Cybernetics in Economics

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Abstract:

In 1965 Kyn and Pelikan published in Czechoslovakia the book "Kybernetika v Ekonomii" (Cybernetics in Economics). This article, which was published in Prague in English gives the summary and discusses some more important ideas of that book. The book was quite successful and influenced significantly the way economists were at that time looking at the centrally planned economic system imported from the Soviet Union. The main ideas were: a) the crucial role of information in coordination of economic activities; b) the requirements of the appropriate decision making rules; c) the refutation of the prevailing negative views of randomness and spontaneity; d) the role of "natural selection" for processes of self-organization in economic systems. This provided an implicit critique of the over-centralized command economy and indicated the necessity to revive the market economy.

During the last two years [before 1965] some Czechoslovak economists have contemplated possibility of applying methods of Cybernetics in Economics. This was an outcome of ongoing attempts to improve the system of planning and economic

management. A need to develop the scientifically founded theory of economic control has naturally brought attention to problems of information, decision-making, automatic regulation, control and organization in economic systems.

As yet there is no agreement about the nature of Cybernetics itself, and even less about the application of Cybernetics in the economy. Some people put the main emphasis on mathematical models and the techniques of transmitting and processing economic information. We believe that Cybernetics in Economics means primarily a specific approach to economic problems, in which the objects of investigation are not physical processes, but exchange of information and decision-making. That is why the exposition in the book places stress on problems of organization and control in economic systems. The book is presented in a popular way and does not require any great knowledge of mathematics even though the authors are convinced that Cybernetics has in mathematics a great ally .

The first chapter gives a summary account of the basic concepts that may not be specific to cybernetic view of reality, but are useful for the later exposition. These are such concepts as object, system, input, output, structure, behavior (deterministic, stochastic), isomorphism, homomorphism, models, etc. This chapter also introduces ideas of 'analysis' and 'synthesis' of systems and brings examples of the behavior of very simple 'feedback' systems. Also the concepts of 'stability' and 'equilibrium' are introduced.

We considered it useful to differentiate consistently throughout the book between the concepts 'object' and 'system'. Object we take to mean the actually existing thing or a collection of existing elements connected by mutual interactions. A system, on the other hand, represents a certain abstraction of the actual object. It originates when we define which of all the elements we include in the system, their properties and mutual relationships. When we use the system in place of objects, we always

reduce the number of elements, properties, and relations, so that the system is never a full picture of the object. Of course, this also means that the systems never include full information about the objects. According to the way the system is reduced, the conclusions derived by the analysis of the system can be more or less adequate to reality. This is important for conclusions that are derived from theoretical models of reality.

Economics is not just a descriptive science; it attempts to find the nature and logic of economic processes. One of its most important tasks is to predict the future states of economic objects. But it is never possible to draw conclusions from direct observation only. They must be made by deduction from the behavior of economic models. The model, however, is always a simplification of reality and, therefore, deductions about future developments derived from it can only approximate the actual development.

The conclusions drawn by Marx, Ricardo and Marshall differ considerably, although they were concerned with the same real object, for they were deduced from different theoretical models. In all three cases the conclusions were deduced quite logically and convincingly, but the correctness of each depends on how the theoretical model corresponded to reality. The actual development of capitalist economy seemed to confirm Marx's prediction better than those of Ricardo and Marshall. This shows that Marx's model may have been more adequate for solving this question. Of course this does not mean that Marx's model was equally adequate for solving all questions. It is quite possible that Marshall's model might be more adequate than Marx's for the analysis of demand.

A model has always a specific purpose. It is set to solve certain problems. The fact that it is adequate to the solution of some problem does not prove that it is adequate for all.

The second chapter gives an historical account of the origin of Cybernetics, of the viewpoint of cybernetic investigation, and of the relation of Cybernetics to other sciences, especially economics. The third chapter is called, 'Information and the Decision-Making Process'. Besides introducing the concept of information and explaining problems of measuring the amount of information, attention is devoted here primarily to algorithm and program. Algorithm is an exact procedure that in finite steps--consisting of given elementary logical or mathematical operation--leads from the information received to the decision. The notion of algorithm, however, can be somewhat generalized if we abandon the requirement of finality and include random choice according to a given distribution of probabilities among the basic operations. Then we can consider the method of trial and error also to be an algorithm.

