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AGENT-ORIENTED MODELING OF MACROECONOMIC SYSTEMS

Formal representations of separate components of the economic system are considered, which is regarded as the interaction of economic agents of various types. The need to introduce mechanisms for coordinating the activities of economic agents in the process of their interaction is formulated.

According to generally accepted ideas, the economic agent has (or may have) a certain independence in the choice of the mode of his functioning (his state). In this case, the agent is "immersed" in an environment external for him, which arises as a result of the activities of other agents [1]. Within the framework of this approach, there arises the problem of choosing a mechanism for coordinating the joint functioning of the agent and the environment, which is reduced to the coordination of a multitude of agents - elements of the economic system. As a prerequisite for their joint functioning, material and (or) financial balance occurs, since the main activity of economic agents is the release (production) and expenditure (consumption) of material goods that are transferred to the environment and, accordingly, are withdrawn from it; "environment" is formed by the rest of the participants in the system. To avoid the situation of inconsistency of actions, mechanisms of coordinated functioning of the agent and the environment are necessary, or, which is the same thing, coordinating the activities of agents among themselves. Such mechanisms should be considered as economic mechanisms for coordination of agents.

Under the economic agent, depending on the degree of aggregation, we mean a person, a group of people, an enterprise, an industry, a region, and so on. When describing the agent, we will be mainly interested in those characteristics of the agent that can be used to study its interaction with other agents. In this case, the internal and external descriptions of the agent are possible. The first one specifies the objective function, the system of preferences, the system for assessing the effectiveness of technological regimes. The second – the reaction of the agent to the external environment. In both cases, a set of potentially available states (a set of admissible alternatives) is assumed to be known.

The result of the activity of an economic agent is the transformation of goods, or products, and the term product is understood quite widely. It contains, in particular, products in the traditional understanding of this word – production assets, consumer goods, natural resources, etc., services, various types of labor. With respect to these products, it is always assumed that they are "infinitely divisible" and "individual": the quantity of the product consumed by one agent can not be consumed simultaneously by another. An alternative product is an information product.

According to [2], it is assumed that in the system circulates $n=|N|$ products among $m=|M|$ agents. Each agent i consumes and (or) produces products from a set N. In accordance with this, two sets are distinguished: X^i and Y^i – in the space of product sets R^n.

The set X^i is interpreted as a consumer set – available consumer sets of (quantities) of products – vectors $x^i = \left(x_1^i, \ldots, x_j^i, \ldots, x_n^i\right) \in X^i$, where x_j^i – the quantity of product j, available to consumer i. As a rule, it is considered that $X^i \subseteq R^n$, ie $x^i \geq 0$. The latter condition may not be available. Then negative coordinates are treated as "given" products, and positive ones - as "purchased" in appropriate volumes.

Production activities can be described in one of two ways: in the variant with flows and variant with stocks. If you use the variant with flows, then the difference in production and consumption by the agent is fixed.

Like the consumer set, the technological set is determined $Y^i \subseteq R^n$: vector $y^i = \left(y_1^i, \ldots, y_j^i, \ldots, y_n^i\right) \in Y^i$ is interpreted as a technological method (technological regime). In this case, vector y^i consists of components $y_j^i \left(j = 1, \ldots, n\right)$, where $y_j^i \geq 0$, if product j produced in this way, and $y_j^i < 0$, if it is consumed in the same way, in quantity $\left|y_j^i\right|$.

The state of agent i is the vector $z^i = \left(x^i, y^i\right) \in Z^i \subseteq \left(X^i \times Y^i\right)$, also referred to as a locally acceptable state for the agent i (that is, permissible from the point of view of an individual agent). Aggregate vector $z = \left(z^i\right)_{i=1,\ldots,m}$ represents the state of the system as a whole (it is composed of sub-vectors $z^i, \quad i \in M$, states of individual elements of the system). The state of the system as a whole is locally permissible (for the system), if

$$z \in \prod_{i=1}^{n} Z^i = Z . \qquad (1)$$

Among all the set of locally admissible states, it is necessary to select a subset of states that would be globally admissible in the sense that the total consumption (costs) in the system did not exceed the total production (it is assumed that the system is closed). This condition is very weak - it allows that some of the products are not used; it also does not take into account what are the actual releases and costs in the system.

