Fundamental socio-economic coordination process and metacoordination

Parinov, Sergey

CEMI RAS

25 October 2023

Fundamental socio-economic coordination process and metacoordination

Sergey Parinov, CEMI RAS
sparinov@gmail.com,
https://www.linkedin.com/in/sergey-parinov/

2023-10-25

Abstract: In the agents' socio-economic activity coordination, the factors important for the results of this activity, information about which, as Hayek noted, is distributed among the participants of the activity, can be taken into account by agents with varying degrees of completeness. The perfection of procedures for identifying such factors and the degree to which they are taken into account in the coordination process can determine greater or lesser benefits of agents from their joint activity. Thus, improving coordination characteristics can be considered as one of the sources of increasing the benefits of agents from their joint activity. In this study, the concept of a shared mental model (SMM) is used as a way for agents to take into account information that is important for coordinating their activities and which is initially distributed among all agents. Based on a number of hypotheses, the SMM features are described under three main options for communications between agents: direct communications, indirect communications, and the absence of communications. The transformation of the SMM into a universal instrument for coordinating socio-economic activities, the main elements of which are the "interface" and the "calculator", is considered. The functioning of the universal coordination instrument is based on the fundamental process of coordination, which is present in all types of coordinated socio-economic activities. Among consequences arising from the results obtained are considered the possibility of generalizing the concept of general equilibrium, methodological connections with the concept of transaction costs and with the institutional economics. It is noted that this approach makes it possible to explore ways to build a unified model of socio-economic coordination, as well as to develop a metacoordination mechanism designed to improve existing coordination mechanisms and design new ones.

Keywords: shared mental model, universal coordination tool, fundamental coordination process, metacoordination

JEL: P0, O1, O3

Table of contents

1. Introduction

The proposed study aims to describe the fundamental process of socio-economic coordination, which is present in all types of joint socio-economic activity of agents (people). A similar problem in relation to coordinated socio-economic systems, rather than to agents, was discussed almost 30 years ago in (Malone, Crowston, 1994, p. 91), but was never solved (Crowston et al., 2015).

Solving this problem requires expanding and clarifying the definition of socio-economic coordination. In this study, coordination is understood as the realization by agents (people) of their natural ability to take into account each other's activity and intentions in relation to their joint activity in three main communication options: 1) direct communication; 2) indirect; and 3) in the absence of communications (Parinov, 2023b). The joint activity is carried out by agents in order to obtain benefits, the amount of which depends, among other things, on the characteristics of coordination. For example, the amount of the benefit depends on the completeness of consideration in coordination of factors important for joint activity, information about which is distributed among agents (Hayek, 1945).

Based on the definition of coordination, the fundamental process of socio-economic coordination is understood as the realization by agents of their natural abilities to take into account each other's activity through the transformation of their individual mental models into a shared (collective) one (Johnson-Laird, 1980; Mantzavinos et al., 2004; Badke-Schaub et al., 2007). The shared mental model (SMM), which is formed among participants in joint activity under three main communication options, is a universal coordination instrument. A direct association of such a universal coordination instrument is a distributed simulation agent-based model. The content of this model corresponds to the SMM. In the model the agents themselves update their information images, and find by simulations feasible options for their joint activity, negotiate and select the best one for practical implementation. All these procedures are carried out in SMM both in direct and indirect communications, and also on the basis of common rules in the absence of communications (Parinov, 2023a).

The inherent desire of agents to obtain maximum benefits from their joint activities creates motivation to take into account as fully as possible the information distributed among them, which is important for their joint activity. As well as to use other opportunities to improve coordination. Completeness of taking into account important information is achieved by selecting the settings of the universal coordination instrument, including choosing combinations of communication options that provide maximum benefits with minimal coordination costs. This agents' motivation leads to the formation of coordination mechanisms in the socio-economic system, which are the institutional consolidation of the successful and most often used variants of the fundamental coordination process for different types of agents' joint activity.

This study develops an approach according to which agents for each type of their joint activity determine the settings of the universal coordination instrument that allows them to obtain maximum benefits from this type of activity with minimal coordination cost. The universal coordination instrument with different settings gives rise to different configurations of the fundamental coordination process, the institutionalization of which gives rise to observable coordination mechanisms. Thus, all mechanisms of socio-economic coordination are based on the same fundamental process, the different configurations of which for different types of agents' joint activity determine the observed differences between the mechanisms.

With this approach, the observable coordination mechanisms receive a “micro-level” description (Parinov, 2023a). This allows one to systematically describe the differences, for example, between the well-known coordination mechanisms “market”, “hierarchy” and “network” (Parinov, 2023a). Additionally, the proposed description of the fundamental process of socio-economic coordination opens the way to the creation of a unified model of socio-economic coordination. Such a model can become the basis for creating methods for improving existing coordination processes and creating new ones, including through the digitalization of coordination processes (Parinov, 2022).

Considering the possible influence of the fundamental process of coordination concept on other areas of socio-economic sciences, it can be noted that the content of coordination costs quite accurately corresponds to the concept of “transaction costs”. The minimization of transaction costs considered in the literature (Williamson, 1985) in meaning exactly corresponds to the desire of agents to reduce coordination costs. The dependence of the choice of organizational forms for joint activities of agents on the amount of transaction costs, described in studies of new institutional economics (Coase, 1995; Williamson, 1985), on the basis of the proposed approach can be clarified and detailed. The introduced ideas about the fundamental process of coordination make it possible to rethink and develop the concept of transaction costs and give impetus to the further development of institutional economics.

Another important application of the fundamental process of coordination concept is the search for a solution to an unusual problem: how can the hidden “primary” coordination of the activity of agents, the object of which is the “secondary” well-known observable coordination of different types of activities of agents, be organized? Primary here is coordination, with the help of which agents create or improve coordination mechanisms, without which their main joint activities would be impossible. Secondary is the coordination of the main activities of agents to obtain benefits, examples of which are the market, hierarchy, network, etc. Coordination of the activities of agents to create and improve coordination mechanisms, which in a certain sense is “primary,” was called “metacoordination”[1] in this study.

The need for metacoordination is explained by the regular agents’ demand to maintain and improve the quality of already established coordination, as well as to create coordination mechanisms for emerging new types of joint activities. This need is quite common. For example, a survey of aerospace managers and engineers reported in (Crabtree et al., 1997) noted that on large complex projects, “activities which involve coordination occupy approximately 69% of an engineer's time in collaborative design” (Crabtree et al., 1997, 1997). p. 83). They also estimate that due to coordination problems, the project implementation time increases by at least 20-30%. Thus, properly organized and “cheap” metacoordination increases the efficiency of implementing complex types of joint activities, reduces various types of losses including wasting time, and also lowers the threshold at which agents can create new types of joint activities. All this is a favorable factor for socio-economic development.

The proposed concept of the fundamental coordination process allows one to analyze the possibilities of creating a universal mechanism of metacoordination. Such a mechanism will

[1] Allen Buchanan uses a similar term “metacoordination view” (Buchanan, 2018).

significantly simplify the design of, in a certain sense, optimal coordination mechanisms for various types of agents' joint activity. Optimality in this context means that the coordination mechanisms constructed using the metacoordination mechanism will provide conditions for agents to obtain maximum benefits from their main activities with minimal coordination costs. Thus, this study analyzes the theoretical possibility of constructing a metacoordination mechanism that is universal for all types of socio-economic activity. Universality in this case means that it is enough to have one such mechanism to solve all the problems of designing or improving for the main agents' activity mechanisms of coordination, regardless of the activity types.

Scientific substantiation of the possibility of constructing a universal mechanism of metacoordination seems important for the modern socio-economic activities of agents. This opens the possibility of creating a public online service available to all participants in socio-economic activities in the form of a global online platform for the decentralized design of the coordination mechanisms they need. Such a service, based on modern computer technologies, would compete with existing institutional structures that regulate the creation of new types of joint activities of agents.

Section 2 provides a general context for this study. Section 3 discusses the hypotheses and basic concepts that are used to identify and describe the causal relationships leading to coordination. Section 4 describes a system of causal relationships that creates a universal coordination instrument based on the SMM, which uses the fundamental coordination process. Section 5 discusses some consequences of the fundamental coordination process concept. Section 6 examines the content of metacoordination and analyzes the possibility of constructing a metacoordination mechanism by configuring and adjusting the fundamental coordination process to the specifics of metacoordination activities. In conclusion, some directions for further research are listed.

2. General context of the study

Let us define joint socio-economic activity as the activity of agents (people), the benefits of which depend on the characteristics of the coordination of this activity. The more complete agents take into account in the process of coordinating their joint activity the information that is initially distributed among them, the higher the likelihood of obtaining higher benefits from the corresponding activity. The accounting process can work with the bounded rationality of agents (Simon, 1978) and their opportunistic behavior (Williamson, 1985). As will be shown below, in the proposed approach, agents analyze information about other agents and therefore, theoretically, can identify cases of opportunistic behavior and minimize its impact on their joint activity.

Improving coordination characteristics by developing methods for integrating distributed information, can be considered as one of the sources to increase the benefits of agents from their joint activities. One of the most famous discussions of the problem of complete accounting of factors important for economic activity belongs to Hayek: "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).

