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A MODEL OF INTERACTION BETWEEN THE SOCIO-ECONOMIC SYSTEM AND THE GEOGRAPHICAL ENVIRONMENT

ZBYSZKO CHOJNICKI

So far, analyses of the relationships between man and the geographical environment dealt mainly with the problem of the changes in environment that are due to the growth of population and of industry and to the advance of urbanization. Less attention has been paid to the reverse effects, that is, how those changes in turn affect man, his health, his conditions of living and work, and thus the conditions of economic life.

The adverse effects produced in the course of performing his economic activities on the geographic environment have both immediate and indirect economic consequences.

The immediate economic consequences include the diminution of the existing resources and the deterioration of their quality, and lead to reducing the ecological capacity and disturbing the natural equilibrium of the environment and thus to decreasing its productivity. The indirect consequences consist in decline of the landscape values and in vitiating man's health conditions.

Without going any deeper into the problem of the different forms of man's adverse influences on his environment it must be stressed that they are highly complex in character and have not only one-way consequences. Parallel to destructive or reductive consequences, there are also compensatory effects which level out the losses incurred by introducing other elements or suppletive effects which increase productivity.

In the analyses of man–environment interactions it has been becoming more and more necessary to give an integrate treatment of the diverse relations considered in the economic aspect. To provide the theoretical fundation for this it is necessary to construct a model that will permit the economic interpretation of the relations in terms of two-way flows between the socio-economic system and the geographic environment. Such a model seems to constitute some advance with respect to what has been done in recent years in introducing spatial concepts into economic studies.

As a model for such an analysis we may take the system of interactions in economy as presented in W. Leontief's [13, 14] analysis of production inputs and outputs (cf. also P. Sulmicki [20], and B. Szybisz [21]). The essential element of this analysis is the set of relations between the individual branches of an economy in the form of commodity flows.

The two fundamental systems: environment and the socio-economic system are both subject to changes themselves and, moreover, act upon each other. All changes in the environmental conditions deteriorate, by a feedback effect, man's conditions of living and work. It must be observed here that the attempt to determine the scope of "deterioration of conditions" of the environment has to be based on such an analysis of the changing conditions that leads to the concept of environment ecosystem. This can be explained by the specific role of the biosphere in the relations between man and environment. In his discussion of this role A. Kostrowicki ([11], p. 4) writes: (1) "Most of the forms of human activity consist in the adaptation of nature, mainly of its organic constituents, to man's needs, and it is through this organic nature that most of the feedback actions take place — from environment to human populations and societies." (2) "The relations between man and the elements of environment that are not ecological factors are relatively simple". (3) "Organic nature is not only the intermediary between man and most constitutents of the natural environment but, to a large extent, the creator of this environment".

The concept of ecosystem demands closer elucidation. The term was first used by A. G. Tansley [22] as the fundamental organizing concept of ecology denoting both the biome and its habitat. E. P. Odum [16] denotes by ecosystem, or else ecological system, any space (constituting a natural whole) in which matter is being permanently exchanged between the organic and inorganic constituents of this space as a result of the mutual interaction of living organisms and mineral substances. All components of the ecosystem — both organic and inorganic, the biome and the habitat — can, according to A. G. Tansley ([23], p. 207), be regarded as mutually interacting factors which in a mature ecosystem nearly attain equilibrium, and it is this interaction that preserves the whole system.

In terms of the attributes of general systems, the ecosystem is structured and functional in its character. To use the terminology of Bertalanffy's [2] general systems theory, the ecosystem is an open system tending toward a steady state in accordance with the laws of open-system thermodynamics. Ecosystems in a steady state, i.e., in equilibrium, possess the property of self-regulation, which is similar in principle to homeostasis in living organisms, feedback principles in cybernetics, and servomechanisms in engineering.

