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Tomasz OSSOWICZ*

THE MODEL OF EQUILIBRIUM BETWEEN ECONOMIC DEVELOPMENT AND STATE OF ENVIRONMENT

Abstract: The concept of a model which allows generating states of equilibrium between the economic development and requirements of environment protection in regions is presented. It consists of three modules connected together by feedback links.

The model is an aid in testing, optimizating and evaluating strategy development for the region in its social, economic, spatial and environmental aspects. It is able to forecast evolution of socio-economic systems for alternative environmental policies and various consumption structures.

Key words: environment protection, input-output analysis, economic modelling, socio-economic development.

1. INTRODUCTION

When we say that we support the proecological development we are often not aware of what this idea really means, particularly what it means for everyday life. When we buy any good or service we usually do not know how and where our decision affects the environment. We select better, more useful and cheaper things, but not more safe for environment. The typical consumer does not know about the long and complicated technological chains which figure is his consumption.

The purpose of the model proposed here is to simulate a series of spatial, technological, and economic selections which start from consumer selections and finally affect the environment characteristics of the assumed model of consumption. These three kinds of selections considered as elements of proecological policies need some comments:

* Department of Spatial Planning, Faculty of Architecture, Technical University of Wrocław, Poland.

A. Economic selection. It is considered as cost minimization while the effect to achieve is fixed or utility maximization while the cost is fixed. Economic selection is connected with the state of the environment only when prices and measures of utility contain components depending on changes in the environment. Only in this situation has the consumer information about how his selection influences the environment.

B. Technological selection. Technology is considered here as a set of inputs necessary to attain the required output. The inputs are tools, buildings, rough materials, employees etc. We can select technology if it is possible to attain outputs accepted as completely substitutive by means of different technologies. The selection of technology is crucial for the state of the environment.

C. Spatial selection. The effect of spatial selections is the allocation of activities in space, and as a consequence spatial distribution of contacts (cooperative links) and conflicts (pollution, noxiousness) between them.

2. THE CONCEPT OF THE MODEL

The idea of the construction of the model is to introduce mechanisms which simulate selections described above into the classic framework of the input-output model. A first step in this direction is to make possible technological selections.

In the input-output model the technology of production of a given output *A* can be defined as a column of input-output coefficients. This definition implies that each alternative technology *Tn* of production of output *A* should be represented by a separate column, as it is shown on the figure 1. As an effect of this method of analysis is the output *A* which is practically represented by *n* categories *An, A2, ..., An*. The same *n* categories (representing one type of product) considered as inputs should have *n* rows in the matrix. Consequently output *B* which needs input *A* should be represented by infinite number of columns *B1, B2, .., B*∞ differing in combination of coefficients in rows corresponding to categories *A1, A2, ..., An*. From this moment it is clear that a different, more sophisticated approach is necessary.

It is assumed in the proposed model that one column in the input-output matrix represents the set of alternative technologies of production of a given output. The column corresponds to one technology only if it does not contain inputs which can substitute for one another. It is for example the column for output *B* on the figure 2.

The column corresponds to more than one technology if it contains inputs which can substitute one another. Mutually substitutive inputs have common input-output coefficients. It is the column for output *A* in figure 2. Here are two groups of mutually substitutive inputs. The first one contains: *B* and *C*; the second: *D, E*, and *F*. This approach creates a better basis for the selection of technology.

The second step is to make spatial selection possible. It is assumed in the model that each category of input or output – good or service – is produced by the activity allocated in the region or city divided into zones.

Out→ In↓	*A1*	*A2*	....	*An*	*B1*	*B2*	....	*B∝*	
A1					▦	▦		▦	
A2					▦	▦		▦	
....									
An					▦	▦		▦	
B1	▦								
B2	▦								
....									
B∝	▦								
C		▦		▦					
D	▦				▦	▦		▦	
E		▦							
F				▦					

Fig. 1. The input-output matrix in which a column is defined as one technology

Out→ In↓	A	B	
A		▦	
B	▦ ┐		
C	▦ ┘	▦	
D	▦ ┐		
E	▦ ┤	▦	
F	▦ ┘		

] common input-output coefficient

Fig. 2. The input-output matrix if a column is defined as a set of technologies

The third step is to connect changes in the environment with economic selections. The model simulates how each activity allocated in space influences the state of the environment and how pollution caused by them affects other activities. The losses caused by each activity are calculated and taken into account in the process of selections. The term pollution is understood here widely and denotes all kinds of negative effects which can be induced by activities.

