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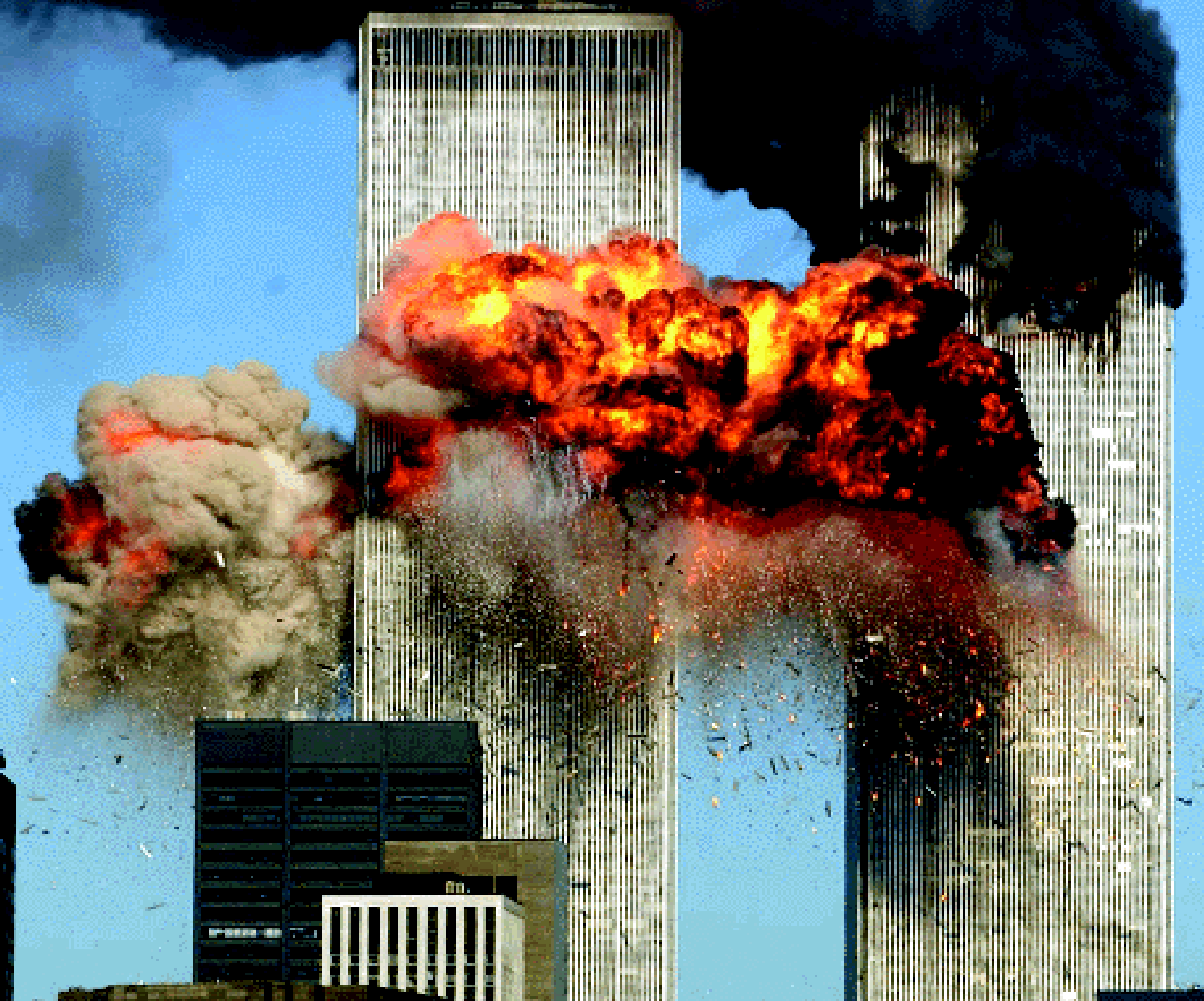

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Scientific articles

Artificial Intelligence Based Simulation of Human Systems. The Case of Terrorist Networks

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Abstract

We raise a question of whether it is appropriate to simulate human and social systems using simple "ant-like" agents, and argue that in order to simulate emergence and evolution of social order, complexity must reside not only on system level (i.e. simple agents with complex relations), but also on the level of an individual agent, in the form of boundedly rational reasoning and planning capabilities. Further, we show that agent's ability to socialize with other agents and form informal friendships is key to the emergence of robust organizational structures.