The integration of information, which is initially distributed among all potential participants in joint activities, is considered as a necessary condition for the emergence of socio-economic coordination. The characteristics of methods for integrating distributed information, which, among other things, is contained in the minds of agents, directly affect the completeness of the agents' consideration of each other's activity and intentions. As a tool for integrating distributed information, this study considers the shared mental model (SMM), which concept has been actively developing in recent decades in the Cognitive Sciences and more specifically in the Teamwork Theory (Johnson-Laird, 1980; Mantzavinos et al., 2004; Badke -Schaub et al., 2007). The SMM concept explains how the information about the conditions for agents' joint activity, which are initially contained in the individual mental models (Craik, 1967) of different agents, synchronize and complement each other. Regular synchronization of the individual mental model content of agents in terms of their joint activities leads to the formation of a SMM in the minds of each participant. Thus, distributed information is integrated in the consciousness of each agent and conditions are created for solving Hayek's problem of using knowledge that is not given to anyone in its entirety.

Synchronization of the content of individual mental models of agents and the appearance of their SMM occurs due to the communications and exchange of information between them. Based on the most general assumption about the number and properties of socio-economic agents, the following main communication options can exist between them: 1) direct communications, i.e. "live" or "face-to-face" communication; 2) indirect, i.e. mediated by the common environment; and 3) lack of communication. By social evolution, agents have developed ways of forming and updating the SMM for these three communication options (Parinov, 2023a). For these basic communication options, agents can keep the SMM content up to date using different methods. Thus, agents take into account each other's activities using SMM for all possible communication options and thereby ensure coordination of socio-economic activity of any type and for groups of agents of any size.

In the minds of each agent, there are many SMMs created for different types of joint activity. SMM of different agents created for the same types of joint activities are similar in content. Based on the assumption that the consciousness of a socio-economic agent is united, we can conclude that in the mind of each agent there are many different SMMs which form a single mental system for determining the content of the agent's joint activities with other agents. This mental system works similarly for all agents, and it provides a universal coordination instrument of each agent.

The main question for this study is: what process, created by this universal coordination instrument, is present in the coordination of all types of socio-economic activities and therefore can be considered fundamental?

There are at least two studies that can be considered as attempts to describe the fundamental process of coordination.

In the mechanism design theory (Hurwicz, 1973; Jackson, 2001; Maskin & Sjöström, 2002; Hurwicz, & Reiter, 2006), socio-economic coordination is not the main subject of study, although it is implied[2]. Considering that the authors of this theory assess its capabilities as

[2] For example, (Hurwicz & Reiter, 2006, p. 14) wrote that the mechanism is "a formal entity intended to represent a system for organizing and coordinating economic activity".

follows: “almost any conceivable method for making social decisions is a possible mechanism in this framework” (Maskin & Sjöström, 2002, p. 239), one can conclude that this theory also claims to describe the coordination of joint socio-economic activity, since such coordination is a method of making social decisions. The formal definition of the mechanism for allocating resources, which is one of the functions of coordination, in the theory of economic mechanisms is so general that such a definition can be considered fundamental.

The disadvantage of the mechanism design theory is its inability to explain the observed differences in the implementation of coordination. For example, the differences between coordination mechanisms such as market, hierarchy and network (Adler, 2001; Powell, 1991; Provan and Kenis, 2008; Weigand at al., 2003). The low explanatory power of this theory stems from the fact that it does not directly take into account causal relationships that explain what and how leads agents to coordinate their socio-economic activity.

Another study directly poses similar to our study’s main questions: “Are there fundamental coordination processes that occur in all coordinated systems? If so, how can we represent and analyze these processes?” (Malone, Crowston, 1994, p. 91). This study defines socio-economic coordination as the management of interdependencies and its stated purpose is to develop an interdisciplinary theory of coordination (Malone, 1988; Malone and Crowston, 1994; Crowston et al., 2015). The authors examine different types of interdependencies and identify the coordination processes that are used to manage them (Malone and Crowston, 1994). Assessing 10 years of progress in this research area, the authors note: “Challenges for future research include developing testable hypotheses (e.g., about the generality of coordination mechanisms) and more structured approaches to evaluate and choose between alternate coordination processes” (Crowston et al., 2015, p. 29). Thus, here too the question of the fundamental process of coordination and its causal relationships remains open.

In the proposed study, the fundamental process of socio-economic coordination is derived from the system of causal relationships, which, under certain conditions and for three main communication options, form SMM among agents, and turn SMM into a universal coordination instrument. The direct association of such a universal coordination instrument is a distributed simulation agent-based model. Its content corresponds to the SMM. The agents themselves update their information images in this model. They find by simulations feasible options for their joint activity, negotiate and select the best one for practical implementation. All these procedures are carried out in SMM both in direct and indirect communications, and also on the basis of common rules in the absence of communications (Parinov, 2023a).

3. Hypotheses and basic concepts

The description of the causal relationships that lead to the emergence of coordination in the joint activities of socio-economic agents requires the adoption of some hypotheses and the definition of basic concepts.

3.1. Hypothesis 1: Agents benefit from their activities

Obviously, socio-economic agents (people) receive certain benefits from their activity. The form and content of the benefits depend on the type of agents’ activity. In this study, following Pareto, benefit is considered as a relative concept, which is determined by

comparing two or more sets of benefits that are the results of the activity of agents. Agents can determine what set of their outcomes is more beneficial or preferable to another.

The concept of benefit for economic and non-economic (social) activities of agents is clarified below.

3.2. Hypothesis 2: Stochastic environment for the agents' activity

Agents carry out activities, which help them to ensure their existence, in an environment with unpredictable (stochastic) changes. The threat to their existence created by the stochastic nature of the environment gives rise to their desire to obtain maximum benefit from their activities.

This study does not assume that agents have complete information about the conditions of choice. Cases of their opportunistic behavior are not excluded (Williamson, 1985). Their bounded rationality is also assumed (Simon, 1978).

3.3. Hypothesis 3: The agent's benefits depend on taking into account the activity of other agents

There are types of socio-economic activity, the agent's benefit from which depends on the nature of the agent's consideration of the activities of other agents. The more fully and accurately an agent takes into account the content of the activities of other agents, the higher its benefit, and vice versa. Forms of accounting by agents of each other's activities, in general, may have signs of opportunistic behavior. However, to simplify the analysis, this study assumes the "constructive" nature of accounting, in which the content of the activities of each agent as a result of taking into account the expected activities of other participants is determined on the basis of "fair" ways of obtaining benefits.

Under these assumptions, an agent's taking into account the activities of other agents will be called coordination (Parinov, 2023a). From Hyp. 1 and 2 it follows that agents strive to take into account the activities of other agents in such a way as to receive maximum benefit from their activities. Thus, improving the coordination of joint activities can be a source of additional benefits for agents.

3.4. Hypothesis 4: Agents have mental models

Socio-economic agents have mental models (Craik, 1967), using which they can determine the content of their activities, taking into account existing and expected conditions for activity, as well as possible changes in conditions (Mathieu et al., 2000, p. 360; Badke - Schaub et al., 2007, p. 7). Agents can transform their individual mental models into shared mental models (SMMs), in which other agents - potential participants in joint activities - are represented by information about their current and proposed activities (Johnson-Laird, 1980; Mantzavinos et al., 2004; Badke-Schaub et al., 2007).

The exchange of information between agents of the "all to all" type creates a SMM with similar content among different participants in joint activities. The ways of creating the SMM and the ways of using it among different agents coincide to a sufficient extent, which ensures that the participants in joint activities have close expectations regarding joint activities and

the compatibility of conclusions and decisions obtained on the basis of the SMM about the content of their joint activities (Jonker, et al., 2011).

The SMM content depends on the individual skills and capabilities of agents to exchange information, accumulate it, and process information. At the same time, agents, comparing the expected and actual results for the variant of their activities calculated on the basis of the SMM, i.e. by trial and error, can identify the shortcomings of the SMM and make efforts to eliminate them.

Researchers note a number of SMM important functions: a) providing members and participants in joint activities with a way to interpret information in the same way; b) sharing expectations about future events; and c) developing causal relationships for the situation under consideration (Mohammed et al., 2010). Due to the possible combination in the SMM of the partially overlapping content of individual mental models, agents can obtain a more detailed or more complete picture of the state and changes in their common environment.

Let us assume that the SMM, which exists in the minds of agents conducting joint activities, is similar to a distributed simulation agent-based model. This model is simultaneously available to all participants in the joint activity for "reading and editing." All agents can update their information images and add other information in this model in a decentralized manner. The history of the model changes is saved to a certain "depth". Such SMM allows each agent to perform model simulation of various options for joint activities in an interactive model, i.e. with the participation of all other agents. Such simulation of activity options can be collective in nature because agents have the opportunity to participate in them. In general, the way to create and use SMM as a coordination instrument depends on the type of communication between agents and is discussed in the next section.

Let us assume that the SMM performs the function of a "calculator". The "calculator" input receives information about the conditions for joint activities of agents, the form of which depends on the communication options used by the agents. The output of the "calculator" is the agreed decision of the agents about the content of their individual activities. Thus, agents use the SMM to calculate the content of their activity, which takes into account information about the conditions for their activity, including the capabilities and intentions of other agents. In this role, the SMM is a universal instrument for agents to coordinate their joint activities, which is discussed in detail in the next section.

3.5. Hypothesis 5: Agents create SMM under different communication options

Agents, under certain conditions, which are discussed in Section 4, can create SMM for all communication options between them. There are three main options for communication between socio-economic agents: 1) direct communications; 2) indirect; and 3) lack of communication. This list is complete and exhaustive, because for any given agent, his/her communications with all other agents, regardless of their total number and individual characteristics, can only be from these three.

Between the listed communication options, there are differences in the way agents take into account each other's activities.

3. 5.1. Direct communication

Direct communication means the interpersonal exchange of information of the “everyone with everyone” type between agents without intermediaries. An example of direct communications is “face-to-face” communication.

