Universal Coordination Instrument of Economic Individuals

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26 January 2022

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2024.02.26

Abstract: This study explores the micro-level of making economic decisions, focusing on processes and causal relationships using which individuals (agents) take into account each other's activities. A central concept employed herein is the Shared Mental Model (SMM) used by participants of joint activity to collect and process information dispersed between them that is essential for their decision-making. The abilities of agents to develop SMMs is examined through three primary modes of communication – direct, indirect, and previous. Based upon these insights, the Universal Coordination Instrument (UCI) was proposed, inherent in all economic individuals. Agents utilize their UCIs via a combined individual-collective approach to accommodate each other's activities. The UCI structure is defined as a specialized agent-based simulation model, which is an environment for agents for their information interactions and consists of "interface" and "computational" blocks. These blocks are configured for each type of joint activity of agents in solving by agents some optimization problem. The results obtained are an extension of microeconomic theory, describing how agents can redefine all conditions for maximizing their objective functions, including the content of the function itself, to best take into account each other's intentions and capabilities, as well as in response to critical disturbances. The key findings of this study are that individuals engage in two types of rational behavior that lead to two types of equilibrium in the economic system. This allows the system to operate efficiently under substantive disequilibrium. In a face of unavoidable disturbances, a rational economic order consists of restoring equilibrium in economic systems as efficiently as possible in response to disturbances. As a potential outcome, the UCI can be implemented as a computer system to facilitate the efficient re-coordination of economic activities and restore equilibrium.

Keywords: microeconomic theory; economic system; instability of preferences; procedural rationality; coordination equilibrium

JEL: D01, D02, D23, D47, D50, D70, D8, D91, O12

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1. Introduction

Advances in cognitive science in recent decades allow us to return to the consideration of an important problem for economic theory, which Hayek formulated many years ago as follows:

> "The peculiar character of the problem of a rational economic order is determined precisely by the fact that the knowledge of the circumstances of which we must make use never exists in concentrated or integrated form but solely as the dispersed bits of incomplete and frequently contradictory knowledge which all the separate individuals possess. The economic problem of society is … a problem of the utilization of knowledge which is not given to anyone in its totality" (Hayek, 1945, p. 1).

Using knowledge that is initially distributed among individuals (agents) who are participants in a joint activity (Klein et al., 2005) makes it possible to discover and take into account factors important for joint activity. The importance of these factors is given by the fact that they can increase the amount of benefit received by agents from their activities. Let us accept the obvious assumption: the more fully agents take into account the factors important for their joint activity, the higher the probability that they will receive greater benefits from this activity.

The actual benefit, in addition to the completeness of taking into account the important factors, also depends on the computational capabilities of agents to process all available information and take it into account in full in the process of determining the content of their activities. Computational aspects of economic decision making have been studied in economic theory from various angles. For example, as the analysis of the economic effect of the limited cognitive abilities of individuals (Simon, 1978), the development of the ideas of limited rationality as a cognitive prerequisite (Williamson, 1985) and many others.

Based on this, let us generalize the previous assumption: the amount of benefit received by agents from their joint activities depends both on the completeness of accounting for distributed knowledge, and on the current capabilities of agents to process and analyze the information obtained as a result of the integration of distributed knowledge.

Traditional economic theory proposes a selection of organizational forms (Williamson, 1993) or a choice between discrete alternative structures (Simon, 1993) as a way to increase benefits in conditions of limited cognitive and computational capabilities of agents. In the mechanism design theory, Hurwitz uses the concept of a "Walrasian auctioneer" to discuss

the problem of integrating distributed knowledge (Hurwicz, 1973). The cognitive science allows one to consider the problem of collecting, analyzing and using information distributed between agents, including resolving situations with incomplete and contradictory information, as the functioning of mental models existing in the minds of individuals (Craik, 1967; Jonker, et al., 2011). This approach, in comparison with traditional analysis that operates on organizational forms or discrete alternative structures, is micro-level. It allows us to consider the problem of using distributed knowledge to benefit from joint activities at the level of individuals as their use of their natural abilities to take into account each other's activities using various options for communicating with each other (Parinov, 2023a; 2023b; 2023c).

As a result of information exchange between agents, their individual mental models become to a certain extent shared and collective (Johnson-Laird, 1980; Mantzavinos et al., 2004; Badke-Schaub et al., 2007). In this study, shared (collective) mental model (SMM) are considered as a tool for mutual consideration by agents of each other's activities. SMM is formed in the minds of agents based on their individual mental models as a result of communications between them and allows agents to use the knowledge distributed between them. SMM represents the common ground (Klein et al., 2005) where participants share knowledge, beliefs, assumptions, expectations, and goals about a particular joint activity. "The expansion of mental models research from an individual to a collective focus stems from a growing recognition that there is a social component to cognition at the individual level, and that decision making occurs at a range of scales from an individual to group to societal level" (Jones et al., 2011, p. 5).

The use of communications, as well as the computing and analytical capabilities of the SMM, for the purpose of mutual consideration by participants in joint activities of each other's capabilities and intentions is considered in this study as a process of coordinating their joint activities. Thus, coordination is understood as mutual consideration by agents of each other's activities, which can take different forms depending on the communication options used by the agents. In this case, the degree of completeness and parameters of taking into account distributed information important for joint activities are characteristics of coordination. Thus, the characteristics of coordination influence the size of the benefits of participants in joint activities. Improving coordination characteristics both through proper settings of communications between participants and improving the configuration of the SMM used by them is a source for agents to obtain additional benefits from their joint activities.

With such assumptions and clarifications, Hayek's formulation of the economic problem of society can be detailed both in terms of describing the context in which the problem exists and in terms of the content of the problem itself. From the point of view of modern interdisciplinary scientific concepts about the mental models of agents and possible options for communication between them, the problem exists in the following context.

A significant part of the knowledge about the factors that are important for the joint activity of agents is in the minds of each of the participants in the joint activity. This knowledge of agents is dynamically updated and replenished. Participants in joint activities get the opportunity to use this knowledge, which is "not given to anyone in its totality", forming and constantly updating the SMM through various communications between themselves. Possible options for communications between agents include: 1) direct communications in the form of "face-to-face" communication between individuals; 2) indirect communications mediated by

changes in the common environment; and 3) previous communications to create SMM in advance for coordinating joint activities in the absence of current communications.

Since the SMM exists in the minds of agents and is an imaginary, but not a directly observable entity, it is necessary to find a convenient form of its representation for scientific analysis. The most obvious association of SMM is a distributed, collectively generated simulation model (Jones et al., 2011, p. 5), in which agents themselves represent and update their information images. Such a simulation model is also a common environment for agents for their information interactions. It contains all agents' ideas about parameters, conditions, restrictions, etc. that are important for their joint activities. Agents use the integrated in the SMM knowledge about the currently existing and expected conditions for joint activity to play (simulate) various options for their joint activities.

The use of SMM for simulating and analyzing activity options gives these actions a collective to certain extent character. With direct communications, collectiveness in the use of SMM allows agents to negotiate on the best content for their joint activities. With indirect communications, some collective characters of the SMM allows agents to determine the best activity content by trial and error or as the "tâtonnement" [1] process. Using a static SMM, created by previous communications, agents individually determine the best action content, assuming that all other participants act using the same SMM.

By such simulations in SMM agents assess the size of the expected individual benefit from their possible joint activities, as well as the individual value of the resources needed by each agent for their activities. Based on the size of the expected benefit, agents determine the best content of their joint activity and translate it into practical implementation.

The economic problem of society arising from this context of using knowledge, which is "not given to anyone in its totality", falls into two parts.

The first part of the problem is the optimal choice of: 1) communication settings between participants in joint activities, including the choice of the optimal combination of communication options; and 2) SMM configuration. A mutually agreed upon solution of these two choice problems provides agents with a method of coordination that, given existing restrictions, allows them to take into account with some completeness the factors important for their joint activities, information about which is distributed between them. The method for solving this problem of choice, the result of which is the creation of a method of coordination, is called "metacoordination" (Parinov, 2023c). Metacoordination allows agents to determine and construct methods of coordination that, under changing conditions for their joint activities, make it possible to find the best content of their joint activities in terms of the expected benefit with minimal costs.

The coordination method created in this way represents the communication settings and the configuration of the SMM, which determine the characteristics of coordination: a) the maximum possible degree of completeness of taking into account important factors, on which the size of the benefit depends, and b) the amount of coordination costs that reduce the total benefit of the agents. These coordination characteristics determine for a given joint activity the maximum upper limit of the expected benefit of the agents, the actual achievement of which depends on the solution of the second part of the problem.

[1] Walrasian tâtonnement. See, for example, explanation in (Hurwicz, Reiter, 2006).

The second part of the problem is the optimal application of the coordination method created by solving the first part of the problem. The problem here is to determine the best content for the agents' joint activities. Optimal use of the coordination method means that agents in the current conditions for their joint activities should find a content of the activity, the benefit from which will be as close as possible to the upper limit determined by the characteristics of coordination, and the costs of coordination will be minimal. However, approaching the upper bound increases the time spent on agents searching for better solutions and, therefore, as the search time increases, the costs increase, and the benefit is lower (Stigler, 1961). For this reason, agents may use acceptable rather than better solution for the activity content (Simon, 1978). The problem of optimal application of the coordination method also has a dynamic aspect associated with the need to support joint activities in a coordinated state in response to the flow of random changes in its conditions.

Thus, the modern solution to the economic problem of society, posed by Hayek, is: a) the optimal use by agents of metacoordination to create effective methods of coordination; and b) optimal use by participants of joint activities of the coordination methods created for different types of their joint activities. The result of metacoordination is a method of coordination with a certain upper threshold of the expected benefit of agents for a given type of their joint activity. The result of coordination is the receipt, using the created method, of actual benefit, the size of which is as close as possible to the upper threshold. In this context, a "coordination mechanism" in its traditional sense corresponds to a method of coordination that is used on an ongoing basis by many agents over a fairly long period of time.

To address these two parts of the problem, this study proposes the concept of a universal coordination instrument. The universal coordination instrument (UCI) is understood as the ability of each agent to take into account the activities of other participants in joint activities, by managing in a mixed individual-collective mode: a) the settings of communication with other participants; and b) the configuration and parameters of the SMM. Thus, choosing the optimal UCI settings is a way to solve the first part of the problem of using distributed knowledge. Using the UCI with settings to determine the content of joint activities that best takes into account each other's capabilities and intentions is a way to solve the second part of the problem. Universality of the coordination instrument is understood as the ability of agents to use this tool to coordinate joint activities of different types.