Ecologists identify and study ecosystems of different size and on different levels of complexity. F. C. Evans [7] emphasizes that the concept of ecosystem includes a hierarchy of systems at different levels of complexity and extent. It seems that the concept of ecosystem may refer both to the elementary level of organization, on which "biocoenosis" or "geobiocoenosis" are taken as the fundamental units, and on higher levels of organization, on which the term ecosystem incorporates a number of fundamental units. E. P. Odum [16] says expressly that as long as the fundamental components continue to exist and function and as long as their functioning exhibits some degree of equilibrium — even for but a short time — so long the given system may be treated as an ecosystem".

The fundamental process that determines the functioning of the ecosystem is the energy–flow in the form of food from its source through a number of organisms. This process is called the food chain. Food chains are not isolated series of organisms but intervene with one another constituting mutually interrelated circuits (systems).

Leaving aside a more detailed discussion of the concept of ecosystem, let us merely point out those among the ecological concepts which include in their research scope the problem of man. However, the attempts at extending ecological studies over problems of man that have been made so far have failed to yield the expected results, perhaps because of the basically different character of the laws governing the socio-economic sphere. If we conceive of human behaviour as merely a higher variant of the "behaviour" of the animal world, or if we treat human populations as component parts of biocoenoses and ecosystems, we are likely to commit a gross simplification and fail to explain the essential links in the evolution of the relations between society and nature.

In studying the man–nature relations we have to employ a very broad understanding of the ecosystem; it should be treated as a macrosystem. Now, to understand adequately any macrosystem it is necessary to study its organization (cf. D. R. Stoddart [19]).

Organization may be seen as a set of elements which, as a group, are capable of fulfilling certain functions such that cannot be fulfilled by any of the individual types of elements in isolation from one another. Each element affects the others and is itself affected by them; moreover, each element operates so as to maximize the effects of its operation for its own benefit. A system attains the highest level of organization when each element maximizes the effects of its own operation. Conversely, whenever the elements operate randomly the system has a low level of organization.

The concept of "organization" is applicable both to the ecosystem and to the socio-economic system. In studying the "man–nature" interdependencies it is essential to clearly define the mutual relations of these two organizations, or, more strictly, the interpretation of the two organizations. The growth of negentropy, that is of organization, which is specific for all systems, is connected with the growth of disorganization within system of lower organization. The dominance of the socio-economic system is an essential factor disturbing the equilibrium between the two systems.

The study of the two systems is based on the observation of definite analogies between the mechanisms of operation of each of them. According to H. E. Daly [5], one such analogy exists between the processes of metabolism and the economic processes. The scheme below illustrates this analogy:

The attempt to define the mutual interrelationships between the socio-economic system and the ecosystem may be based on identifying the different influences inducing changes in the one and the other system. The explanation of the character of that influence may also include diverse elements of each of two systems. In simplified form, this influence can be presented as flows from one system into the other, for each of them has its internal and external flows connecting the two systems. The external flows not only change the volume of the substance of the system but also change the conditions of its influence.

TABLE 1. "Man–nature" model

	Socio-economic system	Ecosystem
Socio-economic system	I	II
Ecosystem	III	IV

After some extension, Leontief's model of input–output flows makes possible the integration of the two systems into the metasystem "man–nature". In its simplest form, this model is presented in Table 1. Field I in this Table stands, in accordance with Leontief's model, for the input–output flows in the