These theses are supported by an implemented system that uses a large number of intelligent agents to simulate emergence of terrorist cells and planning and execution of a bomb plot. We demonstrate these emergent behaviours with a detective story that is plausible enough to be published in a newspaper, yet is a completely fictional scenario created and performed by a cast of intelligent agents by means of self-motivation and self-organization. We argue that addition of individual-level realism to the model significantly boosts face validity of the simulation results.

1 Introduction

It is fascinating to watch an ant colony. As ants search for food and lay down pheromone trails to mark paths, they unwittingly optimize their search patterns for the good of the commune. Others work to enhance or repair the anthill, or lay eggs, or serve the queen.

The emergent social order is evident in many systems, from the anthill to the markets; these systems demonstrate incredible resilience and adaptivity. Yet, it has been the sole privilege of humans to not only participate in emergence of social order, as an ant would, but to study it, comprehend it, and even consciously work to break it. Thus, systems composed of human beings may well abide by a different set of rules for emergence and breakdown of order (Lissack, Richardson (2001)).

In this paper, we argue that the assumption that a human system can be simulated with sets of simple agents needs to be amended to allow agents significantly higher reasoning power, an ability to perceive and affect their environment and an ability to communicate with others. While previously such design might have been severely limited by availability of computing power, the increase in machine capabilities together with some algorithmic optimizations would allow Artificial Intelligence based decision making into the realm of large-scale multi-agent systems.

We present this argument by focusing on modeling terrorist organizations as networks of people, information, resources, events and places. These networks are viewed as evolving over time. Their topology and characteristics are shaped by the individual-level behaviours of agents – behaviours such as working to complete a task, planning future actions, exchanging items and information, and simply socializing.

We present NetWatch – an example of such large-scale multi-agent system, in perspective of its ability to simulate complex social systems by modeling complexity on both the individual agent level as well as system level. In context of modeling terrorist networks, we describe the emergence of network-centric coordination to complete complex planning tasks, and emergence of an organizational structure as a result of the planning process.

We make no claim that our agents present an accurate model of human behaviour on the individual level. What we aim for is an incremental improvement in veridicality of multi-agent models. This improvement can be achieved through implementation of individual agents in the manner consistent with findings in organization theory and social psychology. Our agents engage in realistically modelled tasks based on the tactics of terrorist actions. They plan their actions by decomposing larger tasks into subtasks, and marshaling resources and knowledge. During idle periods, they socialize, form interpersonal bonds and learn from each other. We argue that models built with high levels of realism on the level of an individual agent have a higher face validity and, in comparison to simpler cellular automata models, can be more instructive as to the behaviour of the macro-level social system.

This paper is organized as follows. We start with a discussion of levels of complexity of social simulation systems, illustrating the discussion with examples from a number of subfields (sec. 2). We follow this discussion with a primer on structure of terrorist Networks. In section 3, we discuss the design and implementation of a multi-agent system for modeling social systems. Section 4 tells a detective story of a terrorist plot. A small group of agents conceives a terrorist attack, plans it, trains for it, recruits soldiers, procures weapons and explosives, and finally executes it. The entire process is emergent from the structural properties of the agents' social network, availability of knowledge and resources, and agents' ability to reason about their surroundings and their internal state.

2. Levels of Complexity and Multi-Agent Simulation

The goal of agent-based modeling can be described as creation of computer-based micro-worlds in which heterogenous agents interact on the world with both reacting to the surrounding conditions and effecting change. Agent-based models of complex adaptive systems are frequently based on the following principles (Langton (1989)):

1. The model consists of a population of simple agents.
2. There is no single agent that directs all of the other agents.