Certain ideas about both the SMM and the UCI in general are implicitly present in economic theory. For example, the "console" described by Hurwitz, which implements the actions of the resource allocation mechanism and guides agents in decision making, is a fairly accurate analogy of the SMM:

> "Simplifying to the utmost, we may imagine each agent having in front of him a console with one or more dials to set; the selection of dial settings by all agents determines uniquely the flow of goods and services (trade vector) between every pair of agents and also each agent's production (input-output vector), his "trade with nature." Not all dial settings are possible and some are possible only in conjunction with other dial settings. Thus the feasibility of a complex of actions (a specified combination of dial settings for all agents) can be split into individual feasibility and compatibility" (Hurwicz, 1973, p. 16).

If the idea of the console proposed by Hurwitz is considered in the same context in which the UCI is considered in this study, then it is necessary to additionally: a) determine how agents

create consoles for different types of their joint activities; and b) describe the design of the console, which allows agents to find the best content for their activities, taking into account the possible expected activities of other participants, including an assessment of the expected benefits from these activities. The proposed UCI concept provides answers to these questions more accurately than the Hurwitz console, and therefore is more adequate to the real processes of agents using distributed knowledge to account for each other's activities.

The key difference between this approach and the mainstream of traditional microeconomic theory is the hypothesis that individuals (agents) have a universal coordination instrument that has system-forming properties. By synchronizing the settings and parameters of their UCIs, agents are able to collectively use distributed knowledge to take into account each other's activities in order to obtain maximum benefit from their joint activities. As a result of these actions, interdependencies are formed between agents and connections are established that transform participants in joint activities into an economic system. Such systems are traditionally defined as some organizational or institutional structures. Thus, the approach based on the UCI concept creates a unified methodological basis for describing the principles of creation and features of the functioning of various methods and mechanisms of coordination, as well as different organizational and institutional forms of economic system.

For economic systems, if they are considered as a result of the participants' use of UCI in joint activities, three levels of sustainability can be distinguished. The UCI allows agents to maintain the effectiveness of joint activities and keep sustainability of the system if there is a loss of stability at some levels. For example, if the individual preferences of the participants are unstable, causing a loss of stability of the 1st level, the efficiency of the system is restored by re-coordination which provides the adaptation of the joint activity content to the changed conditions.

In the process of accounting and using distributed knowledge, participants in joint activities rationally choose the best solutions both to determine the optimal method of coordination and the optimal content of their activities. The substantive rationality of agents, which manifests itself in the choice of the content of joint activities, is complemented by the procedural rationality (Simon, 1993). The above-mentioned possibility of maintaining the efficiency of the economic system, when its stability is disrupted, means that agents have procedural rationality, which allows them to compensate for cases of weakening of substantive rationality.

The activity of agents with two types of rationality in the absence of disturbances leads to the emergence of two types of equilibrium in the economic system. The procedural rationality leads to coordination or procedural equilibrium as agents improve coordination characteristics. The substantive rationality leads to substantive equilibrium in selecting by agents the content of the joint activity, which, among other things, manifests itself as the equilibrium of supply and demand in the economic system.

The procedural rationality of agents means that they can maintain the stability of the system and restore both types of equilibrium in it. This opportunity allows one to study economic systems that are in a complex non-equilibrium state or far from equilibrium. Non-zero time spent by agents on implementing UCI functions creates the effect of wave propagation of disturbances in the economic system. The characteristics of disturbance waves influence the parameters of the (non)equilibrium in the system. Such an analysis allows one to study how

an economic system, which can be in varying degrees of disequilibrium, can maintain its efficiency.

Based on the concept of an individual with UCI, who has two types of rationality, the traditional description of the microeconomic problem of maximizing the objective function can be supplemented by: 1) a description of the causal relationships and procedures leading to the emergence of the economic system with certain features of joint activity participants; 2) a description of the principles of creating and using a tool which used by participants to maximize their objective functions. With this addition, agents in microeconomics can redefine all conditions for maximizing the objective function, including the content of the function itself, to best take into account each other's intentions and capabilities, as well as when critical disturbances occur. As such, the UCI concept is an extension of economic theory.

The main conclusion of this study: since disturbances in economic systems are objective and irremovable, a rational economic order in these conditions consists of restoring equilibrium in economic systems as efficiently as possible in response to emerging disturbances. This requires the creation of efficient methods of coordination that will allow the fastest possible restoration of balance in the content of agents' joint activities, as well as efficient mechanism of metacoordination that will ensure the improvement of coordination methods.

In this paper, the presentation of the obtained results is limited to a consideration of the abstract model of the UCI, a description of its settings and methods of functioning for different communication options. This corresponds to the conceptual elaboration of the structure of the UCI and its main functionality as a special agent-based simulation model. The next section discusses general ideas about the SMM of joint activities and communication options for agents, on the basis of which the concept of UCI, presented as a simulation model of a special type, is introduced. Section 3 discusses methods for forming UCIs for various communication options between agents. Section 4 provides a description of how the UCI performs its functions under various communication options. Section 5 discusses the methodological implications arising from the UCI concept. Section 6 provides a general description of the results obtained.

2. A universal coordination instrument for joint activities

Coordination as a phenomenon arises in the process of joint activity of agents (Klein et al., 2005)[2]. The object of coordination is the content of the activities of individual participants. In general, both the activities of people and the activities of artificial agents, for example, computer bots, can be coordinated. This study examines only the coordination of human activities. Therefore, below agents are understood as people carrying out joint socio-economic activities.

Coordinated joint activity occurs when participants have common intentions and communication capabilities (Cohen et al., 1997). Klein et al. also noted "The criteria for joint activity are that the parties intend to work together, and that their work is interdependent" (Klein et al., 2005, p. 6). Taking this into account, joint activity in this study includes situations where participants with common intentions can act based not on current, but on

[2] "Entering into a joint activity requires the participants to coordinate because at least some of their actions affect the goal-directed activities of others" (Klein et al., 2005, p. 5).

previous communications. In this case, the participants mutually assume that they all follow the common rules previously developed for relevant situations. Such situations, as a rule, arise when a joint activity regulates by an institutional structure with coordinating functions.

In (Klein et al., 2005), the concept of "common ground" was introduced to describe the conditions for the emergence of coordination in joint activities. "One of the key aspects of joint action is the process of sustaining common ground to enable coordination" (Klein et al., 2005, p. 37). The common ground occurs if for the participants in joint activities there are (Klein et al., 2005, p. 37):

1) compatibility of types of knowledge, beliefs and assumptions that are important for joint activities, including knowledge of roles and functions, standard routines, etc.;
2) a mechanism for carrying out the grounding process: to prepare, monitor and sustain, catch and repair breakdowns;
3) the basic compact, obliging the participants in the joint activity to constantly check and adjust the common ground.

The noted conditions for the emergence of coordinated joint activities are important, but not complete. The common intention of the parties to work together required for joint economic activity arises if agents expect to get benefit from joint activity that cannot be obtained individually. This opportunity to get more benefit creates motivation for agents to their joint activity.

This study considers only types of joint activities from which the amount of the agents' benefits depends on the characteristics of coordination. For example, the more completely and accurately an agent takes into account the capabilities, intentions and content of the activities of other agents in the process of coordination, the higher the probability of receiving greater benefits, and vice versa. Almost any economic activity meets this condition. If this condition is met, then agents are motivated to take into account the activities of other agents in the process of coordination in such a way that, other things being equal, they receive the maximum benefit from their activities. Then, the improving the coordination characteristics of joint activities can be a source of additional benefits for agents.

The characteristics of coordination, in turn, are determined by the completeness of taking into account important factors and depend, among other things, on the character of communications between agents participating in joint activities and on their ability to process information (Parinov, 2023b).

2.1. Shared mental model of participants in joint activity

Currently, in cognitive sciences, social psychology, and some other fields[3], the concept of mental models of participants in joint activities is actively developing. This concept generalizes and develops the above conditions for the emergence of coordination in joint activities. Among the approaches to the use of the concept of mental models in economic research, we can note the research that are closest to this study, in which mental models are discussed in the context of studying the behavior of agents under conditions of high uncertainty, learning, complexity of choice problems, institutions and ideology (Denzau & North, 1994; Mantzavinos et al., 2004).

[3] For example, in the multi-agent system research (Hindriks, Riemsdijk, 2009)

The mental model determines the agent's beliefs about the world and is used by him to make decisions (Craik, 1967; Jonker, et al., 2011). Mental models can be individual and shared (or collective) (Johnson-Laird, 1980; Jones et al., 2011). Researchers note that the concept of shared mental models (SMM) has been actively developing in recent years due to increased interest in studying the influence of group and social factors on individual decision making (Jones et al., 2011).

In the literature, SMMs are most often defined as “knowledge structures held by members of a team that enable them to form accurate explanations and expectations for the task, and, in turn, coordinate their actions and adapt their behavior to demands of the task and other team members” (Jonker, et al., 2011, p. 133). The description of the requirements for the SMM and its functions notes: “Shared mental models facilitate the team’s progression toward goal attainment by creating a framework that promotes common understanding and action” (Salas et al., 2005, P. 565).

Let us consider how the SMM is connected with the concept of “common grounds”, which, as noted above, is a necessary condition for coordinating joint activities,

Obviously, for SMM to arise, agents must have a compatibility of knowledge, beliefs and assumptions, which is one of the components of the common ground (Klein et al., 2005). If this is true, then there is a necessary commonality between the individual mental models of agents, based on which individual models with the help of communications can turn into SMM.

Communication and exchange of information between participants in joint activities lead to synchronization of the content of their individual mental models related to their joint activities. Thus, communications correspond to the second condition for the emergence of common ground listed in (Klein et al., 2005): a mechanism for carrying out the grounding process. As a result of communications, the participants in joint activities have the common ground, and the formation and regular updating of the SMM. It means that the concept of “common ground” is essentially identical to the concept of SMM.

The basic compact, as the third condition for the emergence of common ground (Klein et al., 2005), is created by agents' motivations to obtain more benefits from their activities through improved coordination. If the SMM is a tool for agents to obtain benefits, then the desire of agents to receive systematic benefits obliges the participants in joint activities, as prescribed by the basic compact (Klein et al., 2005), to constantly check and adjust the SMM.