We say that the state of the system is globally permissible (in a weak form), if

$$\sum_{i=1}^{m} x^i \le \sum_{i=1}^{m} y^i \qquad (2)$$

This ratio means that the total consumption can be satisfied with the total release of all agents. In other words, this means that aggregate demand does not exceed the aggregate supply; however, not all produced products can be used.

The conditions for local and global admissibility are necessary conditions for the functioning of the economic system.

For each state *z* of the whole system is put in correspondence the set of $P^i(z)$ states, that are presented for the agent *i* as more preferred than *z*. The set $P^i(z)$ is the image of a vector *z* for a point-multiple mapping Z ® Z. In the future, this display of preference will be convenient for to denote as $P^i(z)$. Most often we will assume that the mapping $P^i(z)$ is determined by means of some numerical function $u^i : Z \to R^1$ in the following way:

$$P^i(z) = \{z' : z' \in Z, \quad u^i(z') > u^i(z)\} \qquad (3)$$

Function $u^i(z)$ is called a utility function, and the number $u^i = u^i(z)$ shows the value of utility, received by agent *i* in state *z*. It should be noted that the same preference display can be specified using different utility functions.

In the particular case, the preference displey P^i, as well as utility function u^i, can only depend on the state of $z^i = (x^i, y^i) \in Z^i$ this agent (and not the state of the whole system), i.e.

$$P^i(z) = \widetilde{P}^i(z^i), \quad u^i(z) = \widetilde{u}^i(z^i),$$

where z′ – subvector for vector z, corresponding to agent *i*.

We assume that the agents are initially active, i.e. that the function of any agent consists in choosing his state from a certain set of states available to him. At the same time, he behaves rationally, trying to choose the best possible state. In this case, the state $z^{*i} \in Z^i$, which is the solution of the task

$$u^i(z^i) \to \max, \quad z^i \in Z^i . \qquad (5)$$

where Z^i – the set of locally admissible states for the agent *i*, can be called absolutely optimal. The aggregate of such states $Z^* = (Z^{*i})_{i=1}^{n}$ It is a locally acceptable state of the system, but it not always a globally admissible state, i.e. in fact, in such a state, the system can not function! The latter circumstance forces us to introduce some other ways of ensuring the coordination of the economic agents functioning – mechanisms of coordination (economic mechanisms). The task of these mechanisms is, in particular, to ensure global admissibility of the state of the system, while preserving – to some extent – the rational choice of states by their agents. Accounting for agent activity, i.e. taking into account its interests as opposed to its strict enforcement, is an indispensable condition for the analysis of economic systems, in difference to technical ones.

The operation of the coordination mechanisms may be different. In accordance with this, there are two types of coordination mechanisms, which in some cases pass into each other. The first type is the distortion of the set of admissible states for the agent. As a rule, this is a "truncation" of the set of admissible states Z^i, ie replacing it with a set $\hat{Z}^i$:

$$\hat{Z}^i \subset Z^i . \qquad (6)$$

In this case, in accordance with the rationality hypothesis, the agent chooses his state as the solution of an extremal task of the form

$$u^i(z^i) \to \max, \quad z^i \in \hat{Z}^i . \qquad (1.7)$$

The second type is the distortion of the utility function (pre-reverence mapping).

The first type includes such activities as the introduction of budgetary (financial) restrictions, in-kind restrictions (quotas, limits), the issuance of directives on the volume of consumption and production, etc. The second type includes such measures as the change of prices (if the utility function depends on them), some forms of donations, and, to some extent, promotional activities.

The described formalisms make it possible to construct mechanisms for coordinating economic agents both in statics and in dynamics in the process of production, consumption and exchange of products.

References

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