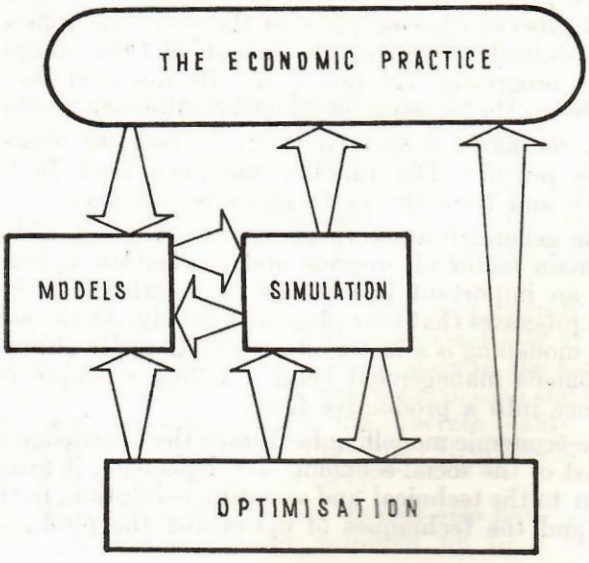

Fig. 3

2. THE GENESIS OF THE PREOCCUPATIONS FOR THE QUANTIFICATION AND MODELLING OF ECONOMIC PROCESSES

The preoccupations for the quantification and modelling of economic phenomena and processes have started at the same time with the formation of political economy as a science.

The necessity to point out the laws governing production, distribution and exchange, the mechanisms generating the economic development has made it possible for the descriptive methods to be more and more replaced by quantification and modelling methods.

William Petty (1623—1687) — considered to be the father of scientific political economy and, to a certain extent, of statistics — was the one to start the scientific explanation of the work-based theory of value. Through an abstracting process which precedes modelling, he points out the fact that the substance of value is given by work incorporated in goods.

We may say that with W. Petty a new stage in the research of economic phenomena and processes begins, his name being associated with numerous results obtained in this domain.

Being a highly cultivated man in the field of economy, mathematics, technique and medicine, William Petty is acknowledged to have been among the first economists to realize that the research of economic phenomena cannot sufficiently make progress as long as qualitative analysis is not based on numerical quantifications.

This conception prompted Petty to write "Political Arithmetics" — one of the most important achievements in the XVII-th century. In the very preface to this work, Petty puts forward the fundamentals of his conception regarding the research of economic phenomena: "Instead of the comparisons, of the superlative words and the speculative arguments, I shall use a language in terms of Number, Weight, or Measure." [1]

Petty remained faithful to this principle throughout his economic research.

W. Petty's preoccupations cover a wide range of economic problems, most actual ones for that time. Thus, Petty is concerned with monetary problems, such as the one referring to the amount of money necessary for a normal circulation, with problems of value, of productive labour and ground rent defining, and so on; he elaborated the first elements of the theory of surplus value.

Also, in terms of quantification and some models unformalized yet, W. Petty studies the oscillation of what he calls the political price (price) around what he calls the natural price (value), as well as the functional relation between the value volume and the labour productivity.

Fr. Quesnay (1694—1774) boasts the reputation of having been among the first economists to have tried a theoretical analysis of reproduction by elaborating the first macroeconomic model.

In his famous "Tableau économique" elaborated in 1788, Fr. Quesnay synthetically sets forth the main moments of the simple capitalist reproduction: production, distribution, circulation and consumption (Fig. 4).

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[1] William Petty: "Political Arithmetics", Glasgow, 1751, p. IX.