Thus, the concept of “common ground”, as defined in (Klein et al., 2005), represents a necessary condition for the emergence of SMM as a tool for coordinating participants in joint activities. Using the SMM that in the minds of each individual agent, the information distributed among agents is collected with a certain completeness and accuracy. It creates necessary conditions for solving the economic problem of society regarding the use of knowledge, which “is not given to anyone in its totality” (Hayek, 1945, p. 1).

Traditionally, the concept of SMM is used to explain the functioning of teams (Jonker, et al., 2011) or small groups, whose members typically interact through direct communications with each other. The proposed study substantiates that agents can create and use SMM as a coordination tool using various communication options.

2.2. Communications between participants in joint activities

Communications between participants in joint activities play a key role in the formation of SMM. “Better communication links would lead to the evolution of linked individuals' mental models converging rather than diverging as they continue to learn directly from the world” (Denzau & North, 1994, p. 10).

Based on the most general ideas about socio-economic agents and the common environment of their joint activities, we will assume that the following main communication options can exist between agents:

1) direct communication, i.e. “face-to-face” communication between team and other small group members, in which coordination of their activities arises as a result of negotiations and agreements between participants;
2) indirect communication, i.e. mediated by changes in their common environment. For example, actions in the market, by which agents come to coordination as a result of tâtonnement for the best content of their activities through trial and error in the common environment;
3) previous communication, which allows agents to create static SMMs in advance to coordinate current joint activities without using communications. Coordination in this case occurs as a result of agents tâtonnement for the best activity content without current communications and without the direct influence of other participants. Such a static SMM may, for example, contain some common rules, institutions with coordinating functions, etc.

This study does not consider the option of a complete lack of communications (i.e., the absence of both current and previous communications), because under these conditions there is no systematic opportunity for agents to take into account each other's activities and, therefore, conscious and ongoing joint activity between agents cannot arise.

The above list of communication options is complete and exhaustive, because for any given participant in a joint activity, the methods of his communications with all other participants, regardless of their total number and individual characteristics, can only be from this list.

The use of the listed communication options by agents is accompanied by certain coordination costs, which reduce the amount of expected benefit from their joint activities. For example, agents, spending time on communication, lose a certain amount of benefit from their joint activities that they could create during this time. In this sense, coordination costs are close in content to the “transaction costs” concept (Coase, 1995; Williamson, 1985).

Different communication options are characterized by different levels of fixed and variable costs:

- Direct communications that allow agents to achieve maximum completeness of consideration of important factors. Fixed costs are determined by the costs of joining “face-to-face” communication between participants in joint activities. In many cases these costs are close to zero. Variable costs, on the contrary, are very high, because direct communication requires the agent to concentrate on the process of information exchange, the intensity of information exchange between agents can be high, analysis

of information to determine the content of the agent's activity may require significant efforts;

- Indirect communications that allow agents to consider the most important factors. Fixed costs are determined by the costs of creating a common communication environment for all participants and a specific signaling system through which they will exchange information. For example, the creation of market infrastructure, prices, money circulation, etc. Variable costs include the costs of using the signaling system, including monitoring and collecting information from the common environment, as well as analyzing the information received to determine the content of the activity.
- Previous communication, which allows agents to act in concert in the absence of current communications based on previously created SMMs. Fixed costs are created by the costs of development and acceptance by all participants of some static SMM. For example, this means creating common rules for groups of agents or institutional structures for the economy. Variable costs are created by the costs of using a static SMM to analyze the current conditions for an activity and determine the best content of the activity.

Based on general considerations, direct communication has the lowest fixed and highest variable costs compared to other options. Previous communication has the highest fixed and lowest variable costs. Indirect communication in terms of costs are between direct and previous.

As noted above, agents, to obtain greater benefits from joint activities, strive in the coordination process to more fully take into account important factors, information about which is distributed between them. This requires more communication between them, which increases coordination costs and reduces the actual amount of expected benefit. Thus, the magnitude of the benefits from joint activities and the magnitude of coordination costs are interdependent variables. Therefore, to obtain maximum benefit from joint activities through coordination, agents need to solve an optimization problem. To do this, it is necessary to determine the optimal combination of communication options and their settings, which for a given type of joint activity will give the optimal balance between, on the one hand, the completeness of taking into account important factors that determine the maximum amount of expected benefit, and on the other hand, the minimum amount of costs to achieve this completeness of accounting .

2.3. Universal coordination instrument

Each agent participates in many types of joint activities, which are performed both sequentially in time and simultaneously. Therefore, in the consciousness of each agent there simultaneously exist many SMMs corresponding to different types of their joint activities. Based on the assumption that the consciousness of a socio-economic agent is united, we can conclude that many different SMMs in the agent's consciousness represent a single mental system. Each agent can systematically generate and update many SMMs as a single mental system in the process of communications with other participants in each type of joint activity. In most cases, such a mental system arises and functions in the same way for different agents. To generalize, one can imagine that each agent has some instrument for coordinating their joint activities with other agents. This instrument is universal, because allows agents to coordinate joint activities of various types with each other.

Thus, the universal coordination instrument (UCI) represents the inherent ability of all agents to collectively construct a coordination method for a given type of joint activity, by selecting communication options and a SMM configuration, which provides the agents, ceteris paribus, with the maximum benefit from their joint activities. This instrument, on the one hand, is individual, because with its help, each participant in joint activities independently determines the content of their individual activities. Excluding hierarchically organized joint activities, in which some agents delegated the right to determine the content of their activities to managers (Parinov, 2023a, p. 5[4]). On the other hand, this instrument is collective, because other agents participate in some way in making decisions about the content of an individual agent's activity.

Based on the previous discussion, agents must carry out the following actions in the UCI to establish and maintain coordination over time (Parinov, 2023b):

1) formation and updating of the content of the SMM using all communication options;
2) playing (simulating) in the SMM various content of possible activities, taking into account the expected activities of other agents, including obtaining individual estimates of the expected benefits and the value of the resources needed by the agent for their activities;
3) negotiation or tâtonnement for the joint activity content, and selection of the best version;
4) translation of the best version of the activity content into practical implementation, including fixation of responsibility for its implementation;
5) maintaining joint activity in a coordinated state in response to disturbances.

Thus, the use of UCI by agents participating in joint activities to achieve and maintain coordination begins with the formation of the SMM (action 1 in the list above) by using three basic communication options. Based on the created SMM, agents perform analysis and mental playback (simulation) of their action content (action 2). If there are sufficient computing capabilities (Parinov, 2023b, p. 11[5]; Parinov, 2023c, p. 14), the agents find a mutually acceptable content of their joint activity (action 3). For the chosen activity content, agents in a certain form fix responsibility for its implementation and start its practical implementation (action 4). Repeating the listed actions ensures the maintenance of coordination (action 5), in response to unpredictable changes in the conditions for activity, which devalue decisions previously made by agents. This sequence of actions 1-5 allows participants in joint activities to take into account the intentions and capabilities of other participants, and under certain conditions leads to the emergence of coordination between them.

The selection and configuration of communication options by which agents fill the SMM with information and update its content is called the “interface” of UCI. Based on the information collected through the “interface,” agents in the SMM generate and play out possible activity content and determine its best version. This part of the UCI is called the “computational” block. Thus, the design of the UCI is considered as consisting of the “interface” and the “computational” block, which have a number of customizable parameters.

[4] Page numbers for the paper (Parinov, 2023a) are given hereinafter according to its freely available preprint version.

[5] Page numbers for the paper (Parinov, 2023b) are given hereinafter according to its freely available preprint version.

The input of the UCI's "interface" receives information about the conditions for the activities of agents, and the output from the UCI's "computational" block is the content of activity of each agent, which takes into account the activities of other agents.

The amount of agents' benefit from the implementation of joint activities, the content of which is determined in the UCI, among other things, depends on the choice of values for the customizable parameters of the "interface" and "computational" block. Agents are interested in optimizing UCI settings for a given type of joint activity to obtain maximum benefits with minimal coordination costs (Parinov, 2023b, p. 12). To do this, they must somehow determine the optimal values of the UCI parameters.

2.4. Operating conditions for universal coordination instrument

The presence of common ground among participants in joint activities (Klein et al., 2005) is a necessary condition for the use of UCI. In addition, for the emergence of coordinated joint activities, a number of other requirements can be identified, without which the UCI does not lead to coordination:

a) For the emergence and maintenance of coordination, the SMM of agents must contain up-to-date and sufficiently complete information about the participants and the conditions of their joint activities;
b) If "a" is satisfied, then there must be at least one variant of joint activity content, the expected benefit of the agents from which exceeds their costs, and the computing capabilities of the agents must be sufficient to find this variant using the SMM;
c) If "b" is satisfied, then the agents' computational capabilities should allow them to determine the content of their joint activity faster than unpredictable disturbances in the conditions of joint activity will disrupt the fulfillment of "a".

Requirements "a" - "b" are quite obvious. It follows from them that coordination is impossible if the participants in the joint activity and/or their SMM do not have the necessary characteristics. For example, there is no common ground. Condition "c" is more complex, so let's look at it in more detail.

The ability of agents to coordinate their activities is influenced by the stochastic nature of the common environment and the agents themselves. In conditions for joint activity, including the states of the agents themselves, unpredictable changes (disturbances) occur with a certain frequency. For the emergence and maintenance of coordination, the relationship between the computational capabilities of agents and the intensity of the flow of disturbances is important. Among all possible disturbances in the conditions for joint activity, the critical ones are those that devalue the coordination already achieved by the agents and require coordination to be performed again. In turn, computing capabilities of agents determine the amount of time required for them to analyze the input flow of information and make decisions about the content of their activities in the SMM.

Coordination is possible if the time interval between critical disturbances exceeds the amount of time required for agents to determine the best or acceptable content of their activity. For coordination to occur, agents need to determine the activity content faster than the next critical disturbance occurs, since it will require repeating all coordination procedures. Coordination will be successful if, in the time before the next critical disturbance, the agents manage to receive benefits from their joint activities that cover their costs.

Coordination is impossible if unpredictable changes in the common environment devalue the content of the SMM faster than the agents, using their available computing capabilities, manage to make a decision about the content of their activity, as well as to receive benefits from the activity.