The algorithms that govern decision-making in the human brain are very complicated. Some of them people know and can describe. But it is important to realize that people cannot describe all algorithms they use in practice. Similarly, one can describe some algorithms of economic decision-making (see for example optimization tools of operational research), but can never describe all of them fully. Economic decision-making is more difficult because frequently complete information about the situation cannot be obtained. In such situations it is necessary to guess the probability of success as well as the risk of losses. It is sometimes difficult even to determine which of possible outcomes is the best. For example the optimal state of the economy can be defined as the state that maximizes utility of all the people in society, but the way of measuring this maximum is problematic as the theories of the social welfare function indicate. Many people may have a clear idea of what is good and useful, but find it difficult to formulate it precisely. Individual preferences of people may be incompatible and they may change over time as a result of human experience. For this reason, the human factor cannot be eliminated from economic decisions. Economic decision-making is not only a matter of

knowledge that can be learned, but it is also an art based on intuition.

Real economies are made up of people and for people with all their human qualities and weaknesses. An economic system cannot be designed without regard to man. Therefore the attempts to determine economic value and utility in the same impersonal way as quantities of matter and energy in physics, cannot succeed. The measurement of value and utility is inseparable from man with all his irrational aspects.

A system that makes decisions must contain elements capable of performing a certain group of basic operations and must contain within itself also information about algorithms that would ensure their proper sequence. We call this information about algorithm a program. The program can be contained directly in the structure (hardware) of the system or it can reside in the memory.

Depending on the shares of external and internal information we roughly distinguish the following three types of programs:

- **Closed programs: Systems with a program of this type have no information inputs. The resulting decisions are determined in advance by the internal program.**
- **Unconditioned reflexes: Unlike the preceding program, this system has inputs that bring information from the environment but the system reacts always in the same predetermined way.**

  Conditioned reflexes: A system with a program of this type has even looser connection between the original program and the actual decision. In the preceding case the information from the environment determined directly the decision of the system according to a fixed algorithm. Here the algorithm itself is created through the influence of the environment

Systems with conditioned reflexes are frequently called learning systems because their programs permit learning. Since systems with programs of a reflex type are capable of continuously receiving information from environment, there need not be as much information contained in their programs. Of course the reduction of the volume of information is only a less important benefit of economic planning. It is evident that a function of the plan is to provide a program for economic activity in the future. If it is a closed program, it must determine output of an extensive range of products in advance. Although this was for some time considered to be the only and most effective form of planning its shortcomings are obvious. In such a case the plan must contain enormous amount of information and at the same time the stability of the economic system would be threatened by every unforeseen event, whether this were change in demand, in technology of production or in foreign markets. In contrast to this, a plan of the second category would continuously receive information about the changes in conditions and derive operative decisions that could not be made in detail at the time when the plan was set up. The particular objective would be to plan the reaction to unpredictable circumstances. A plan of the type of conditioned reflexes would mean a further improvement in these reactions. The system would learn from its successes and mistakes are more important that not all the needed information is available initially when the system was constructed. Systems with closed programs are incapable of performing tasks that depend on unpredictable events.

We can now draw some conclusions for Economics and particularly for the theory of economics.

systems that react to changes in environment in such a way that they will achieve certain goal or objective. The objective can be a state or modification of the environment or of the system itself.

It is evident that not all the real systems can be considered 'goal-seeking systems'. We can classify real system in the following three groups:

Systems whose behavior is determined exclusively by physical inputs. Such systems can be either deterministic or stochastic but there is no need to use the concepts of information and decision-making in this case.

Systems whose behavior depends not only on physical inputs, but also on information received, but there is no need for the concept of goal or objective.

Systems whose behavior depends on physical inputs, information received and the goal of the system. These are 'goal-seeking systems'.

Classifying systems according to these criteria is in certain extent arbitrary. Information is always carried by some physical process, but we may or may not ascribe informational significance to it. The same object can be studied either with or without concepts of information and decision-making. If we do not use the concept of information, but observe only the changes in the physical states of the system, we can describe the motions as cause and effect using laws of physics. The concepts of goal-seeking and causality do not necessarily contradict each other, but are merely two different views of the same reality.

The goal-seeking system can originate in two ways:

They may be created by activity of another goal-seeking system .

They may be spawned by the process of natural selection.

The second method needs an environment with abundant energy that contains elements from which such a system can be created. The surplus of energy makes these elements enter into random bonds that are either reinforced or dissolved by further developments. As a result different arrangements of existing elements are sequentially tested for survival. The bonds that arise between elements introduce into the environment qualities that had formerly not existed. As soon as some system is created by chance it can in turn change the probability of creating other systems. The probability of a certain system arising is not directly related to the probability of its disappearing. Thus it could happen that after passage of time some systems would predominate even though when they originated it might have seemed that there was only small probability of that.