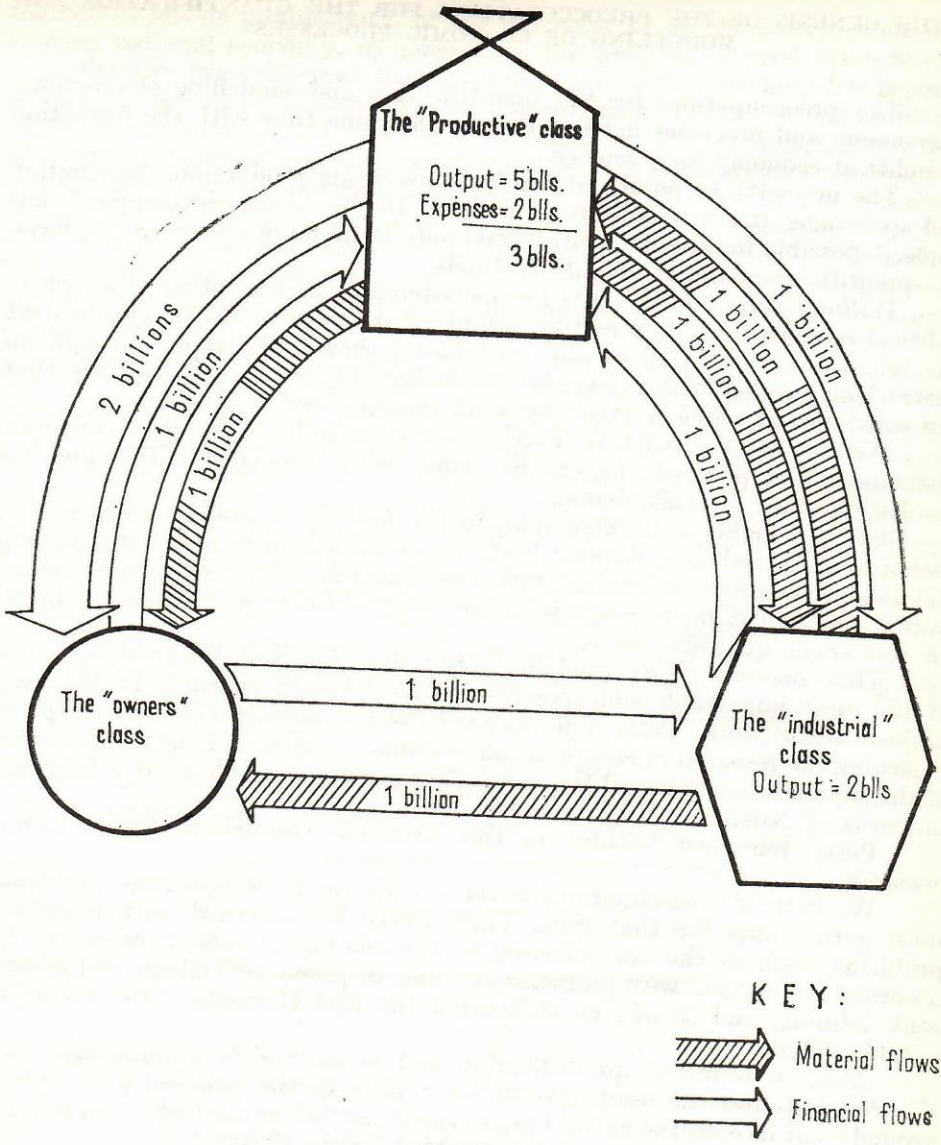

Fig. 4

Based on this, Fr. Quesnay analyses the way the national product circulates among classes, so that following a production cycle and other more circulation cycles, the initial conditions of production are re-established. He also divides productive capital into fixed and floating capital, simultaneously establishing the ratio (5:1) existing then between the two capital components.

The analysis "Economic Table" makes it obvious that the abstracting level achieved by Fr. Quesnay helped him to understand that the circulation

of goods and the circulation of money represent forms of capital circulation. He also examines the relationship between productive and non-productive consumption, the flows that link industry and agriculture and so on (Fig. 4).

The profoundness of macroeconomic model worked out by Fr. Quesnay was highly appreciated by Karl Marx who shows: "This attempt made in the second third of XVIII-th century, in the childhood period of political economy, represents a brilliant idea, no doubt the most brilliant idea which the political economy ever had". [2] K. Marx devotes to the detailed analysis of Fr. Quesnay's Table a special chapter of his work "Theories on Plusvalue". In order to outline the multiple aspects contained by Quesnay's model, K. Marx restates it under the form of an oriented graph, in this way discovering new valences of the "Economic Table".

One may assert that Fr. Quesnay's model contains in embryo the model of inter-branch relationship balance. Due to the abundance of ideas contained, Quesnay's model is also significant for today's economic research. This is proved by the fact that, in the second half of our century, a great number of famous researchers (V. Nemcinov, A. Phillips, P. Samuelson, etc) have re-taken Fr. Quesnay's model, attaching new valences to it.

Under the form of an inter-branch relationship balance the variant of Fr. Quesnay's "Economic Table", elaborated in 1766, is presented in Table 1.

Table 1

Consumption / Production	Agriculture	Industry	Final consumption	Total
Agriculture	2	1	2	5
Industry	1	–	1	2
TOTAL	3	1	3	7

As it results from Table 1, national economy is divided into the two main branches — industry and agriculture — with emphasis on the flows existing between them.

Marking with X_1 and X_2 the volume of agricultural production, of industry respectively, and with Y_1 and Y_2 — the corresponding final consumption, on the basis of the data from the table there follows the next system of equations:

$$0.4X_1 + 0.5X_2 + Y_1 = X_1$$
$$0.2X_1 + Y_2 = X_2.$$

The solving of the above-system of equations leads to the following result:

$$X_1 = 2Y_1 + Y_2$$
$$X_2 = 0.4Y_1 + 1.2Y_2.$$

[2] Karl Marx: "Theories on Plusvalue". Vol. I. Editura Politică, Bucharest, 1962, pp. 257.