The UCI described above, in the presence of the necessary conditions, leads to coordination if the computational capabilities of the agents correspond to the complexity of the task of accounting for each other's activities, which, in turn, depends on the intensity of disturbances and on the amount of information that the agents need to analyze in the SMM.

2.5. Universal coordination instrument as a simulation model

Solving the UCI settings and parameters optimization problem requires the creation of an appropriate model. To build an abstract model of the UCI, it is proposed to use the obvious association of the functioning of the SMM, which is the most important part of the UCI, with simulation modeling: "A mental model is constructed … and can then be run like a computer simulation allowing an individual to explore and test different possibilities mentally before acting. … Changes made to a mental model in the simulation process represent what would happen if such changes took place in reality" (Jones et al., 2011, p. 5).

The initial requirements for a model representation of the UCI are: 1) the model representation being created must describe the coordination process for any type of joint socio-economic activity and for any number of its participants; 2) there may be direct or indirect communications between participants in joint activities, or there may be no communications.

In this study, the UCI, consisting of the "interface" and "computational" block, is considered as a special class of collective agent-based simulation models in which the agents themselves update their information images. Simon wrote that if "knowledge and the computational power of the decision maker are severely limited, then we must distinguish between the real world and the actor's perception of it and reasoning about it" (Simon, 1986, p. 280). Taking this into account, this model distinguishes two levels of interaction between agents: 1) a model representation of "reality", which includes a representation of the common environment for the joint activities of agents, as well as the conditions existing in this environment for their activities; 2) a model representation of the mental reflection of "reality", which corresponds to the content of the SMM.

Mental reflection of "reality", i.e. the second level of the UCI model is created by the functioning of the "interface". Some characteristics of the SMM, for example, the completeness of taking into account factors important for joint activities, are determined by the "interface" settings. The content of the second level of the UCI model can be considered as a certain recursion of the content of the first level, because the mental reflection of reality must have a certain accuracy. "Mental models tend to be functional rather than complete or accurate representations of reality. A mental model is a simplified representation of reality that allows people to interact with the world. Because of cognitive limitations, it is neither possible nor desirable to represent every detail that may be found in reality" (Jones et al., 2011, p. 6).

The accuracy of this recursion is determined by the capabilities of the “interface”. However, the current computing capabilities in the “computational” block determine the agents’ ability to process and analyze the received information. Taking this into account, we will assume that the upper limit for the completeness of the mental reflection of reality is determined by the current computing capabilities of the agents and other limitations of the “computational” block as a whole.

General scheme of data exchange between levels in the UCI model:

- --level 2, mental representation of “reality”--
    - the “interface” defines the content of level 2;
    - the “computational” block, based on the current content of level 2, determines the content of the agents’ activities for level 1;
- --level 1, “reality”--
    - agents implement the calculated content of their activities
    - agents, using configured communications, receive information about changes at level 1 and transmit it to level 2 by using the “interface”.
- --the cycle of actions is repeated from the beginning--

Within the framework of this two-level model, agents play (simulate) and analyze possible options for UCI settings, as well as the possible content of their joint activities, including the size of the expected benefit. In the process of these simulations, agents determine the best content of their joint activity, fix responsibility for the implementation of the chosen activity option, and transfer it to the mode of practical implementation. Observing changes in the common environment and comparing the expected benefits from joint activities with those actually received, agents in critical cases initiate re-coordination or maintenance of coordination of their activities in order to bring the benefit amount closer to the expected one.

The model of the “interface” as part of the UCI contains a set of methods for obtaining and updating information images of participants in a given type of joint activity, which are based on the use of three main communication options. This model also includes methods for updating information about the state of the common environment for participants in joint activities. As settings, the model allows one to make a choice of methods for receiving and sending information for each individual act of communication and exchange of information between agents. Each such act of communication has two characteristics: a) the degree of completeness of transmission/reception of specified information; and b) the amount of costs for transmitting/receiving specified information.

The model of the “computational” block as part of the UCI operates as a distributed agent-based simulation model. This model is simultaneously available to all participants in the joint activity for “reading and editing”. All agents can update their information images in a decentralized manner in this model, as well as add other information to the model. The history of changes in the model is saved to a certain “depth”. The “computational” block allows each agent to play (perform model simulations) various contents of joint activities using information images of all agents. Such playbacks of activity contents can be collective in nature, because in some communication options, agents can actively or passively participate in the model simulations of each other.

The main functions of the “computational” block of the UCI:

1) model simulations of possible activity contents and assessment of the agent’s expected benefits;

2) negotiation or tâtonnement for choosing the best activity content and translating it into practical implementation;
3) maintaining the implemented activity content in a coordinated state, including adjusting and improving coordination characteristics.

The following sections discuss how the functions of the "interface" and "computational" block of the UCI are implemented for all main communication options.

3. Functions of the "interface" in the universal coordination instrument

The "interface" as part of the abstract UCI model is responsible for the SMM formation and updating its content by using communications. In the literature, SMM has traditionally been viewed as a phenomenon that occurs because of direct communications between participants in teams and other small groups (Jones et al., 2011). In this section, we consider the principles of forming SMM by participants in joint activities using all main communication options: 1) direct communications; 2) indirect; and 3) and previous communications, which allow agents to conduct joint activities in the absence of current communications. Hybrid communications, when agents use combinations of the main communication options (Parinov, 2023a, p. 4) to reduce coordination costs, are not considered.

Direct communications

Direct communications are an interpersonal exchange of information without intermediaries of the "all-to-all" type. Due to such communications, participants in joint activities maintain in each other's mind the information about current individual capabilities and intentions, and also about current content of each other's activities. Thus, in the mode of direct communications, using the UCI's "interface", each individual agent directly transmits to and receives from the SMM the information that is required by the participants in joint activities to compute the content of their activities, taking into account the expected activities of each other.

Indirect communications

In indirect communications, agents leave traces of their activities and/or certain labels in the common environment, which are read and analyzed by other agents to take into account each other's capabilities and intentions in relation to joint activities. The process of SMM formation during indirect communications involves the creation by agents in a common environment of some signaling system (Klein et al., 2005). Activity traces or labels created by agents based on a signaling system, as a rule, have a standardized design. It makes possible to reduce the costs of agents for recognizing and analyzing information received through indirect communications. The information received is accumulated in the individual mental models of agents and is updated as a result of constant monitoring of agents for changes in the common environment. Thus, based on indirect communications, the content of individual mental models of agents is partially synchronized and due to this, the mental models of agents acquire the properties of SMM.

In the mode of indirect communications agents alienate the results of their activities into the common environment and, using the signaling system, notify all other participants in joint

activities about this. For example, if the signaling system is a market, then the agents "bring" goods ready for consumption to the market and present this act in accordance with the requirements of the market signaling system. All other agents monitor such events in a common environment using a market signaling system. By this their individual mental models have and update the "market" information images of each other.

The alienation of information about agents' activity content, rather than the results of activity, is not considered in this study, because this case is close in meaning to direct communication.

Previous communications / lack of current communications

In the absence of communications agents participating in joint activities can use the SMM created as a result of previous direct and/or indirect communications between them. Such a SMM, intended for use in the absence of ongoing communications, is static, because cannot be dynamically updated when agents use it. As a rule, such a SMM is a fixed set of common rules of behavior, or a given plan of action, as well as explicit or implicit norms, given behavioral roles and instructions, culturally generally accepted attitudes, and other institutions with coordinating functions. For simplicity, we will call all such cases coordination of agents' activities based on the common rules.

In the process of social evolution, agents have already formed static SMMs for various situations related to joint activities in the absence of communications between them. Thus, various institutions with coordinating functions have been created. For example, this is how rules work that allow people, in the absence of direct and indirect communications between them, to consume public goods taking into account each other's interests.

Updating such static SMMs is possible, but can be time-consuming and costly. An example is the process of improving institutional structures.

The three methods of forming a SMM for different communication options listed in this section determine the functional content of the UCI's "interface". The "interface" connects the SMM, i.e. a "computational" block, with all participants in joint activities and with their common environment. It is responsible for the completeness of the representation in the "computational" block of factors important for the joint activities of agents, as well as for the timely updating of the contents of the SMM.

4. Functions of the "computational" block in the universal coordination instrument

In the "computational" block of the abstract UCI model, the content of the joint activities of agents is determined based on the current content of the SMM. This is implemented by agents using the following "computational" functions:

1) model simulations of possible activity options, assessment of the agent's expected benefits and the individual value of the resources necessary for their joint activities;
2) agreement or groping for mutually acceptable options for joint activities, choosing the best option and translating it into practical implementation.

Let's consider how the "computational" block performs these functions for three main options of communication between agents. This block is also responsible for maintaining joint

activities in a coordinated state in response to disturbances, but in this paper, for simplicity, this part of the functions is not considered. See them in (Parinov, 2023c, p. 19).

4.1. Determining possible activity content

To determine the possible content of their joint activity, agents individually perform model simulations in the SMM. Possible activity contents are determined in the form of a given initial set. In the process of model simulations, each individual agent, based on the information contained in the SMM, takes into account the expected activities of other participants in joint activities. Analyzing possible activity content, agents also evaluate in the SMM the expected benefits from the corresponding activity.

For economic activity, in the process of such simulations and analysis, the agent additionally determines the individual value of resources produced by other agents, which he needs for his activity and which he would have as a result of the resources allocation in the economy. The agent defines the individual value of resources as the opportunity to obtain, using these resources in his activities, a certain amount of benefit. The greater the expected benefit from the activity content, the higher the value for the agent of the resources he needs to implement this activity content.

The selected by agents their individual joint activity contents are contained in the SMM and are available for analysis to all participants in the corresponding joint activities. In this way, agents can analyze in SMM “other agent’s” activity content which assume their participation. The way “other agent’s” activity content is collected and used in the SMM depends on the type of communication between agents and is discussed in the next section.

In the “computational” block of the abstract UCI model, each agent in a certain way selects acceptable activity content, which has the best estimates of the expected benefit. At the same time, agents evaluate the individual value of the resources that they need to implement the selected activity content.

4.2. Choosing the best activity content

In SMM, selecting the best activity content among the many suggested by participants is carried out by the following procedures:

1) 1) exchange of opinions and proposals between participants regarding the content of joint activities;
2) reaching an agreement or some consensus of all participants regarding the best content of their individual activities.