The role of chance is very important in the process of spontaneous evolution. Systems that already exist are constantly subject to random influences that affect their organization. In biology these fortuitous changes are called mutations. They occur without any intentions to improve or worsen the existing systems. Nevertheless they are the reason that the systems continuously improve.

The principle of natural selection is also important for the progress of human society. Social progress means the introduction of new technologies of production, new economic relationships, new forms of management and organization, better than the preceding ones. Their novelty lies in the fact that they were unknown before they were introduced. There was no information about them and therefore they could not have been consciously introduced with guaranteed success simultaneously throughout the whole society. Mutations in society are also of a fortuitous nature. No experts can guarantee correct filtration of unfavorable mutations so that only favorable remain. Just recall the gallery of scientists and inventors of genius who were not recognized by their contemporaries. Only when the emergence of random mutations is not prevented can advantages of some new forms be demonstrated in practice and thus be extended to all of society. Every society that wishes to speed up its evolution must make random mutations possible. The new forms must have the possibility of showing their advantages or their shortcomings in practice to be compared with previous forms. This is, of course, not easy because society should also prevent survival of unfavorable mutations that could act as cancer on the organism.

We can divide the systems with goal-seeking behavior into regulating, controlling or organizing systems. If we define system in such a way that regulated, controlling or organizing system are a part of it, then we speak of automatic regulation, control or organization.

For a long time Marxists believed that the automatic or spontaneous processes could lead only to imbalances and anarchy in the economy. They concluded that it would be desirable to suppress automatism and replace it--where possible--with the conscious, centralized direction. The error of this idea is apparent. Reducing automatism leads to growth in size of the central administrative apparatus, making it slow, cumbrous and bureaucratic.

In economic systems goal seeking is often manifested as purposefulness and the goals as economic interests. People form their goals according to their individual tastes and abilities, but also under the influence of the social and economic environment in which they live. They are constrained in their behavior in two ways: by material conditions, and by socio-economic factors. The socio-economic determination enters into the decision-making process usually through the objective function. Therefore we must distinguish between activity that man cannot carry on at all from those, which he can but does not perform, because he has no interest in doing so.

There are both similarities and differences between the goals and interests of

different people. There exist general interests but also individual deviations from them. If we regard society as a whole we can think of these individual differences as random deviations. The greater the number of people with common or only slightly different interests in a certain group, the closer are their ties and the closer is their cooperation. We can, therefore, observe the formation of group interests in society.

In designing the control of economic systems, it is necessary to reckon with the fact that these systems are made up of people, that is to say, elements that are themselves systems acting not only purposefully, but also consciously. Therefore each control directive is only one of the information inputs, used by the controlled to make a conscious decision. Controlling people means influencing their decision-making in the desired way. The harmony or conflict of interests between the controlling body and the controlled play an important role. If both parties want to reach the same goal it is not necessary to make the controlling directive compulsory. If such a common interest is lacking, the controlling directive must be supplemented by measures that ensure its effectiveness. Among the means employed the most frequent is the use of force.

Sometimes a deliberate distortion of information is used for this purpose. If, for example, the controlling body succeeds in persuading the controlled that carrying out the orders is in their own interest, although it may be only the end desired by the controlling person or body, people can actually be made to act against their own interests. Nationalism, chauvinism, racism, etc., can be misused by some groups of people to induce others to actions that in reality do not serve their interests.

The fifth chapter deals with some economic models. Here it is not a question of a purely cybernetic view of the economy, but of a certain interpretation of models known from the classical economic approach. First, the various possibilities of introducing systems in the national economy are shown, and the resultant possibility

of constructing different economic models.

Examples that are discussed next include dynamic models of the market (cobweb) and structural Input-Output models (of the Leontief type). On the first glance the original Leontief structural model includes exclusively physical interactions. There are no flows of information or decision-making processes in the model. It is interesting to note that a Leontief Input-Output model can be interpreted in several different ways:

> **as an instrument of a description and analysis of the existing structure of the economy that is, as a process of obtaining scientific information on the state of the national economy;**
> **as a theoretical mathematical model of self-regulatory processes that lead to the creation of economic equilibrium (similarly as in models of Leon Walras). In this case scientific information on the behavior of economic systems, is obtained,**
> **as a part of the algorithm of decision-making by the planning body, which determines the program of activity of economic units. Here there is a decision-making function that contains within itself knowledge of the conditions of economic equilibrium.**

The chapter continues with the comparisons of some aggregate models of growth that are based on the Marxist concept of the process of accumulation and the Keynesian concept of the multiplier process. The Feldmann-Mahalanobis type of model is also shown in simplified form.