The formulae obtained lay stress on the volume of production of the two branches depending on the final consumption.

Adam Smith (1723—1790) in his fundamental work "The Nations' Wealth" — it recently celebrated two centuries since its first publication—develops, on a higher level, Petty's model of value-labour, demonstrating that the source of value is human labour present in all branches of material production.

A. Smith also starts a systemic analysis of a model which emphasizes the price oscillation round value depending on the supply-offer relation.

David Ricardo (1772—1823), taking over and developing W. Petty's and A. Smith's works, on the basis of some systematic research points out to the fact that human work is the only source of value. In a more precise way than his predecessors, he defines the categories of value, use value, price and so on. The model worked out by D. Ricardo also emphasizes the role of work materialized while determining value.

In approaching the modelling of economic phenomena, it was considered as being useful the presentation of classical school, which although its limits and errors, remains in the science patrimony as one of component springs of scientific materialism.

Fr. Quesnay, W. Petty, A. Smith and D. Ricardo used scientific methods in the investigation of economic mechanisms, which made the results obtained by these great thinkers to contribute to the progress of economic sciences. In their research they considered economy as a unitary system, made up from numerous mutually conditioning subsystems. At the same time, they are acknowledged to have widely used the method of logical modelling.

Karl Marx (1818—1883) is the one who really revolutionized the utilization of the modelling method as far as economic phenomena and processes are concerned, its recognition as a scientific investigation tool.

Karl Marx tackles economic phenomena according to a systemic outlook, laying emphasis on the connections and interferences that establish among various compartments of the economic activity pointing out the existing interconditioning relations.

On the basis of a deep analysis of the phenomena and processes taking place in economy, Karl Marx also considers economy to be a dynamic complex system and emphasizes the role played by the law of value in the adjustment and self-adjustment of the capitalist production of commodities.

Bestowing great significance upon mathematics, Karl Marx widely used modelling method as a scientific knowledge instrument. Thus, referring to the quantitative-qualitative analysis of the crises phenomena, Karl Marx said: "I have tried many times — as far as the analysis of crises is concerned — to calculate these ascending and descending movements as some irregular curves and I have thought (and I still do) that this is possible with a sufficiently controlled material, that hence we shall be able to mathematically establish the main laws of crises." [3]

One has to be pointed out that most economic proofs of Karl Marx are real theorems. Very many economists are even today impressed by the

[3] K. Marx, F. Engels: "Letters on The Capital", ESPLP, Bucharest, 1955, pp. 229—230.

fact that for understanding some of economic proofs of Marx, they have to use the results obtained very recently in the field of economic modelling.

To this end, it is significant the conclusion of professor Michio Morishima from the "London School of Economics", who was also the president of Econometry International Society. In a paper published in "Econometrica"[4] journal, Morishima proves that one of the fundamental theorems in the modern economic modelling, namely the Theorem of Frobenius Peron for positive matrices-published by Frobenius in year 1908, was in fact, intuitivelly used by Karl Marx long time ago. At the same time, into the same paper, it is outlined the fact that Marx has descovered and used in his economic analysis Markoff chains, introduced into mathematics much later.

Karl Marx, due to the method of dialectic and historic materialism applied by him to the field of modelling the economic processes, may be considered as the forerunner of the main models appeared in the last years in the field of studying the macroeconomic dynamics.

An example of a scientific application of the modelling method in the study of economic phenomena is provided by the schemes of enlarged reproduction, presented by Karl Marx in the second volume of "The Capital".

In the following, there will be emphasized the way the scheme of enlarged reproduction (Fig. 5.) can be formulated as a dynamic model of economic