3. Each agent details the way in which a simple entity reacts to local situations in its environment, including encounters with other agents.
4. There is no rule in the system that dictates global behaviours.
5. Any behaviour at levels higher then individual agents is therefore emergent.

Langton's first principle emanates from the general assumption within the sciences ofcomplexity that "simple rules can generate complex behaviours and structures". However, this mandates the practitioner of the art of agent-based modeling to create, for each studied domain, sets of rules that fulfill two seemingly contradictive requirements.

First and foremost, the rules must adequately represent the subject of study. This can be formalized by maximizing the behavioral likeness of the individual agent and the subject of study.

However, the above rules need to also be simple and reliant on a fully myopic view represented in Langton's third principle.

The pressures of reconciling simplicity and veridicality, combined with adherence to Occam's Razor, produce a tendency towards simplicity, thus sacrificing face validity of the emergent behaviours or the model itself (Carley (2002)). Furthermore, the temptation upon the practitioner to create interesting emergent behaviours can result in local rules within each agent that are designed to implicitly generate or alter a global rule - thus also tainting the validity of the simulation.

A solution to this dilemma may require a rethinking of Langton's principles and acceptance of universal complexity, or existence of complexity at every level of study - individual, group, organizational and systemic.

We posit that the creation of high-fidelity models of socio-technical systems requires the combination of analytical models with empirically grounded simulation. Our system, NetWatch combines the advantages of simulations that accentuate fidelity of an individual agent with advantages of simulations that accentuate fidelity of the agent's environment and networks. In NetWatch the topology is viewed as a result of cumulative agent interactions - and thus evolves continuously. Such fluid network configuration allows us to model emergence of novel network topologies in response to stress or task pressures, as well as study self-healing behaviours in dynamic networks.

NetWatch combines the ability to simulate complex, large organizational networks with the ability to realistically model individual agents and their interactions. Such realism is rooted in the use of artificial intelligence techniques and robust knowledge representation - as a backbone of every agent. Using realistic (or empirically derived) specifications of complex tasks, agents plan their actions according to their goals and their resource and information requirements.

2.1 Terrorist Organizations and Scale-Free Networks

An argument has been made (Robb (2004)) that terrorist networks may exhibit features of scale-free networks and can thus be treated as such in analysis and derivation of attack scenarios.

Scale-free networks have been observed in many contexts ranging from networks of airline traffic to sexual networks and Web link patterns. The high probability of emergence of scale-free networks, as opposed to evenly distributed random networks, is due to a number of factors, including:

- Rapid growth confers preference to early entrants. The longer a node has been in place the greater the number of links to it. First mover advantage is very important.
- In an environment of too much information people link to nodes that are easier to find - thus nodes that are highly connected. Thus preferential linking is self-reinforcing.
- The greater the capacity of the hub (bandwidth, work ethic, etc.) the faster its growth.

It has also been observed that scale-free networks are extremely tolerant of random failures. In a random network, a small number of random failures can collapse the network. A scale-free network can absorb random failures up to 80% of its nodes before it collapses. The reason for this is the inhomogeneity of the nodes on the network – failures are much more likely to occur on relatively small nodes.

However, scale-free networks are extremely vulnerable to intentional attacks on their hubs. Attacks that simultaneously eliminate as few as 5-15% of a scale-free network's hubs can collapse the network. Simultaneity of an attack on hubs is important. Scale-free networks can heal themselves rapidly if an insufficient number of hubs necessary for a systemic collapse are removed.

Scale-free networks are also very vulnerable to epidemics. In random networks, epidemics need to surpass a critical threshold (a number of nodes infected) before it propagates system-wide. Below the threshold, the epidemic dies out. Above the thresh-old, the epidemic spreads exponentially. Recent evidence (Pastor-Satorras, Vespignani (2001)) indicates that the threshold for epidemics on scale-free networks is zero.

However, the reality of terrorist networks does not fit neatly into the scale-free network model. It has been observed (Rothenberg (2002)) that non-state terrorist networks are not only scale-free but also exhibit small world properties. This means that while large hubs still dominate the network, the presence of tight clusters (cells) continue to provide local connectivity when the hubs are removed.