Let's consider how these procedures are implemented in the main communication options.

4.2.1. Direct communications

Exchange of opinions and suggestions

In direct communications, the exchange of opinions and suggestions is an observable and well-studied process. Agents, in the form of “face-to-face” communication, exchange ideas for their joint activity content, including proposals for improving existing activity content. In

this way, agents can both propose changes to the ideas of other agents and propose their own new ideas for analysis by other participants.

Reaching an agreement

Obtaining the consent of all participants in joint activities regarding the choice of its best content occurs in the process of exchanging opinions and suggestions. The agreement of all agents with the choice of a certain version of their joint activity content as the best occurs under the influence of two factors. On the one hand, there is the desire of each agent to obtain the maximum benefit from their joint activities. On the other hand, agents strive to limit the increase in coordination costs, caused by the increase in the amount of time spent searching and agreeing on the best activity content for everyone.

Simon, developing Stigler's ideas, analyzed situations where the costs of searching for information may exceed the benefits of finding the best option (Simon, 1978). In such cases, agents are motivated to choose not the best, but satisfactory solutions:

> "... the question is not how the search is carried out, but how it is decided when to terminate it ... The question is answered by postulating a cost that increases with the total amount of search. In an optimizing model, the correct point of termination is found by equating the (expected) marginal improvement of the set of alternatives. In a satisficing model, search terminates when the best offer exceeds and aspiration level that itself adjusts gradually to the value of the offers received so far. (Simon, 1978, p. 10).

Similar reasoning about the costs of searching a solution applies to the situation under consideration in this paper. An increase in the amount of benefit expected by participants in a joint activity from continuing their efforts to improve the coordination characteristics is accompanied by a corresponding increase in the amount of time spent on coordination and, as a consequence, an increase in coordination costs. Thus, it is beneficial for agents to agree to the implementation of an acceptable or satisfactory, and not the "best" version of the activity content. Because continuing negotiation to obtain greater benefits requires additional time, which makes the best version less profitable in total than the acceptable current one.

For economic activity, the amount of the agent's benefit depends, among other things, on the allocation of resources which the agent requires for his activity. Since the total benefit of an agent from his activities depends on the results of the resources allocation, the process of reaching an agreement among agents on the activity content includes simultaneous agreement on the distribution of resources created by participants in joint activities. With direct communications, reaching an agreement in the process of agreeing on the content of the activities of all participants and agreeing on the distribution of resources between them occurs simultaneously. The costs of agents associated with searching for the best allocation of resources force them, in this case, to make acceptable decisions instead of better ones.

If the amount of the individual participants' benefits depends on the amount of their overall benefit, then this creates a motivation for them to strive to allocate resources in accordance with their maximum individual values, determined as described in section 4.1. This motivation arises from the fact that overall benefit increases if each agent receives maximum individual benefit, due to the allocation of resources in accordance with their individual values.

At the same time, the need that arises during direct communications to obtain the consent of all participants both on the choice of activity content and on the distribution of created resources gives agents a potential opportunity to ensure that they receive an acceptable share of the increase in benefits from their joint activities. Thus, the process of coordinating activities based on the direct communications tends to allocate resources in accordance with agents' maximum individual values of these resources.

The desire of agents to obtain maximum benefits in the process of agreeing on the content of joint activities creates a tendency towards equilibrium in the relationships of participants in joint activities. In the absence of disturbances in the conditions for joint activity, achieving equilibrium is possible. This state means that the agents have determined the Pareto optimal version of their joint activity content, in which no agent can increase his benefit from joint activity without reducing the benefits of other agents.

4.2.2. Indirect communications

Exchange of opinions and suggestions

In indirect communications, agents exchange opinions and suggestions by interacting with a common environment rather than with each other. Based on the current content of the SMM, agents individually determine the best joint activity content and alienate it into the common environment in the form of an offer for other agents. Agents formalize such offers in accordance with the requirements of a specific signaling system. In this study, the alienation of proposed activity content is considered as the alienation of a ready-made result of an activity, which can be either a resource or some action. For example, as a result of such alienation, agents' offers appear on the market in the form of resources created by them or services (actions) provided.

Reaching consensus

Achieving the consent of all agents to implement some variant of joint activity in indirect communications is implemented as a procedure of a typical market tâtonnement, i.e. as a series of attempts by agents to guess each other's demand and offer each other resources that will be in demand. A sign of reaching agreement in this case is a situation when all produced resources are demanded by agents. To achieve this state, agents analyze information about the reaction (demand) of other agents to the activity content (resources or/and services) they propose. Using this information, they adjust the proposed content of joint activities, creating and alienating new resources or/and services into the common environment. Coordination of agents' activities in this case occurs by trial and error. Agents step by step take into account in their activities the reactions and expectations of other agents more and more accurately, because this is a way for them to get the maximum benefit from joint activities.

The distribution of resources is agreed upon in accordance with their maximum individual values using the same procedure. Because the probability of obtaining resources on the market is higher for those agents who have shown the highest demand for them. The accuracy of resource allocation depends on the accuracy of the expression of the individual value of the resource in the amount (characteristics) of demand for it from interested agents.

The desire of agents to obtain the maximum benefit, by tâtonnement through trial and error for the activity content that will be most in demand by other agents, creates a tendency to equilibrium in the joint activity contents among all participants. Achieving equilibrium is possible if there are no disturbances in the conditions for joint activity. Such equilibrium means that the agents have determined the Pareto optimal content of their joint activities, in which no agent can increase his benefits from joint activities without reducing the benefits of other agents.

With indirect communications, agents can find the Pareto optimal activity content that will give them the maximum benefit if the following conditions are met:

- The SMM used by agents contains fairly accurate information about the conditions for joint activities;
- Prices, as a measure of the magnitude of demand and supply for resources, accurately reflect the expected benefit of agents from their joint activities and the associated individual value of resources, calculated in SMM.

4.2.3. Previous communications / lack of communications

Exchange of opinions and suggestions

In the absence of communication between agents, there is no direct exchange of opinions and proposals. However, agents can use previously created KMM, for example, general rules, to determine the content of their joint activities, since the intention of agents to use general rules gives their individual metal models the properties of KMM. A previously created KMM allows agents to play and choose options for their joint activities, assuming that to determine the content of their activities, other participants under the same conditions use the same KMM or the same general rules.

Reaching consensus

Obtaining the consent of all participants in joint activities regarding the choice of the best activity content, in the absence of communications, is implemented in a simplified form. The previously created SMM allows agents to individually choose an activity content with maximum benefit for themselves, but without the opportunity to receive a response to this choice from other agents. The choice by participants of joint activities of the content of their activities based on the same static SMM, for example, rules common to all participants, means the presence of a certain consistency between the activities of individual participants. Under these conditions, the degree of coordination of the agents' activities depends on the quality of the static SMM that the agents use compare with the situation in which this SMM is applied. If random disturbances change the conditions for joint activity, then it is necessary to change the corresponding static SMM. Maintaining coordination in this case means monitoring the performance of static SMMs and adjusting them if necessary.

In this case, agents determine the best content of their activity through trial and error. They analyze the effectiveness of the chosen activity content and if the actual benefit is less than expected, then they try to improve the activity content. Tâtonnement in this case occurs without communications between agents and, therefore, other participants cannot influence each other in the process.

It should be noted that in the absence of communications, the activities of agents can also be coordinated based on a common plan, which is one of the varieties of static SMM. The activity of agents who do not communicate with each other, but carry out the "perfect" plan of action, theoretically, can have a high level of coordination.

A state of equilibrium between participants in joint activities operating without communication with each other based on a static SMM is possible. In the absence of disturbances in the conditions for activity, agents use trial and error to individually find the best content of their activity. When finding the best content of an activity, equilibrium does not arise as a balance of interests of agents, but is determined by the impossibility of agents to influence each other's state in the absence of communications between them. This situation can be considered a case of degenerate equilibrium.

5. Discussion

The principles of formation and functioning of UCIs for all main communication options discussed in the previous sections provide grounds for using the concept of "economic individual with UCI" for the purposes of both theoretical economic analysis and practical applications. In this section we analyze some methodological implications arising from this concept.

5.1. A unified methodological basis for the study of coordination and economic structures

From the assumption that all agents have a UCI, it follows that coordination for all types of joint activities is created with the participation of the agents themselves. The observed forms of various methods of coordination created by agents can differ significantly, because depend on the communication options used for coordination in different cases. For example, in indirect communications, coordination is perceived as the action of Smith's "invisible hand", which creates Hayek's "spontaneous order". Another example, coordination based on static SMMs created by previous communications is usually interpreted as the action of institutions (Williamson, 1985).

The creation of a UCI with settings that is common for participants in some type of joint activity manifests itself in the economy as the emergence of some new organizational or institutional structure. The observable properties and characteristic of such structures are determined by the dominant communication options in the corresponding UCI (Parinov, 2023a). The basic properties inherent, for example, in teams and small firms, which are often defined as organizational structures of the "network" type, are determined by direct communications between their participants (Parinov, 2023a, p. 5). The properties of hierarchical structures are a consequence of direct communications in which participant-executors delegated their rights to make decisions about the content of activities to participant-managers (Parinov, 2023a, pp. 5-6). Important properties of market structures are determined by indirect communications (Parinov, 2023a, p. 10). The properties of institutional structures arise from the use by agents of the results of previous communications in the form of pre-formed static SMMs.

The proposed approach makes it possible to analyze possible transformations of one structure into another. For example, transformations of the "each to each" type for: a) teams and

network structures; b) hierarchical structures; c) market structures; d) institutions with coordination functions. As well as the formation of various hybrids from these structures. As a result, when considering the important task of economic theory about the choice between organizational structures, it becomes possible to replace the traditional choice between "discrete alternative structures" (Simon, 1978) with a flexible choice of UCI settings, which allows from a micro-level position to systematically analyze and design the required structures with specified properties.

Thus, the concept of an economical individual with a UCI creates a unified methodological basis for analyzing the functioning and designing various methods of coordination that form various structures with coordinating functions in the economy.

5.2. The emergence of economic systems and their stability

Individuals (agents) with a universal coordination instrument have system-forming properties. By synchronizing the settings and parameters of their UCIs, agents can collectively use distributed knowledge to take into account each other's activities to obtain maximum benefit from their joint activities. As a result of these actions, connections are established between agents and interdependencies are formed. From individual agents, a group of participants in joint activity, which represent an economic system, is formed. In such economic systems the agents are connected to each other through a common UCI and have common interests related with their joint activity.