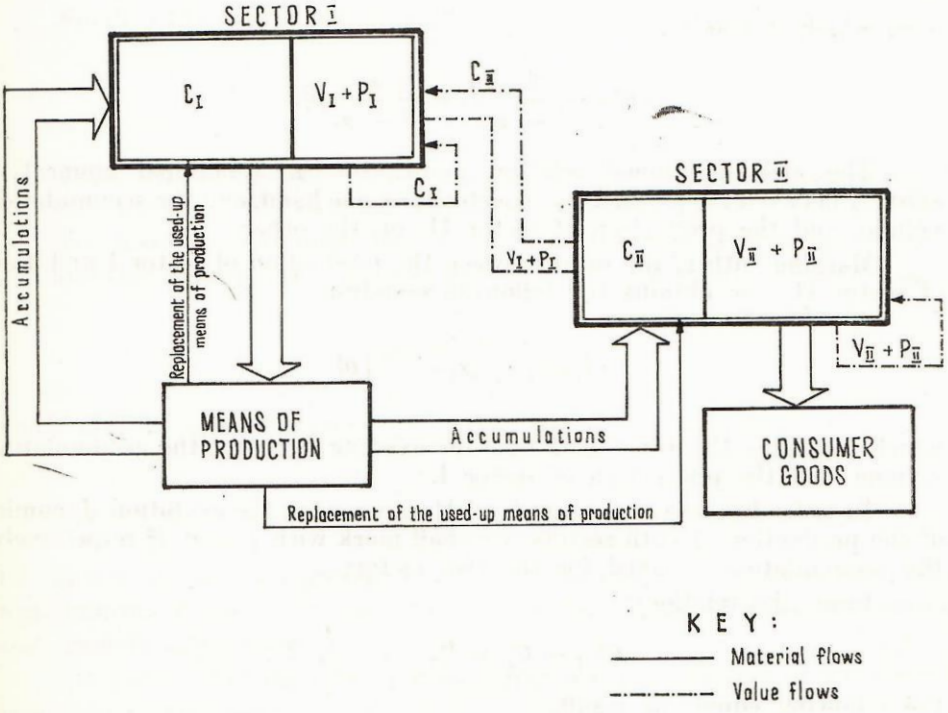

Fig. 5

[4] M. Morishima: "Marx in the Light of Modern Economic Theory", Econometrica, July, 1974.

growth. In order to do this, we shall start from the fundamental relations in the scheme of enlarged reproduction worked out by Karl Marx:

$$C_t^1 + V_t^1 + m_t^1 = p_t^1$$

$$C_t^2 + V_t^2 + m_t^2 = p_t^2.$$

The next parameters will be introduced:

$$\alpha_1 = \frac{C_t^1}{p_t^1}; \quad \alpha_2 = \frac{C_t^2}{p_t^2}.$$

There is the following equality among the quantities above:

$$C_t^1 + C_t^2 + I_t = p_t^1$$

where I_t stands for the accumulation volume in the year t. By means of the elements introduced, one can go on writing the next equality:

$$\alpha_1 p_t^1 + \alpha_2 p_t^2 + I_t = p_t^1$$

from which it results:

$$p_t^1 = \frac{1}{1 - \alpha_1} I_t + \frac{\alpha_2}{1 - \alpha_1} p_t^2.$$

The afore-mentioned relation points to the functional connection existing between the production of sector I, on one hand, and the accumulation volume and the production of sector II, on the other.

Marking with g_t the ratio between the production of sector I and that of sector II, one obtains the following equation:

$$I_t = \left(1 - \alpha_1 - \frac{\alpha_2}{g_t}\right) p_t^1$$

which indicates the functional relation existing between the accumulation volume and the production of sector I.

In order to study, based on Karl Marx's model, the evolution dynamics of the production of both sectors, we shall mark with I_t^1 and I_t^2 respectively, the accumulation assigned for the two sectors.

From the relations:

$$C_{t+1}^i - C_t^i = I_t^i, \quad i = 1, 2$$

the following equations result:

$$p_{t+1}^i - p_t^i = \frac{I_t^i}{\alpha_i}, \; i = 1, 2.$$

Marking with h_t the ratio between the accumulation assigned for sector I and that assigned for sector II, one gets the equations:

$$p_{t+1}^1 = p_t^1 + \frac{h_t}{\alpha_1} I_t$$

$$p_{t+1}^2 = p_t^2 + \frac{1 - h_t}{\alpha_2} I_t$$

which represent the *dynamic equations* of the two sectors.

The dynamic equation of accumulation is the following:

$$I_{t+1} - I_t = (1 - \alpha_1)(p_{t+1}^1 - p_t^1) - \alpha_2(p_{t+1}^2 - p_t^2)$$

it may be also written this way:

$$I_{t+1} = I_t + \frac{1 - \alpha_1}{\alpha_1} h_t I_t - (1 - h_t) I_t.$$

Finally, the next dynamic equation of accumulation results:

$$I_{t+1} = \frac{h_t}{\alpha_1} I_t.$$

Based on the equations deducted, one may study the rising trajectories of both sectors of the national economy.

For instance, assuming that the growth rate of production in sector I is r_t^1, and that of sector II is r_t^2, from the equations of revolution there obtains:

$$\frac{r_t^1}{r_t^2} g_t = \frac{\alpha_2}{\alpha_1} \frac{h_t}{1 - h_t}$$

which may be also written as:

$$h_t = \frac{\alpha_1 g_t r_t^1}{\alpha_1 g_t r_t^1 + \alpha_2 r_t^2}.$$

The above equation brings into relief the ratio that must exist between the accumulation achieved in the two sectors depending on their production and growth rate ratio.