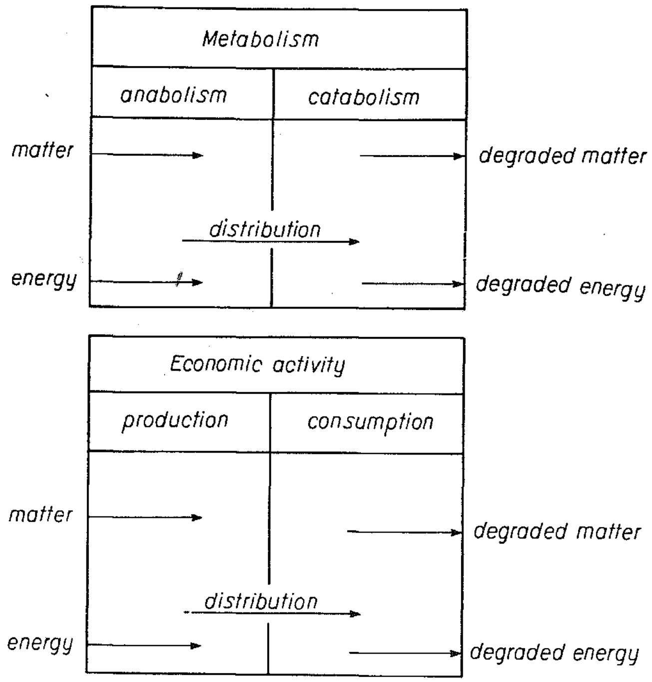

Fig. 1

socio-economic system. Isard ([9], p. 310) points out that "the strength of this analysis lies in its detailed presentation of (1) the production and distribution characteristics of individual industries of different regions, and (2) the nature of the interrelationships among these industries themselves and among these industries and other economic sectors". Accordingly, it represents the essential features of the structure of multi-industrial economic system on the regional and the interregional planes.

The ecosystem of the geographic environment can also be analysed in terms of the input-output model, provided we treat it as a set of mutually interrelated processes that demand certain inputs and yield definite outputs. The system of flows within the ecosystem is represented by field IV.

By their activity the two systems provide themselves mutually with definite final inputs and outputs which get outside each of them. These flows constitute the foundation of the mutual dependencies and influencies. Field II represents the flows from the socio-economic system to the ecosystem which are in fact the subsidiary, i.e., side-effects of the society's production activities. Field III, on the other hand, represents the inputs of nature that enter the sphere of the society's productive and consumptive activities.

The dimensions that characterize the flows of the integrated system constitute three groups of phenomena:

(1) flows, that is the values produced or consumed within a definite period such as, e.g., the output of coal, the consumption of plankton;

(2) resources, that is the values existing at a given moment, e.g. water resources;

(3) conditions, that is the values that are attributes varying with time, e.g., air temperature.

TABLE 2. An extended model of inputs and outputs of the metasystem "Man–Nature"

	To	Socio-economic system			Ecosystem							
	From	(1) Agriculture	(2) Industry	(3) Population (consumption)	(4) Vegetative world	(5) Animal world	(6) Microorganisms	(7) Atmosphere	(8) Hydrosphere	(9) Litosphere	(10) Degradation of energy and matter	x_n
Socio-economic system	(1) Agriculture	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}	x_{16}	x_{17}	x_{18}	x_{19}	$x_{1,10}$	x_1
	(2) Industry	x_{21}			x_{24}							
	(3) Population (Labour)	x_{31}			x_{34}							
Ecosystem	(4) Vegetative world	x_{41}			x_{44}							
	(5) Animal world	x_{51}	x_{52}	x_{53}	x_{54}	x_{55}	x_{56}	x_{57}	x_{58}	x_{59}	$x_{5,10}$	x_5
	(6) Microorganisms	x_{61}			x_{64}							
	(7) Atmosphere	x_{71}			x_{74}							
	(8) Hydrosphere	x_{81}			x_{84}							
	(9) Litosphere	x_{91}			x_{94}							
	(10) Sources of external energy (Sun)	$x_{10,1}$			$x_{10,4}$							x_{10}

The proposed extension of the model is presented in Table 2. Separating the two fundamental systems by a dividing line this table furnishes a tentative outline of the basic relations occurring both within the systems themselves and between them.

Within the socio-economic system we have, in analogy to the traditional input-output analysis, to distinguish two fundamental sectors of production and population as an autonomous sector. The proposed division of production into agriculture and manufacturing is of course a simplification intended merely to expose the two principally different modes of transforming matter and energy in production processes, i.e., through the participation of living organisms, on the one hand, and by transforming inorganic matter, on the other. An operational model, however, would demand a more detailed division into production branches. Moreover, the criteria of such a division would also have to be different from those employed in "traditional" analyses. To cite a simple example, it is necessary to give separate treatment to thermal and water power stations, for although their respective products are identical, their impact on the ecosystem is dissimilar as their respective "inputs" to the particular components of the ecosystem are entirely different.