In economic systems, if they are considered as a result of the use of common UCI by participants in joint activities, three levels of sustainability can be distinguished:

1. The stability of the relationships between participants that arose as a result of determining the best content of their joint activities. At this level of stability, the preservation of relationships between agents ensures that they receive the expected benefits in a sustainable manner until critical changes occur in the conditions for their joint activities.;
2. The stability of the relationships based on which the participants in joint activities use a certain method of coordination. Where the coordination method is a common UCI with some settings. At this level, system stability is created by agents' using of a given coordination method. The stability exists until critical changes occur in the conditions for the functioning of the UCI with settings.;
3. The stability of the relationships on which the participants' improvement of their current method of coordination for a given joint activity is based. The stability of the system here is based on the use of metacoordination, the properties and parameters of which are discussed in (Parinov, 2023c, p. 25).

An economic system with three levels of stability under certain conditions can remain efficiency even if the relationships of the 1st and 2nd levels lose stability.

For example, if the individual preferences of participants are unstable, causing a loss of stability of the first level, the efficiency of the system can be ensured by the rapid adaptation of the joint activities of agents to changed conditions due to its re-coordination. More frequent use of UCI for re-coordination increases agents' coordination costs and reduces agents' expected benefits. The condition for maintaining the efficiency of the economic system in this case is to maintain the level of coordination costs not higher than a certain

threshold, ensuring that agents receive an acceptable amount of total benefit from joint activities.

If the second level of stability is lost, for example, due to critical changes in the conditions for the functioning of the UCI, the efficiency of the system can be restored by searching for new UCI settings, which means constructing a new or improving an existing method of coordination.

5.3. Procedural rationality and coordination equilibrium

At the second and third levels of stability of the economic system, in contrast to the first level, participants in joint activities, using relationships at these levels, can take into account distributed knowledge. Based on the information collected, they rationally select the best solutions aimed at increasing the expected benefits from their joint activities. At the second level of sustainability, agents show rationality in choosing the content of activities to obtain maximum benefit. In this case agents demonstrate the substantive rationality (Simon, 1978; Denzau & North, 1994). At the third level of sustainability, the rationality of agents is manifested in the choice of the best methods of coordination. The type of rationality exhibited at the third level of sustainability corresponds to Simon's concept of "procedural rationality," which means "the effectiveness, in light of human cognitive powers and limitations, of the procedures used to choose actions" (Simon, 1978, p. 9). Coordination methods are procedures used by agents to make choices about the content of their joint activities, so to create them, agents must have procedural rationality.

At each level of the economic system stability the rational agents create some rational economic order. It is the result of the agents' search for optimal conditions for their joint activities in order to obtain maximum individual benefit from it. The rational economic order created by using the UCI can exist with the bounded rationality of agents (Simon, 1978) and under their opportunistic behavior (Williamson, 1985). Such cases are possible scenarios for the behavior of individual agents when forming the SMM and determining the optimal settings for the UCI. For example, the opportunistic behavior can occur through the intervention of individual selfish agents in using common UCI.

Since agents analyze information about each other in the SMM, then, theoretically, they can find and eliminate inconsistencies in the initially distributed information, summarize and complement limited information, and also identify cases of opportunistic behavior. One of the properties of UCI, which it received from SMM, is the ability of agents to minimize the impact of all these factors on the results of their joint activities.

The presence of procedural rationality allows, under certain conditions, to compensate for cases of weakening of substantive rationality. It follows from the above-mentioned possibility of maintaining the efficiency of the economic system when the stability of first-level relationships is disrupted. Consider the weakening of substantive rationality, for example, due to the instability of individual preferences of agents (Weizsäcker, 2005; Bronk, Beckert, 2022). In traditional economic theory the unstable preferences mean that participants in joint activities cannot achieve a stable equilibrium between their supply and demand. In the context of this paper, this situation corresponds to a lack of equilibrium (disequilibrium) between the agents' activity contents. It is a sign of the implementation by agents of decisions that are not completely rational in the current conditions at the second level of relationships in the system.

The problems of theoretical description and analysis of the behavior of agents and economic systems caused by the instability of individual preferences can be resolved by using the assumption that agents have procedural rationality. This assumption means that agents have effective (within the limits of their cognitive capabilities and limitations) procedures for choosing a new content for their activity. That is, with each change in preferences, agents carry out procedures in the UCI to re-coordinate and maintain their joint activities in a coordinated state. Thus, violations of substantive rationality caused by various reasons can be eliminated by re-coordinating the joint activities of agents.

In economic theory, one of the consequences of the agents' rationality is the emergence, under certain conditions, of equilibrium in the economic system. The above-mentioned presence of two types of rationality of agents in the absence of critical disturbances leads to the emergence of two types of equilibrium:

- The procedural rationality of agents leads to equilibrium as agents improve coordination characteristics. Equilibrium in this process, i.e. a coordination or procedural equilibrium, means that it is impossible for agents to obtain greater benefits by improving the UCI settings without a significantly greater increase in coordination costs caused by these efforts.;
- The substantive rationality of agents, the same as described by mainstream economic theory, leads to equilibrium in agents clarifying the individual contents of their joint activities. With indirect communications, this case corresponds to market equilibrium between supply and demand.

The coordination equilibrium is a consequence of the desire of agents to create for the conditions existing for their joint activities such a method of coordination that will ensure maximum benefits from their activities with minimal costs of coordination. In this case, the increase in benefits is achieved, among other things, by increasing the completeness of taking into account important factors. This leads to an increase in the complexity of the coordination task, because requires processing and analysis of more information. Increasing the complexity of the coordination problem, in turn, requires agents to increase their computing capabilities, which leads to an increase in coordination costs. The optimal solution is UCI settings, which provide equality between the marginal benefit and the marginal coordination costs.

5.4. Metacoordination solution concept

Agents in the coordination process strive to maximize the completeness of taking into account important factors, information about which is distributed among them, and at the same time minimize their coordination costs. The procedural rationality of agents encourages them to seek UCI settings and algorithms that will maximize the overall benefit from their joint activities. Metacoordination of agents is a way to solve this problem (Parinov, 2023c). One of the metacoordination procedures is to determine the optimal configuration of the UCI's "interface", i.e. determining a combination of the main communication options between participants, which together will give them maximum completeness of accounting at minimal cost. Based on the differences between communication options in terms of variable and fixed costs, a good solution concept for the metacoordination algorithm is the following rules for selecting communication options:

a) use direct communications associated with high variable costs only in situations, or for individual operations in the activities, or at certain time intervals, when disturbances arise in the conditions for joint activities;
b) for case “a”, but when the number of participants or other factors either do not allow or do not require direct communications, use indirect communications, because they require fewer variable costs;
c) in all other cases, use a static SMM created by previous communications, which requires minimal variable costs.

A number of conclusions about the behavior of agents in metacoordination follow from this algorithm. To maximize overall benefit, agents should limit the use of high-cost communication options, such as direct communication, to only cases where the agents' expected benefit would otherwise be reduced. Whenever this does not reduce the overall benefit, agents should dispense with communications using a static SMM. The implementation of these principles manifests itself as the combination of different communication options in the method of coordination that agents create in order to maximize overall benefit. Micro-level analysis of the well-known coordination mechanisms “network”, “hierarchy” and “market” confirms this theoretical conclusion (Parinov, 2023a).

This solution concept for metacoordination algorithm allows one to discuss some practical applications of the abstract model of the economic individual with UCI. Particularly interesting applications are possible by implementing UCI functions based on modern information and communication technology (ICT).

Let us assume that in using a UCI to coordinate some type of joint activity, agents can, if necessary, use the algorithm described above to switch between different communication options. And this is possible without significantly increasing coordination costs. Then, if there are no disturbances in the conditions for joint activity, then the agents use a static SMM, i.e. option "c" from the algorithm. If at a certain point in time, during a certain operation of joint activity, disturbances arise, then the participants automatically switch to using options “a” or “b”. When the disturbances stop and their consequences are eliminated, the participants automatically return to using option “c”, i.e. using again a static SMM. Such an adaptive algorithm for using communication options and adjusting the UCI settings to the disturbances flow represents, in a certain sense, an ideal method of coordination. It allows one to bring coordination costs to the minimum possible level, while maintaining the maximum possible completeness of taking into account important factors.

The possibility of implementing an adaptive algorithm for using communication options, which can be created when implementing ICT-based UCI, allows, theoretically, to abandon the discrete choice between alternative organizational or institutional structures (Simon, 1978). If such an adaptive algorithm is implemented, then agents will be able to change the method of coordination and its organizational structure flexibly and dynamically for a given joint activity in order to obtain maximum benefits with minimal coordination costs.

5.5. Waves of disequilibrium in economic system

The above-mentioned three-level stability of economic systems formed by agents with UCI, as well as the presence of procedural rationality among agents, makes it possible to describe and study the behavior of systems in response to a flow of disturbances that throw the system out of substantive equilibrium. The relevance of such analysis is created by the gradual

growth in the real economic environment of the quantity and quality of disturbances affecting each individual agent. One of the reasons for the increase in the intensity of the flow of critical disturbances is the acceleration of scientific and technological progress. Another important reason is the strengthening of information connectivity in modern society and, as a result, the expansion of the area of influence of "local" disturbances, which in the past affected a significantly smaller number of agents.

The proposed approach allows one to analyze the functioning of the economic system under conditions of a flow of disturbances of different nature and intensity. To simplify the analysis, we consider the impact of disturbances only as a change in the individual preferences of the joint activity participants.

Changes in the conditions for joint activity of agents lead, among other things, to an increase in the instability of individual preferences of agents (Weizsäcker, 2005; Bronk, Beckert, 2022). Individual preferences of agents in the context of their use of a certain method of coordination correspond to a certain state of agents' capabilities and intentions in relation to their joint activitiy. The emergence of new factors in the conditions for the agent's activities, the consideration of which can lead to an increase in the agent's benefits, can change his current capabilities and intentions. These new factors may arise in the state of the agent itself. For example, learning new skills. They can also occur in the common environment of agents. For example, various innovations, new capabilities of other participants, new available resources, etc. The changes in agents' preferences caused by these factors can be manifested in the choice of content as their own activity, as well as in the choice of preferable activities of other agents, or created resources that they need for their own activities.