On the basis of the fore-mentioned formula, the equation of investment evolution is obtained:

$$I_{t+1} = \frac{g_t r_t^1}{\alpha_1 g_t r_t^1 + \alpha_2 r_t^2} I_t.$$

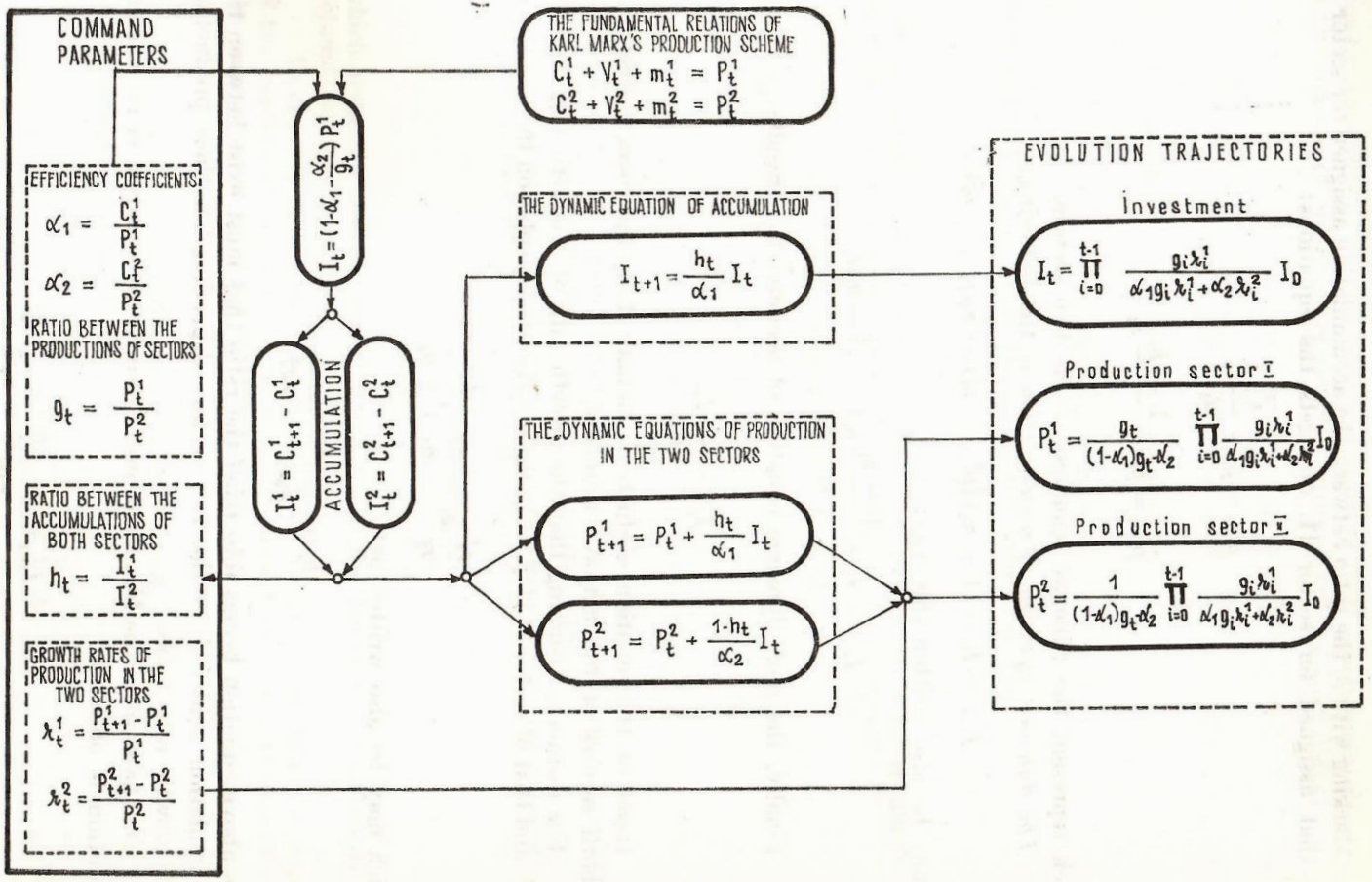
COMMAND PARAMETERS
EFFICIENCY COEFFICIENTS
$\alpha_1 = \frac{C_t^1}{P_t^1}$
$\alpha_2 = \frac{C_t^2}{P_t^2}$
RATIO BETWEEN THE PRODUCTIONS OF SECTORS
$g_t = \frac{P_t^1}{P_t^2}$
RATIO BETWEEN THE ACCUMULATIONS OF BOTH SECTORS
$h_t = \frac{I_t^1}{I_t^2}$
GROWTH RATES OF PRODUCTION IN THE TWO SECTORS
$\lambda_t^1 = \frac{P_{t+1}^1 - P_t^1}{P_t^1}$
$\lambda_t^2 = \frac{P_{t+1}^2 - P_t^2}{P_t^2}$
$I_t = (1-\alpha_1-\frac{\alpha_2}{g_t}) P_t^1$
ACCUMULATION
$I_t^1 = C_{t+1}^1 - C_t^1$
$I_t^2 = C_{t+1}^2 - C_t^2$
THE FUNDAMENTAL RELATIONS OF KARL MARX'S PRODUCTION SCHEME
$C_t^1 + V_t^1 + m_t^1 = P_t^1$
$C_t^2 + V_t^2 + m_t^2 = P_t^2$
THE DYNAMIC EQUATION OF ACCUMULATION
$I_{t+1} = \frac{h_t}{\alpha_1} I_t$
THE DYNAMIC EQUATIONS OF PRODUCTION IN THE TWO SECTORS
$P_{t+1}^1 = P_t^1 + \frac{h_t}{\alpha_1} I_t$
$P_{t+1}^2 = P_t^2 + \frac{1-h_t}{\alpha_2} I_t$
EVOLUTION TRAJECTORIES
Investment
$I_t = \prod_{i=0}^{t-1} \frac{g_i \lambda_i^1}{\alpha_1 g_i \lambda_i^1 + \alpha_2 \lambda_i^2} I_0$
Production sector I
$P_t^1 = \frac{g_t}{(1-\alpha_1) g_t - \alpha_2} \prod_{i=0}^{t-1} \frac{g_i \lambda_i^1}{\alpha_1 g_i \lambda_i^1 + \alpha_2 \lambda_i^2} I_0$
Production sector II
$P_t^2 = \frac{1}{(1-\alpha_1) g_t - \alpha_2} \prod_{i=0}^{t-1} \frac{g_i \lambda_i^1}{\alpha_1 g_i \lambda_i^1 + \alpha_2 \lambda_i^2} I_0$