The final step is to choose the model of selection. Here the model of intervening opportunities is used to simulate the process of selection, while physical space measured by costs of transportation used in the classic implementation of this model is replaced by economic space measured by more generalized costs. These costs include costs of production or functioning, costs of transportation, costs of losses caused by pollution or alternatively costs necessary to reduce pollution.

3. STRUCTURE OF THE MODEL

3.1. General structure of the model

The model consists of three modules connected together by feedback type links. These are modules: COST, ALLOCATION/SELECTION, and POLLUTION (cf. figure 3). From first letters of the module names the model is called CASP.

At first the module COST calculates the unit costs (prices) of each category of good or service produced by activities separately for each zone. These costs, called here complex cost, have to be paid by activities which demand the goods and/or services for production and/or consumption. The calculated cost includes:

– cost of production as a sum of costs of inputs necessary to produce output and selected by ALLOCATION/SELECTION module;

– cost of land calculated according to current demand/supply relation in the land market;

– cost of conflicts being due to losses caused by pollution simulated by the POLLUTION module;

– cost of transportation depending on distance and kind of goods to be delivered;

– gain from quality, that is the reduction in cost due to additional qualities of the good or service offered in a given zone and which are gained by the buyer.

When increasing demand for any good or service meets the upper limit of production the cost increment is proportional to the demand/supply ratio.

The module ALLOCATION/SELECTION simulates co-operative links between concentrations of activities in zones. Each activity located in each zone selects the suppliers of demanded inputs. The size of demand is determined by input-output coefficients. The process of selections is simulated by means of the intervening opportunities model while the complex costs calculated by the COST module replace distances used in the classical implementation of this model. Each type of selection is controlled by the parameter of selectivity reflecting the level of requirements or fastidiousness of a given activity in the process of selection. A large review of models constructed on the basis of the intervening opportunities model as well as considerations on parameter of selectivity can be found in BAGIŃSKI and ZIPSER (eds), (1990).

As consequences of the cooperative network obtained are:

– sets of inputs selected by each activity in each zone which is the basis for the calculation of cost of production

– flows of trips of persons and/or goods between activities within the region;

– allocation of activities in space;

– global quantities of activities.

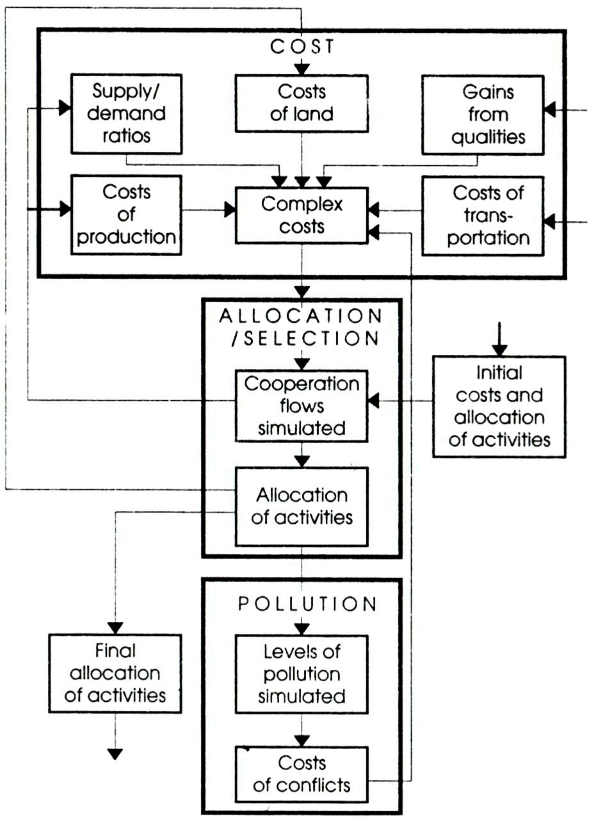

Fig. 3. The general structure of the model CASP

It is important to note that the activity can select between mutually substitutive inputs produced by different activity-suppliers. It makes the model a little Darwinistic in character. Activities which offer too expensive goods or services may little by little disappear. Activities producing cheaper goods or services develop. If it is assumed that the cost of conflicts is a substantial part of the complex cost, mainly activities friendly to each other and friendly to the environment would have a chance of survival.