Direct communication is an intuitive way to form and use SMM to coordinate activities. In this case, taking into account each other’s activity occurs as a process of reaching agreements about “who do what” between the participants in joint activities.

Through the continuous information exchange of the “all-to-all” type, agents maintain in each other's minds an up-to-date understanding of each other's current capabilities and intentions. This process of belief formation requires that agents must anticipate what other agents will do and what they will need to do in order to do it (Mathieu et al., 2000, p. 274). Other authors write: “Working cooperatively requires that team members coordinate by anticipating and predicting each other’s needs through common understandings of the environment and expectations of performance” (Salas et al., 2005, p. 565).

3.5.2. Indirect communication

Communication of the “all to all” type becomes indirect when they are mediated by changes in the common environment. To do this, agents leave traces of their activities and/or put 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. Indirect communication, like direct one, allows agents to reach agreement on the content of their joint activities, but this happens in a special way.

The process of forming and using SMM in indirect communication involves the creation by agents in a common environment of some signaling system. Activity traces or labels created by agents based on the signaling system specification, as a rule, have the same (standardized) design. It reduces the costs of agents for recognition and analysis of information received through indirect communication. The received information is accumulated in the individual mental models of agents and is updated because of agents’ constant monitoring of changes in the common environment. Thus, based on the indirect communications, the content of individual mental models of agents is partially synchronized and due to this, the mental models of agents get the properties of SMM.

Coordination based on indirect communication has been called “stigmergy” in the literature (Elliott, 2006; Marsh and Onof, 2008; Elliott, 2016; Heylighen, 2016). “In its most generic formulation, stigmergy is the phenomenon of indirect communication mediated by modifications of the environment” (Marsh, Onof, 2008, p. 1). When applied to economic systems, stigmergy is associated with the operation of a market coordination mechanism: “Probably the best-known example of stigmergic self-organization is the ‘‘invisible hand’’ of the market: the actions of buying and selling leave a trace by affecting the price of the transacted commodities” (Heylighen, 2016, p. 5). The process of reaching agreements in indirect communications assumes that agents, by trial and error, placing labels in the common environment and analyzing the response, “tatonnement” for the content of their activity, which is most demanded by other agents.

In this study, it is considered that indirect communications are carried out by agents alienating ready-made results of their activities into the common environment. For example, agents place goods on the market that are ready for consumption. In this way, agents offer

other agents the options of their joint activities for agreement. The alienation of information about activity options, rather than its results, is not considered in this study, because this case is close in meaning to direct communication.

3.5.3. Lack of communications

To act consistently in the absence of communications, agents participating in joint activity use common rules of behavior, or a given plan of action, or explicit or implicit norms, roles and instructions created in advance and/or existing as cultural and behavioral generally accepted attitudes. We will call this case the joint activity of agents based on the common rules.

Using the common rules, agents by default assume that all participants in a given type of activity act on the basis of the same rules. By this they take into account the activity of each other. In social evolution agents have already formed common rules for various situations related to joint activities and not requiring communication between them. For example, this is how the rules for the use of public goods work, which allow people, even in the absence of direct or indirect communications between them, to consume public goods taking into account each other's interests. Traffic rules determine the permitted maneuvers of traffic participants in the absence of signals from other participants in sight. The rules for preparing scientific publications and citing them determine how scientists, without communicating with each other, must use each other's results for the purpose of collective development of scientific knowledge.

When agents, in the absence of communications, need to take into account the activities of other agents, then, as assumed in this study, they use the SMM. However, in this case, the SMM arose not as a result of communications between them, but as a result of the adoption of the same rules for execution by all participants in the joint activity. The use of common rules by agents for their joint activities is equivalent to the use of SMM.

The method of forming SMM based on the common rules has various special cases, one of which is the action of agents in the absence of communications based on a "common plan." The presence of a "common plan" implies that someone, based on his/her information about some joint activity of all participants, develops a plan of action for each participant who does not have communications with each other. If the "common rules" is traditionally quite conservative method, then the "common plan", communicated to each agent, can be dynamically adjusted to changing conditions, as well as individualized due to its adaptation to the capabilities of a particular agent.

It should be noted, agents can use the common rules method in an opportunistic way. In this study such cases are not considered, because it is assumed that the SMM allows agents to detect and deal with such cases.

All three SMM forming methods, based on the direct, indirect and without communication options, will be called in this study as an information "interface". The "interface" connects the SMM with agents and with the common environment of the agents. So, the "interface" is responsible for the representation completeness in the SMM of factors important for the joint activity of agents, as well as for the timely updating of the SMM content.

3.6. Hypothesis 6: Agents use SMM for all types of activity

Agents use SMM to coordinate all types of their joint socio-economic activity, but there are some differences in this process for economic and non-economic (social) activity.

3.6.1. Economic activity

Economic activity, by definition, consists of processes of production, distribution, exchange, and consumption. Each of these processes is a joint activity of agents and requires coordination (Parinov, 2023a). In the production process, agents create resources in the form of means of production and consumer goods that they need to ensure their existence. The division of labor typical of economic activity creates the need for distribution and exchange between agents of the results of their individual activity. Since everything created within the division of labor system can be demanded by agents to support their existence, all agents must have access to the processes of distribution and exchange of all created resources. Such access is a necessary condition for each agent to benefit from the division of labor system. To simplify the analysis, we will limit our consideration of the coordination of economic activity to the process of coordinating: a) the production of resources; and b) the distribution of produced resources among agents.

3.6.2. Non-economic (social) activity

In joint non-economic activity, there are no processes directly related to the production, distribution, exchange and consumption of resources. An example of a joint non-economic activity is human participation in automobile traffic. In this case, drivers take into account the movement of other drivers' cars, as well as traffic rules, to achieve their goals. The goal of their joint activity in the most general form can be defined as the desire to reach the required location by car at minimal “cost”. Another example of non-economic activity is the preparation and distribution of publications by scientists, which contain the results of their scientific research, with the aim of developing the scientific knowledge. It should be noted, in both examples the activity may have an indirect economic meaning. For instance, participation in automobile traffic can be a part of the driver's economic activity, or scientists need writing publications to obtain higher remuneration. However, the nature of the relationship between participants in non-economic activity is not related to the distribution of life-sustaining resources. Thus, the relationship between participants in automobile traffic consists in coordinating the movement of cars, and the relationship between the authors of scientific publications consists in the collective creation of new scientific knowledge.

In accordance with Hyp. 3, the benefits received by agents from their joint activities depend, among other things, on the characteristics of the coordination of this activity. Let us determine the general content of the benefit and what affects its size for economic and non-economic activities.

3.6.3. Agents' benefits from economic activity

The economic activity’s benefit is determined by the quantity and quality of resources to support life that agents receive from their activity. The resources received by agents and, accordingly, the benefits of agents in the case of economic activity depend not only on the results of activity, but also on the results of the distribution of life resources among agents.

The characteristics of coordination of economic activity affect the amount of the benefit. These characteristics for the production include the agents' ability to find the best solution "who produces what and in what sequence". For the distribution it includes the ability to distribute resources among agents by the agents' ability to use these resources most effectively. Coordination cost, which is discussed below, reduces the amount of agents' benefit from their joint activity.

In the SMM, agents evaluate the benefits from their proposed activity in the following way: agents individually analyze in the SMM what results need to be obtained from their activity to receive in exchange from other agents the desired content of life support resources. The procedure for determining benefits works in SMM regardless of the communication options used by agents.

It is important to note that money and monetary circulation are necessary for agents to reduce costs both for the process of distribution and exchange of created resources, and for assessing the amount of the agents' benefit expected from their economic activity.

3.6.4. Agents' benefits from non-economic activities

The non-economic activity's benefit is determined by the realization of the activity's goal. Different content of the activity can provide different amounts of benefits. The amount of benefit for the activity of a given content depends both on the completeness of taking into account all important factors and on the amount of coordination costs. For example, the size of the benefit of a participant in automobile traffic directly depends on the completeness of the agent's consideration of various factors that arise during the movement and it inversely depends on the amount of the agent's costs for performing maneuvers and traffic rules.

In the most general form, the differences between economic and non-economic activities from the point of view of their coordination processes are determined by the fact that obtaining benefits from economic activity is mediated by the process of the produced resources distribution. Whereas for non-economic activities there is no "distribution" stage. The benefits of agents from their non-economic activities depend only on the results of the corresponding activities of the agents.

3.6.5. Coordination costs

For any communication option, agents spend a certain amount of time and effort on coordinating activity, which in this study represent coordination costs. So, direct communication typically requires more coordination costs than indirect ones. Coordination of activities without communications, i.e. based on common rules, has the lowest level of coordination cost.

Coordination costs reduce the agents' benefits from their joint activity. For example, agents, spending time on coordination, lose a certain amount of benefit from their joint activities that they could create during this coordination's time. In this sense, coordination costs are close in content to the concept of "transaction costs".

3.7. Hypothesis 7: Free will and equal rights of agents

Agents have free will and equal rights to choose the content of their joint activities. All joint activity participants must agree with a certain variant of their joint activity to turn it into implementation. This statement has the exception when executing agents have delegated their right to make decisions on the content of activity, for example, to agent-managers within the framework of hierarchical coordination (Parinov, 2023a). The procedure of reaching agreements is performed by agents in their SMM and it is discussed in the next section.

The consent of each agent to accept a certain variant of joint activity for its practical implementation is determined by the following condition: the individual benefit of the agent from the agreed upon variant of activity minus its costs of coordination must be maximum. Under this condition, agents may agree with the implementation of an "acceptable" rather than a "best" activity option. Because further negotiation of the current option to obtain greater benefits requires additional time, which makes the best option less profitable than the acceptable current one.