For example, attack on Al Qaeda's Afghanistan training camps did not collapse its network in any meaningful way. Rather, it atomized the network into anonymous clusters of connectivity until the hubs could reassert their priority again. Many of these clusters will still be able to conduct attacks even without the global connectivity provided by the hubs.

Furthermore, critical terrorist social network hubs cannot be identified based on the number of links alone. For example, Krebs (Krebs (2002)) observed that strong face-to-face social history is extremely important for trust development in covert networks. Of similar importance is the relevance of skills and training of agents inside a cell to the task at hand. Thus, importance of any individual within the network should be rated on a vector of factors pertaining to its qualities as an individual as well as types and qualities of its links.

Rothenberg (Rothenberg (2002)) notes that postulating a path of a set length from everyone in the global network to everyone else (i.e. scale-free nature of a terrorist network) runs contrary to the instructions for communication infrastructure set forth in the Al Qaeda training manual (Al-Quaeda (2001)). Thus, if a terrorist network was observed to be scale-free, it can be argued that its scale-free nature is not a matter of design and can possibly be an artifact of the data collection routines. For example, snowball sampling is biased toward highly connected nodes, so extensive use of this technique may result in observation of scale-free core-periphery structures where none exist (Biernacki, Waldorf (1981)).

2.2 Cellular Networks

Terrorist organizations are often characterized as cellular-composed of quasi-independent cells and featuring a distributed chain of command. This is a non-traditional organizational configuration; therefore, a different model of terrorist networks has emerged (Rothenberg (2002)), (Carley, Dombroski, Tsvetovat, Reminga, Kamneva (2003)), (Carley, Lee, Krackhardt (2002)).

While this model may not t a simple mathematical definition such as scale-free or small-world network, its base is in empirical and field data (Goolsby (2003)). Cellular networks have been formally defined by Frantz and Carley (Frantz, Carley (2005)) in terms of network components and properties, and can be derived through an optimization process that fits a parametric representation of the network to empirical data (Tsvetovat, Carley (2005)).

Rothenberg (Rothenberg (2002)) observed a number of properties of a cellular network:

- The network is redundant on every level: Each person can reach other people by multiple routes - which can be used for both transmission of information as well as material. On the local level, there will be a considerable structural equivalence (Tsvetovat, Carley (2005)), (Lorrain, White (1971)).
- On the local level, the network consists of small cells (4-6 people) that are densely connected, and operate with relative independence and little oversight on the operational level.
- The network is not managed in a top-down fashion. Instead, its command structure depends on vague directives and religious decrees, while leaving local leaders the latitude to make operational decisions on their own.
- The organizational structure of a terrorist network was not planned, but emerged from the local constraints that mandated maintenance of secrecy balanced with operational efficiency.
- The removal of a cell generally does not inflict permanent damage on the overall organization or convey significant information about other cells. Essentially, the cellular network appears to morph and evolve fluidly in response to anti-terrorist activity (Sageman (2004)).

This leads to a hypothesis that cells throughout the network contain structurally equivalent (Lorrain, White (1971)) and essential roles, such as ideological or charismatic leaders, strategic leaders, resource concentrators and specialized experts. Given this hypothesis, one can further reason that operations of a particular cell will be affected in a negative way by the removal of an individual filling one of these roles.

3. NetWatch: an Agent-Based Model of a Terrorist Organization

3.1 Agent-based Modeling of Dynamic Networks

NetWatch agents are intelligent adaptive information processing systems, constrained and enabled by the networks in which they are embedded. These networks evolve as individuals interact, learn and perform tasks. The design of the NetWatch multi-agent model is based on the principles of agent-based models of complex adaptive systems outlined by Langton (Langton (1989)) and reiterated in section 2 of this paper.

We make an important distinction from Langton's agent-based modelling principles (Langton (1989)). In NetWatch and related models, agents are not defined as simplistic automata following a small set of deterministic rules. Instead, the agents can plan and reason about task completion and formation of their social networks and make strategic moves to maximize their utility.