The module POLLUTION at first simulates the spread of harmful agents emitted by some activities. It can be noise, air or water pollution, waste or any other negative effects. Then the cost due to losses sustained by the environment and sensitive activities are calculated. One part of these losses charges activities causing pollution, and second charges activities which sustained losses. The first part is considered as a penalty, second one as a cost of mistaken location. The last can be interpreted as being paid from public money. The shares of both categories of cost depend on assumed environmental policies.

The processing starts from the initial allocation of activities and initial costs, and is performed in an iterative way until a state of equilibrium is attained.

Next the formulation of modules is presented.

3.2. Module COST

Complex cost c_{ijn} of good or service produced by activity n (called here also good or service category n) in zone i is given by:

$$c_{ijn} = z_{jn}\left(c_{jn}^{p} + c_{j}^{p} + \frac{c_{j}^{L}}{\omega_{jn}} + c_{jn}^{F}\right) + c_{ijn}^{T} + D_{jn}$$

where:

c_{ijn}^{T} – cost of transportation of goods and/or persons necessary to attain a unit of good or service n produced in zone i, and used in zone j;

D_{jn} – gain from qualities of a unit of good or service n produced in zone j;

c_{jn}^{F} – cost of conflicts charged on a unit of good or service n produced in zone j, and calculated by the POLLUTION module;

c_{jn}^{P} – cost of production of unit of good or service n in zone j; it is calculated by:

$$c_{jn}^{p} = \frac{1}{a_{jn}} \sum_{s} \sum_{l} \sum_{k} \left(c_{ljk}\, v_{lkjn}^{s}\right)$$

a_{jn} is a quantity of activity n (or of production of good or service n) in zone j, and v^s_{lkjn} is flow of category l produced in zone k to zone j, where it is used in the production of good or service n determined in the selection process of type s; both variables are calculated by the ALLOCATION/SELECTION module;

ω_{jn} – maximal density of activity n in zone j, which can be allowed;

c^L_j – price of land for in zone j modified in subsequent iterations according to the current demand/supply ratio by the formula:

$$c_j^{Lb} = c_j^{Lb-1} \frac{\sum_k \frac{a_{jk}}{\omega_{jk}}}{P_j}$$

where P_j is capacity of land for in zone j and b is number of iteration; this element is similar to the formulation of floorspace and land market in Echenique's MEP model (WEBSTER et al., 1988, pp. 67, 483–488);

z_{jn} – demand/supply ratio for good or service n in zone j if an upper limit of its production M_{jn} is assumed; it is given by:

$$\text{if} \quad a_{jn} \le M_{jn} \quad \text{then} \quad z_{jn} = 1$$

$$\text{if} \quad a_{jn} > M_{jn} \quad \text{then} \quad z_{jn} = \frac{a_{jn}}{M_{jn}}$$

3.3. Module ALLOCATION/SELECTION

Here each activity located in each zone selects suppliers of the demanded inputs. Goods and services being demanded inputs are divided into groups which contain ones being mutually substitutive. For each activity looking for an input from a given group the selection process is simulated separately.

All concentrations of activities being suppliers are sorted into ranges by the complex cost of goods or services produced by them. According to the mechanism of intervening opportunities model used here the process of selection is performed subsequently from the range of the cheapest opportunities to the range of the most expensive ones. The chance of acceptance of opportunities from the given range diminishes while the number of opportunities considered before increases.

The implemented formula is as follows:

$$v^s_{jnlk} = a_n \alpha^s_{kn} \left[exp\left(-p_s \sum_{z=1}^{t-1} M^z_{sj} \right) - exp\left(-p_s \sum_{z=1}^{t} M^z_{sj} \right) \right] \frac{a_{lk}}{M^t_{sj}}$$

where:

α^{s}_{kn} – input-output coefficient determining demand of activity n for goods or service k or substitutive to them used in selection process s;

p_s – parameter of selectivity for selection process s;

M^{z}_{sj} – a sum of quantities of concentrations of activities producing the goods or services mutually substitutive which are being selected within selection process of type s and the complex cost of usage them in zone j is located in range z;

t – number of complex cost range for which the process of selection is performed.