The desire of each equal agent to obtain the maximum benefit from his/her joint activities, as well as the need to obtain the consent of all agents to implement some given variant of joint activity, means that agents in the process of coordinating activities strive to find an equilibrium solution. For such a solution, the amount of individual expected benefit calculated by agents in the SMM for their agreed upon activity option is close to Pareto optimal for the existing conditions for their joint activities, including the costs of its coordination. In this situation, increasing the benefit of any agent is impossible without reducing the benefit of other agents.

3.8. Hypothesis 8: Disturbances in the common environment

Following Hyp. 2 in the agents' common environment and in the state of the agents themselves, random (unpredictable) changes occur with a certain intensity. Let us call them the "disturbances". The flow of random disturbances changes the conditions of joint activity for which the agents agreed on the content of their activity. Consequently, the previously agreed solution ceases to be Pareto optimal. As a result, agents get motivation to restore or improve coordination.

Assuming that the common environment of agents constantly produces such disturbances, we can conclude that the "movement" towards equilibrium and Pareto optimality due to improved coordination of the joint activities of agents constantly exists. We will call such a situation with a constant process of improving coordination as maintaining coordination. To maintain coordination, agents re-solve the task of coordinating their activities at each critical disturbance in the conditions for their activities.

3.9. Hypothesis 9: Agents have limited computing capability

The mental capabilities of agents and the current power of computer and algorithmic information processing tools, that agents can use in the modern world, determine their current computing capability. The amount of time that agents spend processing the SMM input information flow to make decisions about the content of their joint activities depends on the current computing capability. The probability of disturbances occurring in the conditions for the agents' activity (Hyp. 8) limits the amount of time that agents can spend calculating the content of their joint activities. Consequently, the current computational capability of agents

for a given intensity of random disturbances limits the maximum complexity of analytical problems that agents can solve to decide on the content of their joint activities.

4. The fundamental coordination process

Based on the hypotheses and concepts presented in the previous section, let us consider a set of representations about causal relationships, which, under certain natural conditions, leads to the emergence of socio-economic coordination. The requirements for this task are: 1) the set of representations 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.

The reason for the emergence of coordination is the desire of agents to receive more benefits from their activities (Hyp. 1-3). The consequence of this reason is the use by agents of their natural capabilities to form and actualize the SMM. And the use of SMM to determine the solution on the content of their activities taking into account the activities of other agents. The solution should allow agents to get the maximum benefit from their joint activities. Agents create SMM for each type of their joint economic and/or non-economic activity (Hyp. 6).

Thus, as an instrument for achieving and maintaining coordination by agents participating in joint activities, this study considers the SMM (Hyp. 4), which is formed by agents using the three main communication options (Hyp. 5). SMM plays the role of a universal coordination instrument because agents use it: a) to perform analysis and mental simulation of their activity variants limited by their computing capabilities (Hyp. 9); and b) to find and agree (Hyp. 7-8) a mutually acceptable variant of their joint activities, regardless of the type of socio-economic activity and the number of the activity participants.

In the previous section, a comparison of SMM with a distributed agent-based simulation model, which works as the “calculator”, was proposed. In addition to the “calculator”, agents create the “interface”, which is necessary for the formation and updating of the content of the SMM using three communication options. In its full form, the universal coordination tool consists of the “interface” and the “calculator”. The SMM formation and the “interface” creation were described in the previous section. This section considers the basic functions and procedures of the “calculator”.

The main “calculator” functions as a part of the universal coordination instrument are: 1) simulations and creation of agents’ joint activity variants and assessment of the agent’s expected benefit; 2) negotiation on the joint activity variants proposed by agents, choosing the best one and translating it into practical implementation; 3) maintaining coordination of the implemented variant, including adjusting and improving coordination characteristics.

4.1. Determining variants of activity

To determine the possible content of joint activity, agents individually perform simulations in the SMM of possible activity variants. When simulating and analyzing activity variants, each individual agent takes into account the expected activity of other joint activity participants using information about them contained in the SMM. Analyzing activity variants agents evaluate the expected benefits from the corresponding activity. Agents use the obtained

benefit estimates to compare and select the best of their own variants and offered by other agents.

If agents perform economic activity, while simulating they additionally determine the individual value of the resources produced by other agents, which they need to receive in the process of distributing the results of economic activity among all agents. The agent defines the individual value of resources as the opportunity to obtain, using these resources in his activities, a benefit of a certain amount. The greater the expected benefit from an activity variant, the higher the value for the agent of the resources he/she needs to implement this variant.

The variants of agents' joint activities created and proposed for approval are contained in the SMM and are available for analysis to all participants in the corresponding joint activity.

4.2. Negotiation of joint activity variants

Negotiation in the SMM of the variants for joint activities proposed by agents to select the best one is carried out by a certain procedure, which consists of: a) a process of exchange of opinions and proposals; b) the process of reaching an agreement for all agents regarding the best variant for their joint activities. Let us consider how this procedure is implemented with direct communications, indirect and without communications for any joint socio-economic activity, including specific additions for the economic activity.

4.2.1. Direct communication

a) In direct communication agents exchange opinions and suggestions in the form of "face-to-face" communication to improve available variants for their joint activity. Based on SMM, agents can propose changes to all existing variants and/or propose new variants.

b) Obtaining the consent of all participants in joint activity regarding the choice of the best variant for their joint activities occurs in the process of exchanging opinions and proposals. The agreement of all agents with the choice of a certain variant as the best is influenced, on the one hand, by the desire of each agent to obtain the maximum benefit from their joint activity using this variant, and on the other hand, by the desire to limit the increase in coordination costs caused, in particular, by the increase in the amount of time spent searching and agreeing on the optimal variants for everyone.

An increase in the expected benefit from continuing negotiation is accompanied by a corresponding increase in the time spent on coordination and, therefore, an increase in coordination costs. Increasing coordination costs reduces agents' expected benefits. Agents accept a joint activity variant for implementation if it provides the maximum benefit to all agents, taking into account the expected reduction in this benefit as the agreement continues. Thus, agents may agree to the implementation of an "acceptable" rather than a "best" activity variant, because continuing to negotiate the current variant to obtain greater benefits requires more time, which makes the best variant less profitable than the acceptable current one.

For economic activity, the amount of benefit an agent receives from his/her economic activity depends, among other things, on the results of the distribution of resources among all agents. Therefore, the negotiation on a variant of economic activity also includes the negotiation of the distribution of resources created by all agents participating in joint activities. If the

individual value of resources is determined as described in Section 4.1., then the distribution of resources among agents according to their individual value gives the agents a maximum total benefit, a portion of which accrues to each agent. The need to obtain the consent of all participants on the choice of activity variant and on the distribution of created resources means that each agent can ensure that he/she receives an acceptable share of the increase in benefits from the joint activity. Thus, agents receive maximum benefit from their economic activities if resources are distributed among them by the estimates of their individual value calculated in the SMM.

The desire of agents to obtain the maximum benefit, subject to their equality in a negotiation on the content of their joint activity, tends to equilibrium in the agents' joint activity. Achieving equilibrium in this case means that the agents have determined the Pareto optimal variant for their joint activities, in which no agent can increase his/her benefit from joint activity without reducing the benefit of other agents.

4.2.2. Indirect communication

a) In indirect communication agents exchange opinions and proposals, created in their SMM, by interacting with a common environment, but not directly with each other. Based on the SMM content, agents individually determine the best variant for their joint activity and alienate it into the common environment in the form of a proposal for other agents. Agents use some signal systems to present their proposals. Such proposals are based on agents' beliefs about the expected activities of other agents. In this study, the alienation of proposed activity variants 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, proposals from agents arise on the market, which have the form of created resources or services (actions) provided by agents. The same scientists alienate resources into the common environment in the form of their publications, and participants in automobile traffic perform actions in the form of sending signals to other traffic participants.

b) In indirect communication reaching an agreement of all agents to implement some variant of their joint activity is implemented as a series of agents' tries to guess each other's demand and offer each other the needed resources. A sign of reaching an agreement in this case is a situation when agents demand all produced resources. To achieve this state, agents analyze in SMM the information about reaction (demand) of other agents to their proposed activity variants (resource or service). Using this information, they adjust the proposed variant for their joint activities, creating and alienating renewed resources or services into the common environment. Negotiation among agents in this case occurs by trial and error. Agents step by step take into account in their activity the reactions and expectations of other agents more and more accurately, because this is a way for them to get the maximum benefit from their joint activity.

For example, participants in road traffic who conduct joint non-economic activities use a generally accepted signaling system, i.e. give signals and take into account the signals of other participants before maneuvers. All participants in automobile traffic analyze the results of activity (i.e., movements) and the signals of other participants in their visibility zone. Based on this information, each participant determines the best movement variant for himself, which takes into account his expectations about the character of other traffic participants movements. Through trial and error, traffic participants negotiate the patterns of movement in

traffic to obtain maximum individual benefit from this activity, which is to reach the destination with minimal losses.

In another example, scientists who are participants in another type of non-economic activity present their proposals for the development of scientific knowledge in the form of publications. The response of other scientists to the content of publications in the form of reviews and citations helps scientists-authors adjust the content of their research to better align it with the expectations of other scientists. In this way, scientists determine the content of their activity, which is most in demand by other participants in the joint development of scientific knowledge, and which brings them the maximum benefit in forms of the use (citations) of their results by other scientists and the raise of their academic reputation.