Let us consider a situation when the period of preference stability becomes increasingly shorter, and the dominant situation becomes the unknown of agents' preferences for any extended period of time. The lack of preference stability means the impossibility of achieving a stable equilibrium in the agents' activity content. This leads to an increase in the time when the system is away from equilibrium state.

Participants in joint activities compensate for the increased instability and uncertainty of their preferences by increasing the frequency of using UCIs to maintain the coordination of their activities. Each critical disturbance in the conditions for their joint activity initiates in the UCI a procedure for searching and agreeing on new content of the agents' activity in order to maintain the joint activity in a coordinated state.

Between the time moment when a change in current preferences occurs and the moment when equilibrium arises in the content of the agents' joint activity, there are several important intermediate stages. The implementation of each of these stages takes agents a certain amount of time. Let us look at these steps with some simplifications:

1. Time t_1. The agents have completed stage 1, associated with the formation of their new current preferences in the UCI, based on which they then carry out the procedure for determining the new content of their joint activities. When forming their preferences, agents take into account the preferences (intentions and capabilities) of other participants known to them through the UCI.

2. Time t_2. Agents have completed stage 2, which consists of determining the optimal content of joint activities. Agents made decisions on the content of their activities taking into account

the information available in the UCI about the expected activities of other agents. To this time, the current preferences of the agents correspond to the current content of their activity.

3. Time t_3. Stage 3 has been completed, which consists in transferring the activities chosen by the agents into the mode of practical implementation. The agents' decision about the content of their activity based on their preferences that existed at time t_1 begins to be practically implemented at time t_3. In indirect communications, the preferences of agents at time t_3 manifest themselves in the common environment in the form of a certain structure of their supply and demand, i.e. at this stage, agents' preferences take observable form.

4. Time t_4. Stage 4, related to the coordination of the volumes of created resources based on the previously formed structure, has been completed. With indirect communications, this leads to balancing of the supply and demand volumes. A state of substantive equilibrium arises in the system.

Each of the listed stages lasts a certain time interval. The duration of these intervals depends on the type of communication between agents. During the implementation of these stages, new disturbances may arise in the system, leading to a change in the current preferences of the agents. In this case, preferences no longer correspond to the current content of activity and the existing structure of supply and demand in the system. Therefore, the state of equilibrium in the system also not correspond to the current agents' preferences. In this case, agents must repeat Procedures 1-4 described above to align the results of their activities with their new preferences.

Thus, the flow of critical disturbances in the system, changing the preferences of agents, may generates a wave-like propagation of changes from the stage 1 to 4. The movement of "waves" of changes in the environment of the economic system is created by the sequential implementation of the procedures of stages 1-4 in response to each critical disturbance. The characteristics of the disturbances flow determine the characteristics of the propagation and attenuation of the "waves". In an economic system, under conditions in which a "wave" of change does not end before the next "wave" starts, regular discrepancies arise between the content of stages 1-4. For example, between current preferences (stage 1), which already correspond to the changed "perturbed" conditions for joint activity, and the current content of the agents' activities (stage 2), which still determines the supply-demand structure (stage 3), corresponding to the old preferences, etc.

The occurrence of "waves", their periodicity, as well as their other characteristics are determined by the following parameters:

a) intensity of critical disturbances as a frequency of random disturbances in time;
b) the complexity of the accounting problem, which, for given computing capabilities, determines the amount of time required in the UCI to compute the content of the agents' activities. This complexity can be changed (e.g. reduced) by the agents by changing (reducing) the completeness of accounting for important factors (Parinov, 2023b, p. 24);
c) the computing capabilities of agents, which determine the time during which the accounting problem in the UCI can be solved and the content of the activity can be determined. These capabilities can be increased by agents in different ways (Parinov, 2023b, p. 33).

The combination of the noted parameters determines the characteristics of the discrepancies between the state of stages 1-4 (preferences, content of activity, supply-demand structure, supply-demand equilibrium state). These discrepancies, in turn, determine the properties of the economic system. For some dependencies between parameters "a-b-c", discrepancies may exist between each stage of 1-4. Such cases can be defined as a strong disequilibrium of the economic system. In a similar way, other gradations of strength/weakness of disequilibrium in the economic system can be determined.

The described wave-like propagation of disturbances occurs in all types of communications between participants. However, each communication option has its own features in the propagation of disturbances. Let us briefly consider just one feature: the differences in the amount of time that each communication option requires to complete stages 1-4. With direct communications, the total duration of all stages 1-4 is relatively small, because in face-to-face communication agents can quickly complete all its procedures. With indirect communications, the time required to complete the stages is longer, because it depends, among other things, on the development of the signaling system and the common environment as a whole. In the absence of communications, when agents use previously created the static SMMs, the execution time of stages 1-4 can be very long. Therefore, the method of coordination used the static SMM usually works most effectively for joint activities in the absence or "prohibition" of disturbances.

The economic theory statements, based on the stability of preferences, as well as those defined for the situation of substantive equilibrium, are fulfilled in the time interval $t_4 - t_1$, if no new critical disturbances occur during this time. In this case, there are no obstacles to ensure that the structure of supply and demand at stage 4 is in accordance with the preferences of the participants in the joint activity at stage 1. However, at a high intensity of critical disturbances, the traditional theory is applicable only on short time intervals, until the correspondence between the equilibrium state and the preferences of agents is violated. At other points in time, when waves of change propagate through the system and the state of equilibrium does not correspond to preferences, as one might assume, some of the economic theory statements do not apply. Consequently, there is a demand on a theory that explains the behavior of an economic system in conditions of wave-like propagation of changes in its environment and for states far from the substantive equilibrium.

5.6. Expansion of economic theory

Mainstream microeconomic theory describes how agents (individuals and firms) seek ways to maximize their objective functions by making decisions about the content of their production, distribution, exchange, and consumption. The decisions made by agents manifest themselves as a certain allocation of limited resources among economic participants.

In the proposed study, based on the concept of individuals with UIC, who have two types of rationality, the traditional description of the microeconomic problem of agents maximizing their objective functions is supplemented by:

1) a description of causal relationships and procedures leading to the emergence of an economic system from participants in joint activity, the properties of which depend on the communication options used;
2) a description of the principles of creating and using a certain tool, called a universal coordination instrument, by which participants in joint activities maximize their

objective functions and determine the behavior of the corresponding economic systems.

With this supplement, the microeconomic problem of maximizing objective functions is expanded by the agents' ability to dynamically redefine all conditions for maximizing the objective function, including the content of the function itself, which appears in the UCI. This makes it possible to describe how agents take into account the changing capabilities and intentions of participants in their joint activities, in particular as a result of disturbances.

Such an extended formulation of the microeconomic problem can be naturally reduced to the traditional one if no critical disturbances arise in the state of the agents and in their common environment. In such conditions, agents do not need to revise the already obtained solution for maximizing their objective functions. At the same time, the extended formulation allows one to consider the conditions for maintaining the efficiency of the economic system when critical disturbances occur. For example, in conditions of instability of individual preferences of agents.

Simon wrote: "Decision processes … exist inside human heads. They are subject to change with every change in what human beings know, and with every change in their means of calculation" (Simon, 1976, p. 84). The ideas developed in this study about decision-making that led to the emergence and functioning of economic systems completely relate to the processes that occur in the minds of people. Harari called a similar state of mental connectedness between people the "imagined order": "We believe in a particular order not because it is objectively true, but because believing in it enables us to cooperate effectively and forge a better society" (Harari, 2014, p. 117-118).

As noted in Section 2.5, the content of the agents' SMM, which can be called as their "mental world", is the result of the individual agent's psychological reflection of the real world and sharing these reflections with each other. The result of the actions of each agent in the mental world is the formation, in a sense, of an optimal plan, which the agents try to implement in the real world. Based on the experience gained from implementing this plan, agents adjust and improve both the content of the entire mental world and the action plan to obtain greater benefits from their activities in the real word. Thus, the results and characteristics of economic activity, including, for example, its efficiency, are determined by the success of the activities of agents both in the mental world and in the real one.

Based on the analysis of observed processes in the real world, traditional economic theory tries to guess the structure of the mental world and the causal relationships operating in it. It is necessary to create a complete and logically consistent picture of the interconnected factors and processes that determine the decisions and actions of agents in the real world. One of proposals for improving the representation of the mental world in economic theory is to create a theory of procedural rationality: "As economics acquires aspirations to explain behavior under these typical conditions of modern organization and public life, it will have to devote major energy to building a theory of procedural rationality to complement existing theories of substantive rationality" (Simon, 1978, p. 14-15).

In this paper, the growth of uncertainty caused by an increase in the intensity of disturbances in the conditions for joint activity of agents creates, as Simon noted, the "typical conditions of modern organization and public life". The approach proposed in this study examines the relationship between substantive and procedural rationality. The procedures here refer to the

agents' use of UCI to create coordination methods for different types of their joint activities. The systematic inclusion of the concept of procedural rationality in description of the economic system proposed in this study develops the economic world picture, expands the boundaries of economic theory, and can claim to complement existing theories of rational choice, the need for which Simon wrote.

The current boundaries of economic theory are now, in most cases, understood as follows: "Economics … is the study of the allocation of scarce resources among unlimited and competing uses" (quoted from (Simon, 1978, p. 1)). By including individuals with UCI in economic analysis, economic theory can be defined more broadly. For example, as a theory that studies how the economic individuals create tools to take into account each other's activities and form by this the economic systems in order to obtain maximum benefit under stochastic disturbances. With this approach, the study of the allocation of limited resources among competing goals, which is the core topic of current economic theory, is a special case that occurs in indirect communications between participants in joint activities.

6. Conclusion

This study develops the idea that all participants in joint activities have a universal coordination instrument, consisting of a shared mental model, which is formed and updated through communications between them. With this instrument, participants receive and use information distributed among them (Hayek, 1945) to better account of each other's activities. Based on this, the economic individual with a universal instrument of coordination possesses both substantive and procedural rationality (Simon, 1978). Since this concept describes the process of collecting and processing distributed information in shared mental models created by agents, this allows for the limited rationality of agents and their opportunistic behavior (Williamson, 1985).