Still greater difficulties have to be overcome in dividing the ecosystem into "sectors". The division presented in Table 2 is intended to identify the fundamental sectors of the ecosystem. These latter represent: (1) the fundamental groups of organic nature, including man as an element of biological reproduction, (2) the fundamental physical systems of the geographical environment, and (3) moreover, the volume of the solar energy that enters the system and, in accordance with the laws of thermodynamics, the corresponding degradation of an organized into an unorganized system.

Without entering the complex issue of application of the principles of thermodynamics to ecological energetics it must be said that a general idea of the energetics of the ecosystem can be obtained by determining the volume of energy flowing through the ecosystem and adding to it the consumption of the energy accumulated in this system (cf. J. Phillipson [17]).

Table 2 is no more than a mere conceptual framework; it has to be filled in with concrete data drawn from a knowledge of the interrelations resulting from the inputs and outputs occurring between the diverse sectors of the two systems. To be more adequate to reality, the table would have to include a very detailed classification by sectors as well as relevant factual data. An analysis of ecological studies shows that abundant research materials that could be employed in devising such a table are available. But the most realistic approach, though, seems to consist in the elaboration of certain parts of the table including but some relations only, namely such that would solve definite problem issues, for instance that of water economy on interregional scale. Such a research undertaking would obviously necessitate the participation of a large team of experts in many fields.

But the elaboration of the table or even of its parts only is hardly more than a collection of data concerning exchange processes within the system "man–environment". In order to pass from pure description to the identification of the relationships referring to this exchange, which are necessary for later prognostication and planning, we have to determine the input coefficients in analogy to the procedure adopted in Leontief's model. Theoretically these coefficients can be derived from the balance equations expressed in material units by the formula:

$$X_i = \sum_{j=1}^{n} x_{ij} \qquad (i = 1, 2, \dots, n)$$

On the basis of this formula, the coefficients can be defined as:

$$a_{ij} = \frac{x_{ij}}{x_j}$$

Obviously, the evolution of the system "man–nature" will proceed harmoniously under the prevision that adequate proportions between the inputs of each system will be maintained, that is that the coefficients a_{ij} will have adequate values.

From the definition of the coefficients it follows that $x_{ij} = a_{ij}X_j$. Hence, if the coefficients are assumed to be known, we can formulate a system of balance equations consisting of n first-order equations with n unknowns

$$\sum_{j=1}^{n} a_{ij}X_j = X_i \qquad (i = 1, 2, \dots, n)$$

The coefficients may be constructed either in virtue of statistical studies of inputs and outputs or may be derived from the results of studies of the natural sciences.

The system of interrelations presented in Table 1 suggests that the coefficients should be divided into four groups.

The first group consists of coefficients referring to the socio-economic system (field I); they have the character of socio- or economico-technical coefficients.

The next group consists of what may be called natural coefficients (field IV) as they refer to the inputs and outputs within the ecosystem. Such coefficients may be calculated primarily from data provided by ecological studies. The results of studies of food chains and networks in different types of ecosystem provide the possibility to obtain an approximate quantitative determination of the respective input and output coefficients.

The third group consists of technical-natural coefficients referring to field II; they cover the problems of inputs from the socio-economic system to the ecosystem. These inputs represent the secondary system of relations which results from the side-effects of economic activity and which manifests itself as a rule (though not exclusively) in the adverse changes in the geographical environment. Many studies concerning the utilization of resources, especially in water economy furnish rich materials which may prove useful in calculating this type of coefficients.

The fourth group of coefficient comprises the technical-natural coefficients referring to the field III, that is those which cover the relations of inputs connected with natural resources and conditions that pass form the ecosystem to the socio-economic system.