For economic activity, the process of reaching agreement during indirect communication is quite accurately described by the "Walrasian tatonnement" procedure. This comparison becomes even more correct if SMM is viewed as a "Walrasian auctioneer." The common environment in this case is the market. The signal system is the market rules. Agents alienate into the market their proposals for their joint activity in the form of resources and services ready for consumption. In this way, market supply is formed. Agents express their preferences regarding the distribution of resources created by other agents in the form of demand for the corresponding resources. Agents take into account information about prices, supply and demand for resources and repeat the above. Repeated repetition of this procedure leads to balancing of market demand and supply both in structure and in quality/quantity of resources, which means coordination of the economic activities of agents.

By the same way, the distribution of resources is agreed upon in accordance with agents' maximum individual values, because resources on the market typically go to agents who have 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 following conditions also apply:

- If prices, as a measure of the magnitude of demand and supply for resources, accurately reflect the expected benefit of agents from their joint activities calculated in the SMM and the associated individual value of resources.
- And also if the SMM, used by the agents, contains accurate information about the conditions for joint activities.
- Then the agents will be able to find the Pareto optimal activity variant that will give them the maximum benefit.

The desire of agents to obtain the maximum benefit using the "tatonnement" through trial and error to determine the activity variant that will be most in demand by other agents, tends to an equilibrium in the agents' joint economic and non-economic activity. Achieving equilibrium in this case means that the agents have determined the Pareto optimal variant for their joint activities, in which no agent can increase its benefits from joint activities without reducing the benefits of other agents.

4.2.3. No communication

a) There is no exchange of opinions and proposals if there is no communication between agents. However, agents use the common rules to determine the content of their joint activity, since the agents' intention to use the common rules provides their individual mental models with the properties of SMM. Such a SMM allows agents to simulate and choose variants for

their joint activity, assuming that the activity of other agents in the same conditions are based on the same rules.

b) Reaching an agreement of all participants in their joint activity regarding the choice of the best variant for their activities, in the absence of communications, is implemented in a simplified form. SMM, based on common rules, allows agents to choose individually an activity variant with maximum benefit for themselves, but without the possibility of receiving reactions of other agents on this choice. The choice of activity content based on common rules, by default, means that such activity is consistent with the activities of other agents. Under these conditions, the actual coordination of the agents' activity depends on the quality of the common rules that the agents use. Agents can adjust the common rules to improve their joint activity coordination. If random disturbances change the conditions for joint activity without communication among agents, then the corresponding common rules need to be changed. Maintaining coordination in this case means the performance monitoring of current common rules and adjusting of them if necessary.

It should be noted that in the absence of communications, the activity of agents can also be coordinated based on a common plan. The activity of agents who do not communicate with each other but carry out the “perfect” plan of action that someone provided to them, theoretically, can have a high level of coordination.

A state of equilibrium in relations between participants in joint activities operating without communication and using the common rules is present, although in a degenerate form. In this case, equilibrium is not the result of motivations and restrictions of agents, but is given, because is determined by the inability of agents acting on the basis of common rules to influence each other in the absence of communications between them. So, this situation is considered as the degenerate equilibrium.

4.3. Maintaining coordination

Maintaining coordination of joint activity begins from the moment of its practical implementation. Let us assume that the beginning of the practical implementation of the agreed variant of joint activity is the acceptance by its participants of a certain responsibility for its implementation. The method of fixing the responsibility of agents in this case is various types and forms of contracts (Williamson, 1985). The contract should set up a “penalty” for the agent who violates the agreed upon decision. In this study, contracts as a way of fixing the responsibility of agents are considered as part of the SMM. An agreed activity receives an attribute in the SMM indicating that it can be performed. In addition to this, a method is required to withhold the “penalty” from agents who violate the contract and to compensate losses to “victims”.

The procedures for coordinating joint activity discussed above allow agents to implement the “acceptable” variants, which can have a reserve for increasing the agents’ benefits. In implementing some given variant of joint activity, agents can continue to search for new variants of activity or agree on improvements in current variants that promise them an increase in the amount of benefit. In the absence of disturbances in the conditions for joint activity, agents can eventually find a variant of joint activity that is Pareto optimal. In which none of agents can increase their benefit from joint activity without reducing it for other agents.

In fact, the unpredictable disturbances occur from time to time in the conditions for agents' have implemented joint activity. These disturbances can be either the random appearance of new activity variants that promise more benefits compared to the current one, or an unexpected change in the structure of demand, availability of resources, and etc. The real situation is the desire of agents to maintain coordination of their joint activity despite emerging disturbances. Agents respond to disturbances by adapting the content of their joint activities to new conditions in order to maximize benefits. In this case, agents are searching for dynamic equilibrium with a constant tendency to Pareto optimal content of their activity.

4.4. Fundamental Coordination Process

The described above universal coordination instrument provides coordination and brings relationships between joint activity participators closer to an equilibrium. In this instrument there is a basis that remains essentially unchanged in various implementations, differing both in communication options and in the types and properties of joint activities (economic and non-economic, etc.). Summarizing the previous contents of this section, let us present the procedures that form the basis of the universal coordination instrument:

1) the "interface" that is responsible for transforming individual mental models of participants in joint activities into collective ones (SMM), i.e. the interface ensures the formation and updating of the SMM;

2) the "calculator" in which agents simulate activity variants, assess both the expected benefit from these variants and the expected value of resources, as well as select and agree with other agents on the best activity variant and transfer it to implementation mode;

3) maintaining coordination during the implementation of the agreed upon activity variant and improving coordination characteristics to obtain additional benefits by repeating the "interface" and "calculator" procedures.

This set of procedures does not depend on the type of joint activity and the number of its participants. It is present in all types of joint, i.e. coordinated, socio-economic activity of agents. This allows us to consider these procedures as the fundamental process of socio-economic coordination.

Tab. 1 shows the functional structure of the fundamental coordination process. In the cells of the table: a) the symbols "+" indicate the presence of the corresponding element of the functional structure for the corresponding communication option; b) a text, like "collectively", "individually", etc., indicates the implementation specific of the corresponding functional element.

Table 1. Functional structure of the fundamental coordination process

	Direct communication	Indirect communication	No communication
1. Interface			
SMM updating	By "face-to-face" communication	Through common environment	Tracking changes in common rules
2. Calculator			

2.1. Choosing variants for joint activity	+	+	+
- generation and analysis of variants for joint activities [and resource allocation]*	collectively	individually	individually
- taking into account the expected activities of other agents	collectively	individually	individually
- assessment of expected benefits [and value of resources]*	collectively	individually	individually
2.2. Negotiation about joint activity	+	+	-
- exchange of opinions and suggestions	By "face-to-face" communication	Through common environment	-
- reaching an agreement	By "face-to-face" communication	Through common environment by "trials and errors" method	-
3. Maintaining coordination			
Repeating "interface" and "calculator" procedures	+	+	+

*) for economic activity only

This fundamental process leads to coordination when the following conditions are met:

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 activity;
b) If "a" is satisfied, then there must be at least one variant of joint activity, the expected benefit of the agents from which exceeds their coordination cost, and the computing capabilities of the agents must be sufficient to find this variant using their 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".

Conditions "a" and "b" are obvious. It follows from them that the fundamental process of coordination does not work properly if the participants in joint activity and their SMM do not have the necessary characteristics. Condition "c" is more complex, so let us discuss it in more detail.

The ability of agents to coordinate their activity is influenced by the stochastic nature of the common environment and to a certain extent 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 critical. Computing capabilities determine the amount of time required for agents to analyze the input flow of information and make decisions about the content of their activities in the SMM. From the point of view of maintaining coordination, 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.

Socio-economic coordination is possible if the time interval between critical disturbances exceeds the amount of time that agents need to coordinate their activities. For coordination emergence, agents need to achieve a coordinated state faster than the next critical disturbance that will require re-coordination of activity. At the same time, agents must manage to receive benefits from their joint activity that cover their coordination cost.

Coordination is impossible if unpredictable changes in the common environment devalue the content of the participants' SMM faster than they, 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 fundamental coordination process described above leads to coordination if the computational capabilities of the agents correspond to the complexity of the coordination task, which, in turn, depends on the intensity of the disturbances and on the amount of information that the agents need to analyze in the SMM to coordinate their activities.

Agents implement a fundamental coordination process in parallel with their main joint activities and on an ongoing basis. The reason for this is the motivation of agents to reduce coordination cost and increase benefits if an "acceptable" option for the content of their activities is currently used. Another reason is created by random disturbances in the conditions for joint activity, which require agents to make efforts to maintain coordination in their joint activity.

5. Some consequences

Let us consider some consequences arising from the fundamental coordination process concept.

5.1. Observable manifestations of the fundamental coordination process

The fundamental process of coordination can manifest itself, i.e. becomes observable, in different forms. Its manifestation form depends on the dominant communication option used by agents for the "interface" configuring. In accordance with the conceptual model of the coordination mechanism design (Parinov, 2023b), agents strive to find the fundamental coordination process configuration that, for a given type of joint activity, will ensure they receive maximum benefits with minimal coordination cost. Under the influence of these driving forces, coordination mechanisms are formed for each type of joint socio-economic activity, which represent combinations of settings of the "interface" and "calculator" of the universal coordination instrument. In (Parinov, 2023a), based on the same approach, micro-level descriptions of the well-known coordination mechanisms "market", "hierarchy" and "network" are presented. These descriptions illustrate observable manifestations of the fundamental coordination process.