Rational individuals with UCI seek to maximize the benefits from their joint activities. The amount of benefit of the participants depends, among other things, on the completeness of taking into account factors important for their joint activities, information about which is distributed among them. Increasing the completeness of taking into account important factors increases the costs of agents for communication and information analysis. An increase in these costs reduces the overall benefit of agents. The use of UCI by rational agents means searching for optimal UCI settings at which agents have the maximum total benefit from their joint activities at minimum costs.

UCI with settings is considered as a special simulation model. The "interface" of this model creates a common information environment for agents. The "computational" block allows each agent to determine the content of his activity, taking into account the expected activity of the other participants. It is shown that the universal coordination instrument performs its functions in all main types of communications between participants in joint activities.

The concept of an individual with UIC expands the boundaries of microeconomic theory. The traditional microeconomics problem of maximizing the objective function of agents is solved in this case as part of a more general problem. As part of this general task, agents first, given existing constraints, determine the UCI settings at which they have the maximum expected benefit from their joint activities with minimum coordination costs. Then, based on the UCI with settings, the agents compute the content of each individual activity. The amount of the expected benefit in this case is calculated in the process of solving, in fact, a traditional

microeconomic problem, in which the agents' objective functions, and all other parameters and restrictions arise and are determined within the "computational" block of the UCI in the process of agents simulating possible options for their activities.

Economic individuals with UCI have system-forming properties. Using UCI with the same settings by participants of joint activity creates interdependencies between them that turn them into an economic system. From the point of view of traditional economic theory, such systems correspond to certain organizational or institutional structures. The observed properties of such systems/structures are determined by the communications option that dominates the UCI settings. For example, the properties of teams or small firms, often described as the "network" type of organizational structures, are determined by direct communications between their members. The properties of hierarchical structures are a consequence of direct communications in which some part of participants delegated their rights to make decisions about the content of their activities to managers. Important properties of market structures are determined by indirect communications. The properties of institutional structures arise from the use by agents of the results of previous communications in the form of pre-formed static SMMs.

The desire of agents to maximize the completeness of taking into account important factors with minimal coordination costs leads to the formation of complex combinations of communication options in organizational and institutional structures. For example, in the "network" type structures, agents can use static SMM and also the indirect communications in all cases where it helps to reduce the coordination costs (Parinov, 2023a, p. 5). In market structures, agents, on the one hand, can use static SMMs, if it helps to reduce costs, and on the other hand, they can use direct communications to increase the completeness of taking into account important factors (Parinov, 2023a, p. 10) when it doesn't increase total costs. The composition of the communication options created in this way can be dynamically changed by agents depending on changes in the conditions for joint activity and on the character of disturbances.

An economic system, considered as a group of participants in joint activities, who are interconnected by a common UCI, has three levels of maintaining stability: 1) agents strive to adhere to the calculated content of their joint activity, because in the absence of disturbances, this provides them with maximum benefit from their activity; 2) if the disturbances in the conditions for joint activity arise, then in the absence of disturbances for the UCI operations, agents use the existing common UCI to correct the current content of the joint activity and maintain it in a coordinated state; 3) if disturbances arise in the UCI operations, then the agents use metacoordination to adjust and adapt the common UCI to new conditions.

In the behavior of economic individuals with UCI, which is aimed at maintaining the stability of the economic system, two types of rationality are manifested. Agents exhibit the procedural rationality (Simon, 1978) when maintaining stability at level 3, and the substantive rationality when maintaining stability at level 2. Procedural rationality leads agents to search for UCI settings that maximize the expected benefit from their joint activities while minimizing coordination costs. Substantive rationality, in the context of this study, motivates agents to use a common UCI to select activity content that best takes into account each other's activities to obtain maximum benefit.

Two types of rationality of agents manifest themselves as a tendency to two types of equilibrium in the economic system. Substantive rationality in the absence of disturbances

ensures the emergence of equilibrium in the individual contents of the joint activity of all participants in the system. In traditional microeconomics it corresponds to the equilibrium of supply and demand. Procedural rationality in the absence of disturbances leads to coordination equilibrium, in which the common UCI has settings, the change of which leads to a deterioration in coordination characteristics and a decrease in the expected total benefit of agents.

One of the types of disturbances that can arise in economic systems is the instability of individual preferences of agents. The proposed approach allows one to determine the conditions for the system to maintain economic efficiency when the preferences of agents are unstable. For example, the consequences of disturbances are overcome by re-coordinating the activities of the participants. In this way, the balance between supply and demand, disturbed by changes in the preferences of participants in joint activities, is restored.

Analysis of the relationship between, on the one hand, the time spent taking into account changed preferences and, on the other, the intensity of changes in preferences, allows one to describe the spread of “waves” of disturbances in the economic system. With different characteristics of these “waves,” the economic system can have different states of disequilibrium and maintain different degrees of efficiency.

In economic theory, the economic problem of society refers to the fundamental problem of scarcity, where limited resources must be allocated efficiently to satisfy unlimited wants and needs. To solve this problem, society must, based on an analysis of distributed information, make choices about what goods and services to produce, how to produce them, and for whom they are produced. It is a key concept in economic theory for explaining decision-making processes at the individual, organizational and societal levels.

The results of this study make it possible to expand and generalize the understanding of the economic problem of society: this is the problem of maintaining maximum completeness of accounting for distributed knowledge with minimal costs in the face of a flow of disturbances. The solution to this problem is the universal coordination instrument. The result of solving this problem is that the agents determine the content of their joint activities, which takes into account the capabilities and intentions of each in the best way and with minimal costs. This formulation allows one to more accurately describe the processes of economic decision-making, including the choice of methods of coordination.

The emergence of disturbances leading to an imbalance of supply and demand in the economic system is a natural irremovable process. In these conditions, the solution to the economic problem of society is to create mechanisms that return the economic system to equilibrium as quickly as possible and with minimal costs. This requires the creation of efficient methods of coordination that will allow the fastest possible restoration of balance in the content of agents’ joint activity, as well as efficient mechanism of metacoordination that will ensure the improvement of coordination methods.

Modern ICT have changed the structure of costs associated with communications and computing (Parinov, 2022), which opens up new opportunities in the design of more efficient metacoordination mechanisms, coordination methods, and, as a result, more efficient organizational and institutional structures.

References

Badke-Schaub, P., Neumann, A., Lauche, K., & Mohammed, S. (2007). Mental models in design teams: a valid approach to performance in design collaboration? // CoDesign, 3(1), 5-20.

Bronk, R., & Beckert, J. (2022). The instability of preferences: Uncertain futures and the incommensurable and intersubjective nature of value (s). Max Planck Institute for the Study of Societies, Discussion Paper 22/1.

Coase, R. H. (1995). The nature of the firm (pp. 37-54). Macmillan Education UK.

Craik, K. J. W. (1967). The nature of explanation (Vol. 445). CUP Archive.

Harari, Y. N. (2014). Sapiens: A brief history of humankind. Random House.

Hayek, F. A. V. (1945). The use of knowledge in society. The American Economic Review 35:44, 518-530, 1945.

Hindriks, K. V., & Van Riemsdijk, M. B. (2009). A computational semantics for communicating rational agents based on mental models. In International Workshop on Programming Multi-Agent Systems (pp. 31-48). Berlin, Heidelberg: Springer Berlin Heidelberg.

Hurwicz, L. (1973). The design of mechanisms for resource allocation. The American Economic Review, 63(2), 1-30.

Hurwicz, L., & Reiter, S. (2006). Designing economic mechanisms. Cambridge University Press.

Jones, N. A., H. Ross, T. Lynam, P. Perez, and A. Leitch. (2011). Mental models: an interdisciplinary synthesis of theory and methods. Ecology and Society 16(1): 46

Johnson-Laird, P. N. (1980). Mental models in cognitive science. Cognitive science, 4(1), 71-115.

Jonker, C., van Riemsdijk, M., & Vermeulen, B. (2011). Shared mental models. A conceptual analysis. In Coordination, Organizations, Institutions, and Norms in Agent Systems VI, 132-151.

Klein, G., Feltovich, P. J., Bradshaw, J. M., & Woods, D. D. (2005). Common ground and coordination in joint activity. Organizational simulation, 53, 139-184.

Mantzavinos, C., North, D. C., & Shariq, S. (2004). Learning, institutions, and economic performance. Perspectives on politics, 2(1), 75-84.

Parinov S. (2022). New Approaches to the Improvement of Coordination Mechanisms. Foresight and STI Governance, 16(4), 82–89. https://doi.org/10.17323/2500-2597.2022.4.82.89

Parinov, S. (2023a). Micro-level description of the economic coordination. Preprint at Munich Personal RePEc Archive, https://mpra.ub.uni-muenchen.de/114816/1/MPRA_paper_114816.pdf (published as Parinov, S.I. Micro level of economic coordination processes. Voprosy Ekonomiki. 2023;(2):127-144. (In Russ.) https://doi.org/10.32609/0042-8736-2023-2-127-144)

Parinov, S. (2023b). Socio-Economic Coordination Mechanisms Design: Conceptual Model. Preprint at Munich Personal RePEc Archive, https://mpra.ub.uni-muenchen.de/117282/1/coordination-mechanism-design-en.pdf (published as Parinov, S.I. Towards economic coordination mechanisms design. Voprosy Ekonomiki. 2023;(9):121-137. (In Russ.) https://doi.org/10.32609/0042-8736-2023-9-121-137)

Parinov, S. (2023c). Fundamental socio-economic coordination process and metacoordination. Preprint at Munich Personal RePEc Archive, https://mpra.ub.uni-muenchen.de/118980/1/MPRA_paper_118980.pdf

Salas, E., Sims, D. E., & Burke, C. S. (2005). Is there a “big five” in teamwork?. Small group research, 36(5), 555-599.

Simon, H. A. (1978). Rationality as Process and as Product of Thought. Richard T. Ely Lecture // American Economic Review, May 1978, v.68, no.2, p.1–16.

Simon, H. A. (1976). From substantive to procedural rationality. In 25 years of economic theory: Retrospect and prospect (pp. 65-86). Boston, MA: Springer US.

Simon, H. A. (1986). Rationality in psychology and economics. Journal of Business, S209-S224.

Stigler, G. J. (1961). The economics of information. Journal of political economy, 69(3), 213-225.

von Weizsäcker, C. C. (2005). The welfare economics of adaptive preferences. MPI Collective Goods Preprint, (2005/11).

Williamson, O. E. (1985). The economic institutions of capitalism. New York: Free Press.