The effects of these calculations are the new modified allocation of activities and global quantities of activities.

$$a_{lk} = \sum_{s}\sum_{j}\sum_{n} v^{s}_{jnlk}$$

The quantity of transportation activity type c in zone j - a^{T}_{jc} is calculated differently, from half of the flows from the zone and half of the flows to the zone. It is given by:

$$a^{T}_{jc} = \sum_{s}\left[\sum_{n}\sum_{l}\sum_{k}\left(0.5\theta_{nc} v^{s}_{jnlk} c^{T}_{jnl}\right) + \sum_{i}\sum_{m}\sum_{n}\left(0.5\theta_{nc} v^{s}_{imjn} c^{T}_{ijm}\right)\right]$$

where θ_{nc} is coefficient calculating demand for transportation activity type c necessary to attain good or service n from the cost of transportation.

Then, for each activity k its global quantity A_k can be calculated:

$$A_k = \sum_{j} a_{jk} \qquad A^{T}_{c} = \sum_{j} a^{T}_{jc}$$

3.4. Module POLLUTION

At first the spread of a harmful agent emitted by some activities is simulated. The increment of pollution f (e.g. air pollution, noise, wastes) in zone j caused by activity m located in zone i is:

$$h^{f}_{mij} = a_{mn}\,\beta^{f}_{m} E^{f}_{m}\left(d_{ij}\right) \qquad \text{so} \qquad H^{f}_{j} = \sum_{m}\sum_{i} h^{f}_{mij}$$

is the level of pollution f in zone j, where β^{f}_{m} is the noxiousness of the agent f caused by activity m. E^{f}_{m} determines spread of a harmful agent as a function of distance d_{ij} measured in the environment of spread.

Then two categories of cost are calculated. The penalty cost paid by activity *n* in zone *j* causing hazard *f* is given by:

$$c_{mi}^{FB} = \sum_f F_f \left[\sum_j \left[\frac{h_{mij}}{H_j^f} \sum_n \left[a_{jn} G_i^f \left(H_j^f \right) \right] \right] \right]$$

where G_{nf} denotes losses of unit of activity *n* as a function of level of pollution *f* in zone *j*. F_f determined the share of losses which has to be covered by activity causing pollution. The cost which charges the activity *n* in zone *j* sensitive to hazard *f* is:

$$c_{jn}^{FA} = \sum_f F_f \left[a_{jn} G_{nf} \left(H_j^f \right) \right]$$

Finally the cost of conflicts is attained: $c_{jn}^{F} = c_{jn}^{FA} + c_{jn}^{FB}$

4. IMPLEMENTATION OF THE MODEL

The important feature of the presented model is its ability to select between alternative ways of satisfying the same set of needs. Therefore it can forecast more than the proportions between activities, while the relations connecting them together are established as the classical input-output model does. The Darwinistic character of some elements of the model makes it able to simulate changes in this relation, and as a consequence to simulate evolution of the system where only the 'fittest' survives.

It is planned to implement the proposed model practically on the regional scale. The questions which can be researched with its aid are as follows:

1. How changes of proportions in the model of consumption affect the structure of the socio-economic system and how they affect the state of the environment. This question is specially important today when societies are facing the task of finding in a socio-economic system patterns friendly to the environment.

2. What changes in that structure of the socio-economic system are required to make it less conflicting. What sectors should be restructured if the minimum cost solution is being looked for.

3. Which actions in the field of environment protection are the most efficient.

4. The qualities of environment can be considered as a good being consumed. This assumption returns to the 'philosophy' of environmental protection. According to it the environment is no longer opposed to the

anthropogenic systems. Now it is assumed to be the product demanded by human activity. The proposed model can be used to research probable consequences of such a conversion of the viewpoint.

5. How policies of high penalties which have to be paid by causing pollution affect the economy. Particularly whether 'polluters' could survive paying penalty cost or investing in modifications in technology.

6. What approach in environmental planning is more efficient: to improve technology in order to limit pollution or to keep distance between activities causing pollution and ones being sensitive. This dilemma occurs in Cracow where the area of potential development well connected with the rest of the city lies between the historical center and the great plant causing pollution. If new housing is developed there it will be a hazard. But if this area is left empty the pressure to improve technology used in the plant will not be strong enough.

7. How environmental policies affect the level of unemployment.

8. How various sets of environmental policies and/or assumed models of consumption influence the pattern of spatial allocation of activities.

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