Thus, the observable manifestations of the fundamental coordination process are the coordination mechanisms. For example, coordination mechanisms such as "market", "hierarchy", and "network". Each coordination mechanism is some setting of a universal

coordination instrument for a specific type of agents' joint activity to obtain maximum benefit. For the successful and most frequently used configurations of the fundamental coordination process agents create institutional structures that reduce coordination cost.

5.2. Coordination, Optimality and Equilibrium

The considered causal relationships, which form the fundamental process of coordination, make it possible to discuss in this context the concepts of optimality and equilibrium.

Let us assume that for the fundamental process of coordination all the conditions necessary for coordination to occur are satisfied. As noted above, if agents have equal rights and strive to obtain the maximum benefit from their joint activity, then through trial and error the agents can bring the content of their activity closer to Pareto optimal. When the content of joint activity approaches Pareto optimal, an equilibrium arises in the parameters of joint activity: no agent can, by changing the content of his/her activity, increase his/her benefit without reducing the benefit of other agents.

However, in a real environment, agents may not have time to approach Pareto optimality and equilibrium due to the flow of random disturbances. In this regard, and because of the existence of coordination cost, agents may agree to implement an "acceptable" variant of their joint activity, which gives them not the maximum, but sufficient benefit. This solution allows them to begin to benefit and, at the same time, creates motivation to continue improving their coordination characteristics.

Thus, the application by agents of the fundamental process of coordination creates the driving forces to achieve a state of Pareto optimality and equilibrium in the system of their joint socio-economic activities. However, this state, if achieved, cannot exist for a long time due to the constant flow of disturbances changing the conditions under which the activity was coordinated. The ability of the settings of the universal coordination instrument created by agents for a given type of joint activity to achieve optimal solutions and bring this joint activity into equilibrium can be considered as a characteristic of the quality of the corresponding settings.

General equilibrium in economic theory is defined as the establishment of equilibrium in exchange and production. The fundamental coordination process for economic activity, as noted above, is the coordination of both: the production and distribution (exchange) types of activity. Thus, the driving forces, which activate the fundamental process of coordination for economic activity, create a tendency towards a general equilibrium, which, for the reasons described above, is either not achieved or lasts for a short time.

Assuming the consciousness of agents combines into a single system various instances of the universal coordination instrument created for various types of their joint socio-economic activities, it is possible, based on the unified methodology, to describe a general equilibrium model for the entire complex of human socio-economic activities. This, in turn, allows us to put forward a hypothesis about the possibility of creating a single coordination mechanism for all types of socio-economic activity (Parinov, 2022; 2023b).

5.3. Coordination costs and transaction costs

Coordination costs arise for agents in connection with the setting up and using the universal coordination instrument. It includes the costs of performing the procedures from Tab. 1: 1) formation and updating of the SMM; 2) selection of a joint activity variant based on the SMM; 3) negotiation about joint activity; and 4) transfer of agreed activity variant into practical implementation mode. In content, these costs are similar to transaction costs, which are the costs of searching for information, the costs of measurements, evaluation and control, the costs of negotiations and decision-making, the costs of legal protection, including the execution of contracts, the costs of opportunistic behavior, and etc. (Coase, 1995; Williamson, 1985). Although the cost sources like legal defense, contract enforcement and opportunistic behavior for simplification are not mentioned in Tab. 1., they can arise in procedures of the fundamental process of coordination. Additionally, the ex-post transaction costs discussed in Williamson (1985), which arise when contract implementation goes wrong due to errors and/or disturbances, directly correspond to the costs of maintaining coordination, which is also a part of the fundamental coordination process.

By using the causal relationships that create the fundamental process of coordination, and by assuming that coordination costs are identical in meaning to transaction costs, it is possible to refine some of the classic statements in the field of transaction costs. It becomes possible to more deeply analyze the comparative benefits of various implementations of a given economic activity, for example, depending on the communication option, when more costly communications can be replaced with less costly ones (Parinov, 2023b). For example, one can systematically consider the factors that determine the benefits of implementing an activity either in a market form in which indirect communications dominate, or in the form of a firm in which direct communications dominate. This allows us to reconsider and generalize Coase's assertion that a firm's relative advantage is the ability to economize on transaction costs compared to market transactions (Coase, 1995). On the other hand, the proposed approach allows a more systematic description of the factors and methods of saving transaction costs and the associated criteria for choosing an organizational structure, discussed in (Williamson, 1985).

The area of research developed by the theory of socio-economic institutions (Williamson, 1985) includes the operation of the fundamental coordination process for the case when it is implemented by agents in the absence of communications between them. In this case, agents require common rules that can be established and supported by institutional structures. The approach proposed in this study allows us to reconsider classical institutional concepts in the context of the functioning of processes of socio-economic coordination, which can be fruitful for the development of science.

5.4. Relationships between coordination, collaboration, cooperation, and competition

Let us define collaboration, cooperation and competition between participants in their joint activities as follows:

- collaboration is a joint activity of people according to a common plan;
- cooperation is a joint activity without a common plan, where coordination of activity is achieved in the process of calculation by each agent of the content of its activity based on observations of the activity of other agents, which, as a rule, is implemented by trial and error;
- competition is a joint activity in the presence of competing interests of its participants in limited resources, subject to the presence of a mechanism for resolving this conflict

of interests (for example, there are rules for competition for a higher position between employees in the organization, or price competition between sellers for buyers, etc.).

Let us assume that relationships of collaboration, cooperation and competition between agents are formed in coordinating agents' joint socio-economic activity. In this case, it is possible to determine how these concepts are related to each other using the content of the fundamental coordination process implemented in various types of communications between agents.

As a result of using the fundamental process of coordination to determine the content of the joint activity of agents, the following types of relationships can arise between them:

1. Based on direct communication in the coordination process, the following arise:
   - Pure collaboration, when agents act according to a common plan, realize common goals, and they have no competing interests in limited resources (i.e., there is no competition);
   - A mixture of collaboration and competition, when agents act according to a common plan and realize common goals, but they have competing interests in limited resources and there is a mechanism for resolving this conflict of interests;

2. Based on indirect communications, the following arise:
   - Pure cooperation, when agents who act independently without a common plan and realize their own goals have no competing interests;
   - A mixture of cooperation and competition, when agents acting independently and realizing their own goals have competing interests and there is a mechanism for resolving them;

3. In the absence of communications, the following occurs:
   - Neutral relationships. When agents do not have communication, they act independently of each other and realize their own goals. Due to the lack of communication between agents in their activity, relationships of collaboration, cooperation or competition do not arise (although the participants may assume them).

Since each individual agent has only three modes of communication with all other potential participants in joint activities, then:

- joint activity in direct communication has a pure and/or mixed form of collaboration; this form is the costliest in terms of communication, but also the most effective way of organizing joint activity;
- joint activity in indirect communication has a pure or mixed form of cooperation; but this form cannot be collaboration due to the limitations of indirect communications;
- joint activity in the absence of communication is possible due to the use of common rules by agents, but in this case, it has a neutral form.

6. Metacoordination

The fundamental process of socio-economic coordination is present in all types of joint socio-economic activity of agents, including specific one through which agents design new or improve existing coordination mechanisms. This specific activity of agents to create and

improve coordination mechanisms belongs to the joint socio-economic activity. Even if agents are going to use “as is” a coordination mechanism already created by someone, then in this case there is joint activity between them regarding this mechanism. Agents must assess its suitability for achieving their goals and express consent to use it, taking into account the relationships established by this mechanism between the participants in the relevant joint activity. Thus, the joint activity of agents to create and improve coordination mechanisms itself also requires coordination, in which, accordingly, there is a fundamental coordination process.

In this study, the process of coordination mechanisms design is considered as an objective need of agents that arises when agents are going to conduct joint activity for which there is no previously created coordination mechanism, or existing mechanisms require improvement. Improving coordination mechanisms, as noted in previous sections, is a constant task of agents for two reasons: 1) the possible existence of reserves in current coordination to obtain greater benefits; and also 2) the existence of a flow of random disturbances in the conditions for joint activity of agents. Consequently, the creation and improvement of coordination mechanisms is a regular specific activity of agents. If there is a coordination mechanism for such specific activities, then it reduces the corresponding costs of agents. For example, it reduces the amount of time agents spend on that specific activity, allowing them to use the time saved to gain more benefits from their core activity.

To analyze the approach to a coordination mechanism design problem, on condition that the mechanism is necessary for agents to create other coordination mechanisms, it is necessary to clarify the differences between the following classes of joint socio-economic activity of agents:

a) a core activity with many different types, from which agents benefit;
b) coordinating activity for “a”, which for each type of the core activity uses some coordination mechanism to obtain maximum benefits from “a”;
c) activity to design and improve the coordination mechanisms used in “b”, which should create conditions for agents to receive maximum benefits from “a”;
d) coordinating activity for “c”, which leads to the coordination of the agents’ activity in designing coordination mechanisms and may use some specialized coordination mechanism;
e) activity to create and improve a specialized coordination mechanism for “d”, which should create conditions for designing the mechanisms for “c”, which in turn will create conditions for obtaining maximum benefits from “a”.

Theoretically, this list can be continued because it obviously contains infinite recursion. However, to simplify the analysis, we will limit ourselves to considering the listed classes of agent activity.

Coordination of the agents’ class “d” joint activity was called “metacoordination” in this study because the prefix “meta” denotes the self-directed action of the term. For example, the term "metadata" means data about data. Thus, the term “metacoordination” is understood as the coordination (class “d”) of the agents’ activity to design a coordination mechanism (“c”) to support the coordination of the core activity (“b”). The support of metacoordination (“d”) needs to design a metacoordination mechanism (“e”).