In effect, each agent within NetWatch is built in the same manner as an autonomous robot (Brooks (1985)) (sans the hardware) designed to survive on its own in a hostile environment. In greater detail, the methodology of multi-agent network modeling is based on the following principles:

- Agents are independent, autonomous entities endowed with some intelligence, though cognitively limited and boundedly rational.
- Agents and the networks in which they are embedded co-evolve. While the initial topology of agent network can be used as an independent variable, the community of agents will create a very different topology at the end of a simulation.
- Agents do not have accurate information about the world or other agents and are limited by their perception.
- Agents can learn the state of the world through interaction. Note that while agents do not have access to a global world-view, they can learn about their non-immediate neighbors through communication and collaboration with other agents.
- Agents can be strategic about their communication.

- Agents do not use predefined geometrical locations or neighborhoods. Instead, their choice of communication partners depends on the topology of their social network and evolves over time.

3.2 Formation of Homophyly Groups via Communication

The first agent behaviour to be discussed is that of Idle Chatter. Despite the unassuming name, Chatter is one of the most important steps towards forming of groups in the agent population, thus propagating information and facilitating task performance.

Agents engage in Chatter at their leisure - i.e. when they are not occupied with planning tasks (described in sections 3.3). When the Chatter behaviour is enabled, an agent chooses a partner to communicate with and engages in a round of conversation. In this conversation, information is exchanged and strength of network ties between the two agents increased.

The choice of a communication partner at every time period is based on two factors: *social proximity* of the agents and their *motivation to communicate*. Social proximity is defined as closeness of a relationship between two agents, scaled between 0 and 1 where 0 means “no relationship” and 1 is “very close relationship”.

Motivation to communicate is computed on the basis of *homophyly* (relative similarity) and need (relative expertise). Empirical studies of human communication behavior suggest that, without any external motivation, individuals will spend about 60% of the time interacting on the basis of homopyly and 40% on the basis of need.

Agents operate on their beliefs about what the other agents know. Thus, their calculations can be inaccurate. However, as interaction progresses and agents learn more and more about each other, the accuracy of the agents' perception of the world increases.

3.3 Planning and Execution of Complex Tasks

The design of task structures in NetWatch is based on the premise that organizations are fundamentally information-processing entities. In this view, voiced in Max Weber's work in the early 1900s and elaborated by March and Simon (March, Simon (1958)), (March (1988)), an organization is an information-processing and communication system structured to achieve a specific set of tasks and comprised of limited individual information processors.

In such organizations, tasks are described as sequences of interdependent communications and actions (Thomson (1967)), meaning that the output of a given task is the input for a succeeding tasks. Such tasks are distributed across the individuals within the organization according to the organizational structure. Thus, the subtasks can be represented in a precedence network.

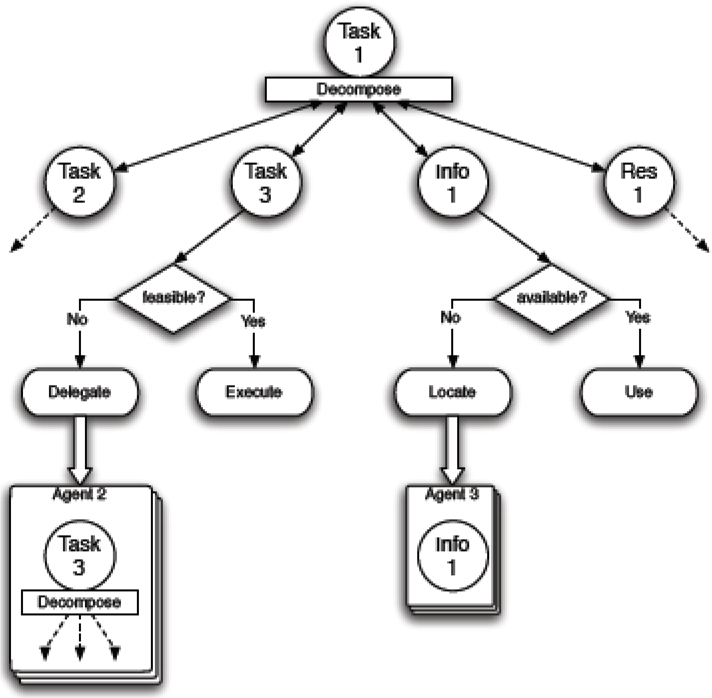


Figure 1: Planning in NetWatch Agents

This view of the organization coincides with the work in the Artificial Intelligence community on creating algorithmic representations of planning tasks. In a 1977 paper, Tate (Tate (1977)) describes the organizational task completion:

The consitutent "jobs" of a plan are specified together with their precedence relationships ... This information defines a graph, termed a project network.

A formalism referred to as a Hierarchical Task Network HTN has been developed in the AI planning community (Young, Pollack, Moore (1994)) to encapsulate the process of automatic decomposition of hierarchical task-subtask structures into an executable precedence networks. A task network in HTN representation is a collection of tasks that need to be carried out, together with constraints on the order in which the tasks can be performed and resources required. HTN Planning works by expanding non-primitive tasks and resolving conflicts iteratively until a conflict-free plan consisting of primitive tasks only can be found.

In NetWatch, agents follow the HTN algorithm. However, the planning problem is further complicated by the fact that planning is done in distributed fashion and none of the agents involved in task completion have access to the complete HTN specification. Furthermore, agents may not have access to the knowledge and resources required for accomplishing even the primitive tasks. All of the above requirements must be satisfied purely by interaction with other agents.

3.4 Execution Monitoring

In traditional multi-agent planning systems, an assumption is made that agents are cooperative (Wagner (2000)). This assumption cannot be true in simulation of adversarial networks. Thus, failure of delegated subtasks or knowledge requests is not only possible, but expected. Delegated operations can fail due to lack of appropriate information at the receiver or level of busyness of the receiver. Alternatively, delegated operations can be strategically rejected by the receiver due to its internal constraints and rules (Wooldridge).

NetWatch addresses this problem via the use of an Execution Monitor process within each agent. Execution Monitor consists of a stack which contains delegated subtasks and requests and a set of rules covering the instances of subtask or request failures, timeout conditions and strategic rejections.

4 Example: Four Days in The Life of a Terrorist Cell

To simulate evolution of social networks and organizations, NetWatch implements a multi-level complex system that involves a large number of simultaneous processes. These processes range from socializing in groups to strategic interactions to distributed planning and execution of tasks. To maintain realism of the system and a level of face validity, it is thus important to not only examine overall outcomes of simulation scenarios, but to also examine individual interactions and processes that occur within the simulated organization.

Doing so on a large-scale basis (e.g. an organization with hundreds of agents, over a long period of time) is impossible due to sheer quantity of generated data, but it is possible to trace interactions, tasks and information flow over a short period of time, with a confined group of agents engaged in a focused task.

The initial data for this example comes from encoding of news stories and legal documents related to the bombing of the U.S. Embassy in Tanzania in 1998. The data has been encoded in MetaMatrix form and includes a person-to-person network with 16 agents, 5 areas of knowledge (*religious extremism, weapons training, driving training, bomb preparation knowledge and media relations*), resources such as *truck, bomb material and building for bombmaking* and a precedence graph containing the main task (*bombing*) and a number of auxiliary tasks (*training exercises and bomb preparation*).

In this example, a religious decree has been issued to the organization to plan and execute a terrorist attack using a truck bomb. Each of the steps described in the trace below is an agglomeration of activities that have occurred in 4 days (i.e. 16 time periods of the simulation). Thus, in a relatively short space, the simulation can cover execution of a terrorist attack from beginning to completion.