Fig. 6

Finally, the trajectories of investment and production evolution in both sectors are given by the equations:

$$I_t = \prod_{i=0}^{t-1} \frac{g_i r_i^1}{\alpha_1 g_i r_i^1 + \alpha_2 r_i^2} I_0$$

$$p_t^1 = \frac{g_t}{(1-\alpha_1)g_t - \alpha_2} \prod_{i=0}^{t-1} \frac{g_i r_i^1}{\alpha_1 g_i r_i^1 + \alpha_2 r_i^2} I_0$$

$$p_t^2 = \frac{1}{(1-\alpha_1)g_t - \alpha_2} \prod_{i=0}^{t-1} \frac{g_i r_i^1}{\alpha_1 g_i r_i^1 + \alpha_2 r_i^2}.$$

With the help of the equations deducted, one may study the trajectories of the production evolution in the two sectors in accordance with the indicators g_i, r_i^1 and r_i^2. The graphic representation of the model is given in Fig. 6.

3. THE CLASSIFICATION OF CYBERNETIC-ECONOMIC MODELS

The equational representation of the many sides and aspects of very complex phenomena that take place in the field of national economy achieves through a great number of cybernetic-economic models which can be classified according to basic criteria as follows (Fig. 7):

- the sphere which the model covers;
- the characteristics of the cybernetic-economic system reflected within the model;
- the time sphere for which the model is designed.

According to *the sphere covered* by the economic phenomena and processes which they reflect, cybernetic-economic models may be classified into the following big classes:

a) global models belonging to the national economy's general cybernetic system;

b) cybernetic-economic models of the components of the national economy's general cybernetic system.

The cybernetic-economic models of the first category generally are assembly models whose role is that of synthetically reflecting the phenomena and processes that characterize the development of the national economy as a whole. They synthesize, assisted by some indicators and variables with a maximum power of reflection, the development level of the productive forces, "the position" and the speed of growth of the general cybernetic system pertaining to national economy. The parameters of the models from the first category characterize step-by-step the state of the national economy's system, the parameters referring to the command-decision functions resulted from the general strategy of the country's economic and social development, those relating to connections with other systems within the sphere of economy, as well as those which synthetically quantify all the results obtained from the activities taking place in the sphere of national economy, the output variables respectively.