Allen Buchanan introduced for scientific circulation the closely related term "metacoordination view" to justify the need for coordination of agents to determine legitimate institutions, which have coordinating functions: "It is not enough that we all recognize that we need an institution; we must coordinate our support on one institution among the alternatives. We need to achieve convergence on judgments that this institution deserves our support, is worthy of our respect" (Buchanan, 2018, p.5).

Given the previously mentioned ongoing need to improve existing coordination mechanisms for core activity "a," metacoordination "d" can be seen as a necessary complement to regular coordination. Consequently, metacoordination is, to a greater or lesser extent, constantly present in the agents' activities. Then, in general, socio-economic coordination should include both traditional coordination "b" and metacoordination "d". However, further, to simplify the analysis, we consider metacoordination, i.e. activity of class "d" and related activity of class "e", regardless of the class "b" activity.

Coordination activity of class "d", which creates metacoordination, can be implemented using a special metacoordination mechanism (class "e"). Within the framework of traditional scientific theories, there is still no theoretical basis for constructing a metacoordination mechanism that would work as a single and universal instrument to help agents design and improve mechanisms for coordinating various types of their core activities.

This section discusses an approach to the metacoordination mechanism design. This approach assumes creating a configuration of the fundamental coordination process to perform the functions necessary to implement metacoordination. The task involves: a) analysis of the specifics of metacoordination, which must be taken into account in the settings of the universal coordination instrument; and also b) defining the settings themselves, which take into account this specificity and create a configuration of the fundamental coordination process necessary for the metacoordination mechanism design. The consideration of this task, which is provided below, is quite general and is limited to an analysis of the fundamental possibility of the universal metacoordination mechanism design.

6.1. Specifics of metacoordination

The specifics of the class "d" activity, i.e. metacoordination, which should be taken into account when designing a metacoordination mechanism, includes the following:

a. This activity of agents is non-economic because metacoordination relationships between agents are aimed not at the production, distribution, exchange, and consumption of resources, but at creating conditions for the emergence of coordination for any type of socio-economic activity.

b. The benefit of agents from their joint metacoordination activity is the ability to obtain the desired benefit from their core activity by creating a coordination mechanism for the core activity. Without a coordination mechanism, agents either cannot benefit from joint activity at all, or their benefit amount will be significantly smaller. In addition, the benefit amount from the core activity depends on the characteristics of the coordination mechanism being created, i.e. metacoordination should allow agents to find the best coordination mechanisms for the core activity.

c. Agents have little previous experience in activity such as metacoordination, because most people do not reflect activity to create or improve coordination mechanisms. In addition, the need for such activity for most people is still quite rare. It follows from this that the metacoordination mechanism must offer agents sufficiently ready-made solutions and convenient means for choosing the best design of the coordination mechanism they need. These support tools should be available to agents as part of their SMM for metacoordination. Therefore, for metacoordination, agents should ideally receive an almost formed SMM, which already contains a set of "building blocks", as well as scientifically based algorithms for generating, in a certain sense, optimal design of the coordination mechanisms required by agents.

d. In metacoordination, when the design of a coordination mechanism occurs, agents in the metacoordination SMM generate and analyze variants of the mechanism they need. They simulate in the SMM a process of using generated variants in relation to a given type of their core joint activity (class "a") and estimate the amount of benefit that they can get from this. By comparing the benefit estimates obtained in this way, agents determine the best variant for the coordination mechanism they need. There is a nesting of procedures for generating, analyzing and evaluating variants. To determine the best variant of a coordination mechanism, agents must, for each given variant of a coordination mechanism, repeat the same procedures to determine the best variant of their core activity for obtaining benefits from the activity coordinated by a given variant of a coordination mechanism.

Taking into account the specificity of metacoordination activity noted above, let us analyze the possibility of constructing a metacoordination mechanism that would have some necessary properties. Such properties, first of all, include the operability of the mechanism for any, including a very large number of agents, as well as its versatility, i.e. applicability for designing mechanisms for coordinating a wide variety of socio-economic activities. In addition, ideally, the metacoordination mechanism should allow agents to create the mechanisms they require with characteristics close to optimal in terms of the ratio of expected amount of benefits and the magnitude of coordination costs.

To build a metacoordination mechanism, it is necessary to determine the settings of a universal coordination instrument, consisting of an "interface" and a "calculator", which will create the configuration of the fundamental coordination process necessary for the emergence of the metacoordination process, taking into account the features described above and having the required properties. When analyzing the necessary conditions for building a metacoordination mechanism, we will use current representations about the capabilities of modern information and communication technologies (ICT), including online (digital) platforms on the Internet, etc.

6.2. Interface: creation and updating of metacoordination SMM

The first necessary condition for launching a fundamental process of coordination among participants in joint activities is the appearance of their SMM. To do this, agents must form an "interface" that will ensure the collection, presentation and updating of the necessary information in the SMM, including information about the intentions and capabilities of all participants in relation to their planned joint activity. Activity of class "d" metacoordination has no special features in this part, i.e. the creation of the "interface" can be done in the usual for all coordination mechanisms way.

Currently, the creation and updating of SMM can be implemented as the launch of an online "metacoordination" platform, which is used by remote potential participants in joint activities to decentralize the entry and updating of information about their capabilities and intentions in relation to a given joint activity. The information images of potential participants created and updated in this way will be available to each other, which will lead to the emergence of a computer version of the SMM. Such an information system can provide agents with all three communication options: 1) direct, e.g., through messengers; 2) indirect, e.g., by observing the digital "traces" of other agents in common virtual environment; and 3) using the common rules for the option without communication.

6.3. Calculator: generation of metacoordination mechanism variants and selection of the best one

The second necessary condition for launching the fundamental coordination process is the use of the SMM content by each potential agent to simulate variants of his/her joint activity of a given type, taking into account the activities of other participants. To do this, agents must have a "calculator" that, based on current information in the SMM, allows them to analyze the generated variants by estimating the expected amount of benefit from its implementation. Selecting the best variant and reaching an agreement among agents on its practical use also occurs in the "calculator".

6.3.1. Generating metacoordination mechanism variants

The metacoordination specific "c" (see Section 6.1.) means that in the usual case agents do not have the skills and knowledge necessary to generate variants of the coordination mechanism for their joint activity of a given type. In this regard, it is proposed to use the description of the 3-step algorithm from (Parinov, 2023b) as a simplified instruction for creating coordination mechanisms.

At the first step of this algorithm, agents choose the most suitable communication option for activity of class "d". In (Parinov, 2023b) this is described as choosing the most appropriate basic form of coordination. At the second step, agents look for opportunities to reduce coordination costs for the solution found at the first step. For example, replacing, where possible, the initially selected communication option with a less costly one, if this does not lead to a decrease in the expected benefit. At the third step, if after the implementation of two steps there are reserves left in increasing benefits through coordination, then the agents create, as described in (Parinov, 2023b), parallel coordination mechanisms to use these reserves, which increases the overall completeness of coordination and the overall benefit of the agents.

An online metacoordination platform can simplify for agents the process of generating initial variant of the mechanisms they require, offering a set of "building blocks", as well as algorithms for assembling from them, in a certain sense, the optimal variants for the coordination mechanisms required by agents for a given joint activity.

6.3.2. Analysis of coordination mechanism variants

Agents check the generated variants of the coordination mechanism for compliance with their requirements. To do this, they calculate the expected benefit from the generated variants. For

metacoordination, the assessment of the expected benefit has the specific “d” (see Section 6.1.). Calculating benefits in this case means simulating and analyzing in the SMM also the variants for obtaining benefits from the core activity under the assumption that the remaining participants carry out activity of a certain content. In this case, the core activity variants and related the full amount of agents’ benefit, which depends on the amount of coordination costs, are determined by the coordination mechanism features, which comply with requirements the agents analyze. By simulating the variants of the coordination mechanism and at the same time the variants of the core activity, agents determine the expected benefit amount. Comparing the estimated benefit for different variants for the coordination mechanism, agents choose the best one.

The agents’ computational capability limits the complexity of analytical tasks that can be solved in SMM. The complexity of the coordination mechanism’s variants analysis including the expected benefit calculation must correspond to the computing capability of the agents. If the computational capability of agents at a certain time can be considered as given, but the complexity of the analysis tasks can be adjusted by agents. This study examines two variables that influence the complexity of the agents’ tasks: 1) the complexity is directly related to the number of potential participants whose activity must be taken into account; and 2) complexity directly depends on the amount of information (for example, the number of details) that the information images of the participants contain. Agents must set the values of these variables in the SMM so that the task complexity allows them to solve it at an acceptable time with current computing capabilities. The required time to get a solution for the analysis task is determined by the ratio of the following factors: the amount of benefit received by agents from the moment of using the solution until the onset of a critical disturbance must exceed the amount of the agents' costs for metacoordination.

An online metacoordination platform containing a SMM can offer agents computer support in the form of a ready-made simulation model, in which agents are represented by their information images (digital twins). Agents can use the power of the platform’s computers and algorithms for model simulation of the coordination mechanism variants and the associated variants of the core activity to determine the expected benefits. In this case, the computing capability of the agents, which is a critical factor, are increased by using the resources of the online platform.

6.3.3. Agreeing on the best coordination mechanism variant

The third necessary condition for launching the fundamental coordination process is obtaining the consent of all participants in joint activity to implement a certain variant of the coordination mechanism. Achieving agreement among agents requires fixing the responsibility of each of them for the proper execution of the activity required in the implementation of the agreed upon variant of the mechanism. In the case of using an online metacoordination platform, the achievement of agreement is ensured through the interactivity of relevant information technology. Using either a traditional SMM or its digital version, agents can exchange views on the creation and/or selection of a mutually acceptable variant of a coordination mechanism.