The sixth chapter makes an attempt at a cybernetic view of the national economy, that is, a view of the economy as informational and decision-making structure. The system created for this purpose consists of people who are interconnected by

informational flows. The environment consists of other social systems and nature. Nature here is taken to include all the physical things relevant to the economic process, including 'artificial' nature - machinery, buildings, equipment, etc. - that are the product of human productive activity.

By acting on nature, society introduces a certain organization into it. Since this action has some goal, we may speak of society as a system with goal-seeking behavior. Unlike technical systems, which can have a goal that is quite general, without any relation to the existence of the system and its elements, we have here interdependence between the goal, the system itself and its elements.

The goal of a social system, is not just survival of the society as a whole, but it is also survival and well being of individual people, who are the elements of which the social system is composed. Compare it to the relation of human body to cells, the elements of which it is composed. The purpose of the existence of cells can be seen as the preservation of the existence of the human organism; the human organism protects its cells only insofar as they are needed for its life. As opposed to this, the existence of man is an end in itself. Man does not exist for society, but society for man. Society cannot sacrifice a person because it is not needed. In the concept of the needs of society we must include the needs of its members.

If we wish, therefore, to consider society as a system with objective behavior, we must realize that there is here an unusual bond between the goal of society and the elements of which society is composed. Whereas in the case of technical apparatus any structure is suitable if its behavior makes possible the achievement of the desired properties of the system, the demand made on structure in society as a whole is to achieve certain economic results, but must at the same time meet the people's wishes in some way. Therefore not every structure that assures a high social product is a suitable one if it forces people to lead an unpleasant life.

People are the individual units in the structure of a social system. Some of the people stand right on the dividing line between society and nature and, with their work, act directly on nature (productive labor) we can call these people the output elements of society. The others are the internal elements of society and their social role is primarily to receive information, make decisions, and provide information for other people.

People may have very diverse abilities to make decisions. This depends on:

complexity of the algorithm by which a person is able to make decisions,
ability to learn, that is flexibility in adapting the algorithm to new situations,
appropriateness of personal goals to the task.

It is obvious that it is not desirable to put people with anti-social goals into important social position even if otherwise their ability to make decisions is excellent. But sometimes it is difficult to choose between a capable worker with unsuitable personal objectives and an incompetent worker whose interests may seem to coincide perfectly with the social goals.

Depending on its place in the structure of the economic system each decision-making position is characterized by its weight and risk.

The weight depends on the size of the subsystem that is being controlled and on the relative reduction of degrees freedom.
The risk depends on the probability distribution of gains or losses.

The risk of decision depends on the amount and kind of information that the decision-making agent obtains. There is not only distortion of information as it is transmitted in the economy, but also a deliberate distortion. Systems that provide information sometimes try to use distorted information to influence the decisions taken by those who receive the information. Therefore a theory of economic information needs more than a statistical theory of information that was elaborated primarily for the needs of communication technique, but it would be necessarily to include also some considerations from the theory of games.

Human capacity to receive and process information is limited. No individual can handle all the types of information needed for a smooth operation of society. Consequently, the whole social control process must be subdivided among various controlling subsystems. For example, we can visualize society as a hierarchy, with the lower base formed by the output elements, and those who make the decisions are placed in upper layers over those who receive and implement the decisions. The base elements send information about the state of nature upward to upper layers of hierarchy. Since each place in the hierarchy has a limited capacity, the amount of information must be gradually reduced. Not all the information collected below can arrive at the highest places. The problem, of course, is how to reduce information without losing what is essential for making decisions. The reduction of information on the way up means that the highest places cannot issue decisions that would contain enough information to eliminate all the uncertainty in the output elements. That is to say, each place in the hierarchy has a certain degree of freedom for independent decisions. The allocation of degrees of freedom within the hierarchy determines what is usually called the degree of centralization or decentralization. High degree of centralization requires large information processing capacity at the upper layers to reduce the risk of centralized decision-making. If there is too much centralization it can easily happen that the costs of transmitting and processing information would be many times higher than the most pessimistic estimates of loss that could occur with an effective reduction of information and a decentralization of a large part of the decision-making.

In the subsequent discussion the book continues with some reflections on the direct transmission of information, the transmission of algorithms, synthesis of parts of the

hierarchy, assignments of personnel to decision posts, and finally with some thoughts on planning.