A number of methodological difficulties will certainly result from both the diversity of the feedbacks and from the character of the coefficients themselves (their diversity and indirectness). In theory, these coefficients provide no considerable difficulties; it may be said that some of them (field II) are of a more stable character than those of field I, though at the present stage of research we may still lack adequate foundations for their relevant estimation. But fundamental difficulties will arise in case of attempting to construct a table of flows in terms of value, specifically in monetary terms. It will be necessary to estimate the monetary value of ecological goods, which have so far been regarded as free goods. This problem demands separate discussion. The initial stage in the construction of the extended input–output table should consist in building a system of natural units, and it is only the interpretation of results that can be expressed in value terms.

The attempts to analyse certain relations between the socio-economic system and the ecosystem made so far as well as the results at hand suggest that the practical application of the input-output model within the system "man–environment" should be restricted to studying a relatively simple region (ecosystem) with the predominance of certain relations, e.g., the industrial system–water economy (ecosystem).

The reductive and destructive impact of economic activity on the structure of ecosystems and on the equilibrium of the "man–nature" system lead to a deterioration of the quality of environment to the extent that eventually adverse economic and ecological effects for man himself are produced. As seen from the angle of economic activity, these adverse effects are due to the side-effects of production, which — though incidental to the purpose of that activity — by deteriorating the environmental conditions may essentially affect the economic life and man's health (cf. O. C. Herfindahl, A. V. Kneese [8]).

Although we have a relatively good knowledge of the processes leading to the degradation of the quality of the environment, no theoretical foundations for the economic analysis of the impact of the secondary effects of economic activity are at hand. With reference to the economic units this impact concerns the processes of production and conservation. With reference to human individuals it is a direct impact in that it affects their health. Moreover, it brings in consequence a deterioration of the landscape values and thus encroaches on the sphere of satisfying the needs of individuals. But these two elements of the impact are mutually dependent, for they express the impact of environmental conditions on man's psychophysical and economic situation.

The theoretical foundation for the economic analysis of the impact of the side-effects of economic activity must be sought in the system of mutual relations of the economy whose simplified model is the input–output analysis. In addition to the basic system of interrelations expressed in the form of flows of commodities and services, it is necessary to study the system produced by side-effects of economic activity and manifesting itself in the adverse changes in the environmental conditions. For instance, a growth in the output of starchworks which increases their profitability may at the same time add to the volume of detrimental sewage which in turn may encumber the production conditions of other plants, if only by increasing their outlays on water purification. These sewage wastes may moreover have a direct negative effect on human health and may disturb the equilibrium of the water biocoenoses (fishing). This example illustrates the emergence of many secondary relations in the course of economic activity, and the economic effect of these relations has no immediate connection with the system of primary relations (i.e. the input–output flows), and the development of the relations as well as their adverse effect on the other economic units and human individuals is no proportion to the advantages gained by the economic unit responsible for the activity in question. Thus, starchworks which refuse to purify their sewage diminish their production cost and increase profit but, by the same, the transfer of these costs to other economic units or human individuals who happen not to be consumers of starch. Transferring the costs to other units is a factor distoring the adequate economic calculation of the economic units. From the standpoint of both the economy and the society, a specific trait of the side-effects is that they distort the economic calculation based on a system of costs and prices. Consequently, the side-effects of economic activity affect the equilibrium of the system of costs. In this connection it must be observed that in adequate economic calculation it is primarily imperative to charge the producer of the side-effect with the costs of preventing the degradation of environment; a more complex problem is the economic calculation of neutralizing the detrimental changes in the environment also from the standpoint of health and aesthetic criteria as well as of restoring a high quality of environment (cf. Z. Chojnicki [4]).

To be effective, the principle of preserving a high quality of environment — both for the benefit of long-term developments in production and of the ecology of man himself — must be supported not only by a relevant system of legal acts but also by an adequate economic calculation incorporated in the country's economic life. Whether or not a progress will be made in this respect depends on overcoming the difficulties involved in the formulation and

implementation of the principles of such a calculation and on establishing a socially based hierarchy of values concerning the present and the future needs in the utilization of the geographic environment of high ecological quality.

Adam Mickiewicz University, Poznań

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