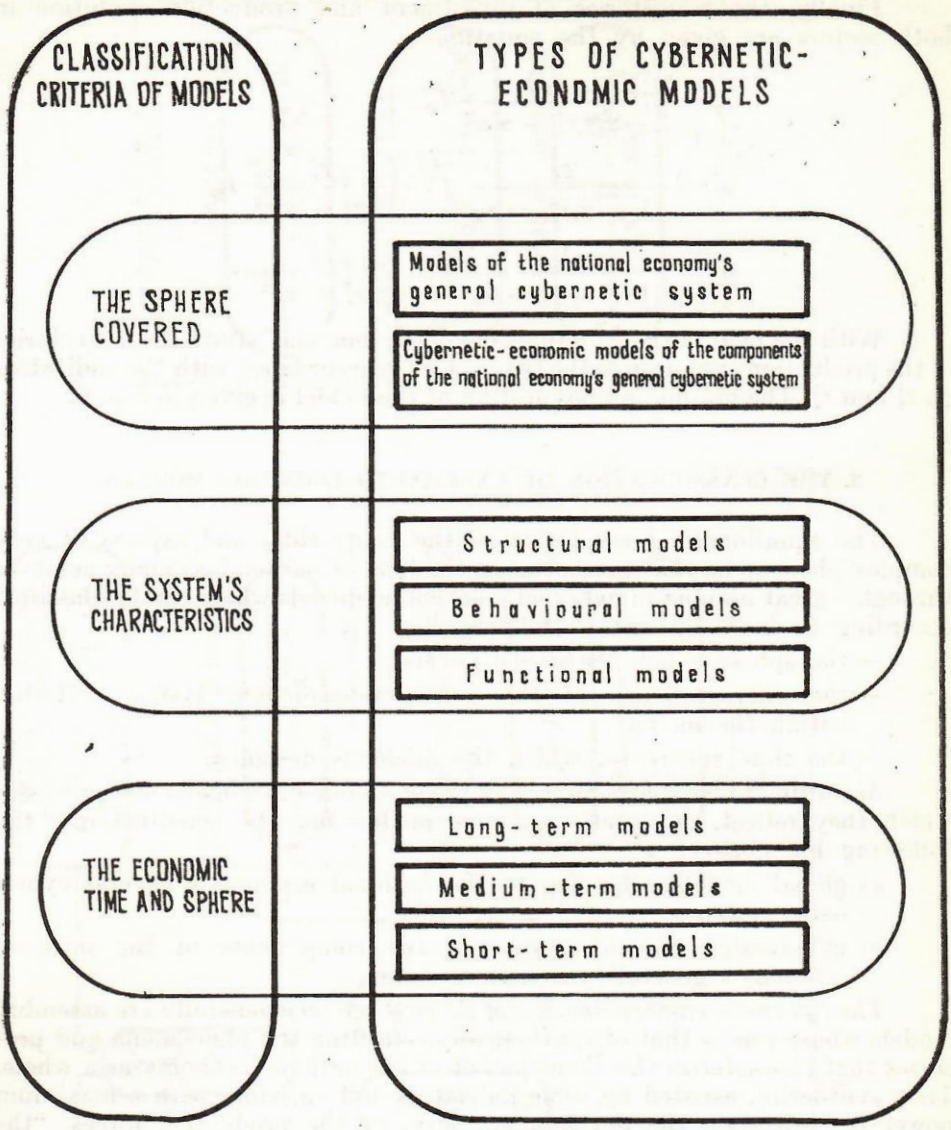

Fig. 7

The cybernetic-economic models of the second category reflect the phenomena and processes specific to each and every constituent of the national economy's general cybernetic system. Thus, there are cybernetic-economic models of the system of command, control, adjustment; cybernetic-economic models of the system of labour productivity, of the system of efficiency-profitability, of the finance and price system, of the material production system and so on and so forth.

It follows that, to each of the 12 systems, the national economy's general system has been structured into, there corresponds one category of cybernetic-economic models on the basis of which emphasis is laid, in the form of an equation, on the specificity of the activities carried out within it, as well as on the system's structure, behaviour and functionality.

From the point of view of the reflected aspect, within the class of cybernetic-economic models of each system, one distinguishes *models of structure, models of behaviour and models referring to the system's functionality.*

The cybernetic-economic models of structure mathematically mirror the connections that establish among the components of the modelled system, as well as their intensity. This class of models plays an outstanding part in the quantification of feedbacks that connect the components of the system under analysis.

One such important class of structural models is represented by the inter-branch relationship balance type.

$$X = AX + Y.$$

The following notations have been used:

X — production vector

Y — final consumption vector

A — matrix of the coefficients of material expenses.

The model of inter-branch relationship balance allows for the identification of the conditions which must be observed in order to ensure a well-balanced and proportional development of the branches of material production. At the same time, by means of the elements of the matrix:

$$\mathcal{A} = (E - A)^{-1}$$

we point out the intensity of the direct connections and feedbacks that establish among the components of the system of material production and that of services, as well as the way the propagation phenomenon manifests itself.

The behavioural cybernetic-economic models reflect in equational form the evolution of systems in the field of national economy, as a result of the activities within them based on the manpower, material, financial and information flows.