Such a process of coordination leads to making a decision, because agents seeking to maximize benefits are motivated to use an acceptable variant of the coordination mechanism instead of searching for the best one for a long time. Continuation of the search for a better variant increases coordination cost and, as a result, reduces the expected benefits of agents.

Using acceptable variants instead of better ones is a compromise, but agents have the opportunity to improve the coordination mechanism already in the process of using it.

The computational capability available to the agents limits the complexity of the coordination task. Adjusting the complexity of this task to suit the available capability is implemented in the same way as described in the previous Chapter. The online metacoordination platform will make it possible to use the power of modern computers and information processing algorithms to solve the coordination tasks, which will allow agents to design significantly more advanced versions of coordination mechanisms.

6.4. Maintaining metacoordination

If the three necessary conditions described above are met, it is possible to create or improve a metacoordination mechanism. As noted, the need to create new mechanisms for the core activities of agents and/or improve existing ones is constantly present. This means the need to ensure and maintain the operation of the metacoordination mechanism on an ongoing basis. Considering that agents operate in a common environment with unpredictable disturbances, maintaining metacoordination is a necessary condition for maintaining the core activities of agents in a coordinated state. Maintaining metacoordination on an ongoing basis means the ability for agents to constantly continue to search for new variants of mechanisms that provide, on the one hand, a reduction in coordination costs, and on the other, an increase in the completeness of coordination by taking into account all factors important for the joint activity of agents.

The coordination of the agents' core activity may lead: a) to Pareto optimality of their activity contents; and b) to the emergence of a general equilibrium in their joint activities. Then this may mean the exhaustion of the current coordination mechanism in increasing the benefits of agents from their core activity. However, constant metacoordination allows agents to find and build a new coordination mechanism that will give them the opportunity to increase the benefits of their activities. Thus, the current metacoordination has the ability to transfer the joint activities of agents to new states of Pareto optimality and equilibrium, characterized by a higher level of benefit.

The implementation of metacoordination in the form of an online platform simplifies the organization of the continuous functioning of the metacoordination mechanism and significantly reduces the threshold for agents to "enter" and use these opportunities for their own needs.

6.5. Conclusions from the section

The analysis carried out in this section confirms a theoretical possibility of a metacoordination mechanism design based on the concept of the fundamental coordination process. With this approach, the metacoordination mechanism receives the property of universality, i.e. applicability to socio-economic activities of any kind. Thus, theoretically, agents' demand to create the coordination mechanisms can be satisfied with a single implementation of the metacoordination mechanism.

The metacoordination mechanism will significantly simplify the creation of, in a certain sense, optimal coordination mechanisms for various types of agents' joint activity. Optimality

in this context means that the coordination mechanisms for the core activity, constructed using the metacoordination mechanism, will be created to provide maximum benefits from agents' core activity with minimal coordination cost. To do this, the algorithms of the metacoordination mechanism for a given type of activity select the settings of the "interface" and "calculator" to create a configuration of the fundamental coordination process that ensures the highest possible completeness of coordination and the lowest possible level of coordination cost (Parinov, 2023b).

If the metacoordination mechanism is implemented in the form of a global online platform, theoretically, it becomes possible to give access to the use of the mechanism to all existing agents and provide them with the ability to design the coordination mechanisms they need in a decentralized way. A global online platform for metacoordination will make it easier for agents to find potential participants in a given activity and agree with them on the details of the coordination mechanism design they need. This also makes it possible to continue to use the digital images of the coordination mechanisms for the core activity, built by agents within the framework of metacoordination, for their intended purpose, i.e. in the form of digital mechanisms for coordinating this core activity.

The metacoordination mechanism allows agents to construct the mechanisms they need, which can take the form of both formal and informal organizations and communities. The metacoordination mechanism as a global online platform, if it appears, will compete with existing institutional structures that regulate the creation of legal forms for the joint activities of agents. Compared to the capabilities of existing institutional structures, the solutions created by the metacoordination mechanism will be based on the concept of the fundamental coordination process and use systemic approach to find the best ways to coordinate the given activity of agents. The use of the metacoordination mechanism gives agents the opportunity to obtain, in a certain sense, optimal solutions for their specific activity. As a result, this will make it possible to transfer part of the traditional regulatory functions of the state to a mechanism of metacoordination, in which the characteristics of coordination and regulation of joint activities will be able to be determined to a greater extent by the participants themselves, removing this burden from the state machine. All this creates a tendency towards increased self-organization and a decrease in the regulatory role of the state. Allen Buchanan wrote about the need for agents to coordinate the use of certain institutions that have coordinating functions (Buchanan, 2018), which exactly corresponds to the idea of decentralized use of the metacoordination mechanism to select for using the institutions as coordination mechanisms.

7. Conclusion

Possible directions for further research and development of the results obtained:

1. A detailed and formalized description of the causal relationships leading to the emergence and maintenance of coordination for various types of socio-economic activity based on the fundamental process of coordination.

2. Development of a unified coordination model for various types of socio-economic activity as a basis for the creation of a general socio-economic theory. Methodological integration with the theory of socio-economic institutions and the concept of transaction costs.

3. Development of a model of the fundamental coordination process in the form of a computer agent-based simulation model, including the formation of the agents' SMM and the emergence/maintenance of coordination among participants in joint socio-economic activities. Integration of this model into simulation models of socio-economic systems for an endogenous representation of the coordination mechanisms in them.

4. Development in the form of an online platform of algorithms for a universal metacoordination mechanism for building new and improving existing coordination mechanisms necessary for agents for various types of socio-economic activities.

Acknowledgments

The author expresses gratitude for helpful advice to G.B. Kleiner and to members of the seminar "Problems of modeling and development of production systems"; and to Lev Bolotin for fruitful discussions and comments that helped improve the text of this preprint.

References

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

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.I. (2023a). 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 (English version is available as a preprint at Munich Personal RePEc Archive, https://mpra.ub.uni-muenchen.de/114816/1/MPRA_paper_114816.pdf)

Parinov S.I. (2023b). Towards economic coordination mechanisms design. Voprosy Ekonomiki. 2023;(9):121-137. (In Russ.) https://doi.org/10.32609/0042-8736-2023-9-121-137 (English version is available as a preprint at Munich Personal RePEc Archive, https://mpra.ub.uni-muenchen.de/117282/1/coordination-mechanism-design-en.pdf)

Simon, Herbert 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.

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

Adler P. S. (2001). Market, hierarchy, and trust: The knowledge economy and the future of capitalism. Organization Science, Vol. 12, No. 2, pp. 215—234. https://doi.org/10.1287/orsc.12.2.215.10117

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.

Buchanan, A. (2018). Institutional legitimacy. Oxford studies in political philosophy, 4, 53-78. DOI: 10.1093/oso/9780198813972.001.0001 https://www.uio.no/english/for-employees/unitpages/jus/pluricourts/events/2019/buchanan_2018.pdf

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

Crowston, K., Rubleske, J., & Howison, J. (2015). Coordination theory: A ten-year retrospective. In Human-computer interaction and management information systems: Foundations (pp. 134-152). Routledge

Elliott M. (2016) Stigmergic Collaboration: A Framework for Understanding and Designing Mass Collaboration. // In: Cress U., Moskaliuk J., Jeong H. (eds) Mass Collaboration and Education. Computer-Supported Collaborative Learning Series, vol 16. Springer, Cham. https://doi.org/10.1007/978-3-319-13536-6_4

Elliott, M. (2006). Stigmergic collaboration: The evolution of group work. M/C Journal, 9(2). https://doi.org/10.5204/mcj.2599

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

Heylighen, F. (2016). Stigmergy as a universal coordination mechanism I: Definition and components. Cognitive Systems Research, 38, 4-13.

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.

Jackson, M. O. (2001). A crash course in implementation theory. Social choice and welfare, 18(4), 655-708.

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.

Malone, T. W. (1988). What is Coordination Theory? Massachusetts Institute of Technology SSM WP # 2051-88, 1988

Malone, T. W., & Crowston, K. (1994). The interdisciplinary study of coordination. ACM Computing Surveys (CSUR), 26(1), 87-119. DOI:10.1145/174666.174668

Mantzavinos, C., North, D. C., & Shariq, S. (2004). Learning, institutions, and economic performance. Perspectives on politics, 2(1), 75-84. https://philarchive.org/archive/MANLIA-3

Marsh, L., & Onof, C. (2008). Stigmergic epistemology, stigmergic cognition. Cognitive Systems Research, 9(1-2), 136-149.

Maskin, E., & Sjöström, T. (2002). Implementation theory. Handbook of social Choice and Welfare, 1, 237-288.

Mathieu, J. E., Heffner, T. S., Goodwin, G. F., Salas, E., & Cannon-Bowers, J. A. (2000). The influence of shared mental models on team process and performance. Journal of applied psychology, 85(2), 273.

Mohammed, S., Ferzandi, L., & Hamilton, K. (2010). Metaphor no more: A 15-year review of the team mental model construct. Journal of management, 36(4), 876-910.

Powell, W. W. (1991). Neither market nor hierarchy: Network forms of organization. ThFr91, 265-276.

Provan, K. G., & Kenis, P. (2008). Modes of network governance: Structure, management, and effectiveness. Journal of public administration research and theory, 18(2), 229-252.

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

Weigand, H., van der Poll, F., & de Moor, A. (2003). Coordination through communication. In Proceedings of the 8th International Working Conference on the Language-Action Perspective on Communication Modelling. Tilburg, The Netherlands.