Thus, a behavioural cybernetic-economic model of the subsystem of fixed funds within the system of national wealth will reflect their rise as a result of the fixed funds recently set working. It has the following equational representation:

$$K_{t+1} = (E - \mu_t)K_t + \sum_{\tau=-0}^{t} \Lambda_{\tau,t} \cdot I_\tau$$

The next notations have been used:

K_t — vector which quantifies the volume of fixed funds in the year t;

I_τ — vector of investment in fixed funds in the year;

μ_t — diagonal-matrix of the puting out of use as result of physical wear of fixed funds;

$\Lambda_{\tau,t}$ — diagonal matrix of the retardation coefficients corresponding to the activities taking place within the investment system.

The cybernetic-economic models regarding functionality are concerned with the reflection in equational form of the connections that establish between the modelled system and the other components of the national economy system, as well as with their intensity. In this way, the cybernetic-economic models of the system of material production and services will reflect its functionality within the economic mechanism by quantifying the numerous direct connections and feedbacks which exist between this system and the system of management, command, control, adjustment with that of population and manpower, of social product and national income, with the system of national wealth, labour productivity, efficiency and profitability, with that of scientific research and technological development and so on.

Within the class of cybernetic-economic models that reflect the functionality of the national economy systems, the main part is played by the model concerned with the *optimal correlation between accumulation and consumption*, which represents a theoretical and practical problem of utmost significance for a high rate development of the national economy.

From the point of view of *the economic time* they refer to, there are *long-term*, *medium-term* and *short-term* cybernetic-economic models.

The long-term cybernetic-economic models cover periods of 10—20 years or more. In equational form, they mirror the general framework, the fundamental coordinates of the modelled system's growth.

An outstanding part play the long-term models of the national economy's general cybernetic system as a whole, which reflect *the strategy* as far as the optimal economic growth is concerned.

The long-term economic growth models materialized in programmes and plans of development provide the frame of reference for the medium-term planning models.

The medium-term economic growth models generally refer to five-year periods which tallies with the economic time necessary to fulfill the programmes of economic and social development, to take the concrete steps for the growth of industrial and agricultural productions, of the other branches of production, as well as of the services department, to ensure the rise of labour productivity, the investment programmes, the perfecting of new techniques, the measures regarding the improvement of the technical and material supply, the fulfilment of the export-import assignments, the uninterrupted growth of the population's material and cultural living standard.

In practice, there are also worked out medium-term models referring to periods over 5 years, such as the ones concerned with development programmes up to 10 years.

The medium-term models of growth provide the frame of reference for the *short-term economic growth models which, as a rule, refer to a period of one year, for annual plans respectively.*

Thus, emphasis is laid on the connections establishing among the long-term, medium-term and short-term models of economic growth where exists a strong osmosis. There are uninterrupted flows of information among the three categories of models — similar to communication vessels — which ensures the continuity of the forecasting and planning process.

Starting from the objectives of country's economic-social development scientifically elaborated by the Romanian Communist Party, the researches

in the field of cybernetic modelling may offer a wide scale of practical solutions for the forecasting and planning activity.

The Nineth Congress of the Romanian Communist Party has opened the prospect of passing from the traditional planning methods to the modern methods, based on the modelling of economic processes by using the cybernetic, mathematic and informatic methods, of modern computing means.

Outlining the important role of modelling for the improvement of economic management and planning methods, the Directives of the Central Committee of the Romanian Communist Party adopted by the National Conference of the Party in December 1967 outlines that: "it is necessary to be used the most improved instruments for the characterisation of economic development as a whole and for each branch, of interbranches relations and among the various sides of production process; it has to be increased the activity towards the determination of interdependence ratio that is obiectively formed in economy and for the modelling of economic processes.[5)]

In the Programme of the Romania Communist Party of building up the many-sided developed socialist society and Romania's advance to communism, it is stressed that an essential direction towards ensuring the scientific management of economic and social life is: "the wide promoting in the work of organizing and managing the society — including also the social phenomena and processes — of modern methods of data analysis, decision and automatic processing.[6)]

The practical and theoretical presentation of modelling is of course very complex; in this study we have tried only a scheme of the concept of cybernetic-economic modelling, as we also done when we presented the concept of cybernetic-economic concept.

We are further concerned with the approach of a series of cybernetic systems and models of optimal economic growth.

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[5] The Directives of the Central Committee of the Romanian Communist Party regarding the improvement of the management and planning of national economy, according to the conditions of the new stage of Romania's socialist development. Editura Politică, Bucharest, 1967, pp. 84—85.

[6] The Eleventh Congress of the Romanian Communist Party. Editura Politică, Bucharest, 1975, pp. 678.