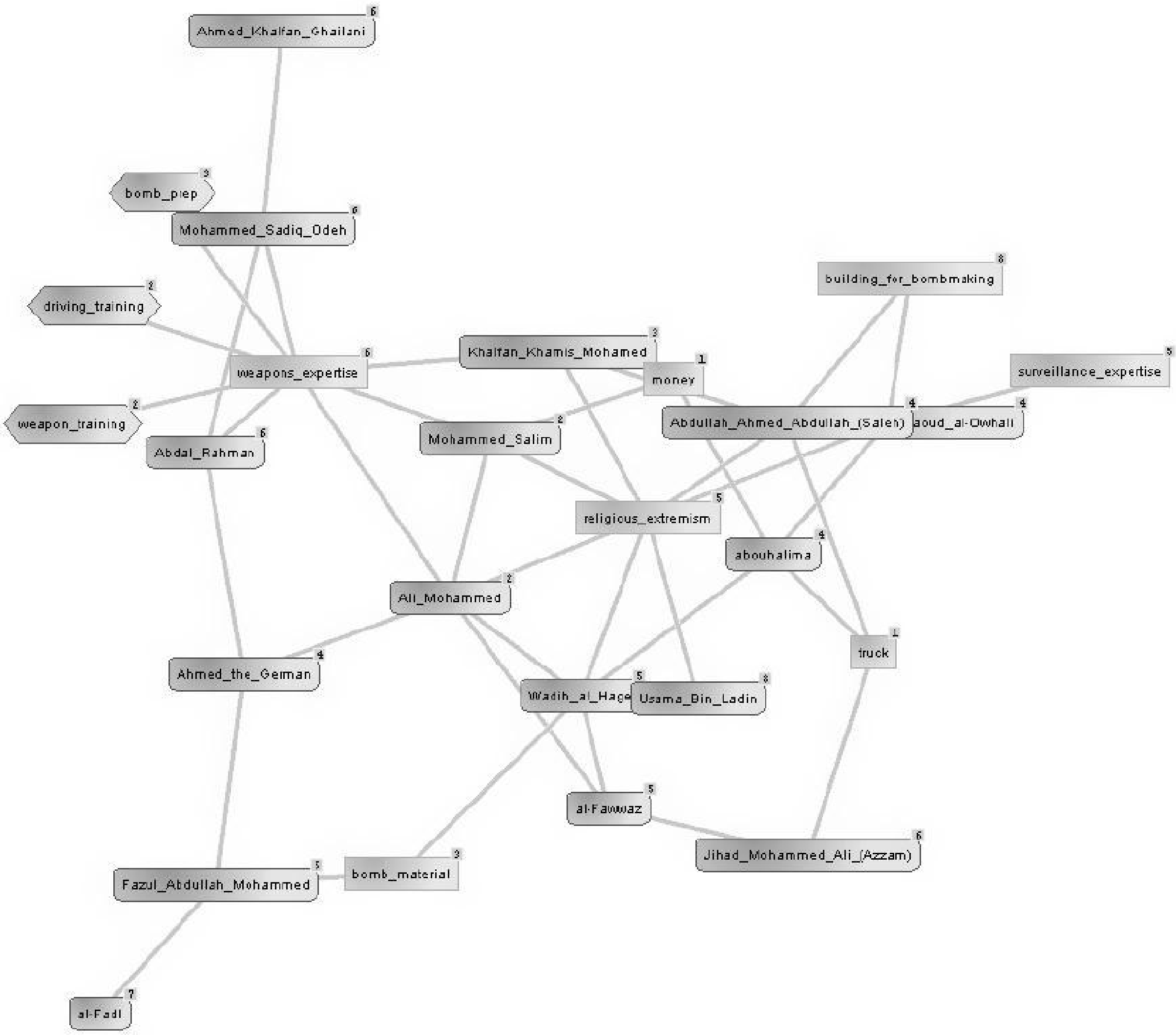


Figure 2(a): Day 1: Start of planning

Figure 2(a) shows the state of the organization before planning and execution of a terrorist attack start[1]. Before planning phase was triggered, the agents were

[1] This example is fully simulated. While names of actors and initial distribution of skills and resources have been obtained from real-world information, the events described below are a product of a computer simulation and should not be construed to indicate the course of historical events or any legal implications thereof

allowed to run freely for 60 time periods (i.e. 15 days). Thus, a certain level of information exchange and attribute contagion has been already achieved. Note, for example, the prominence of *religious extremism* and the number of people connected to it. Triggering of the terrorist attack occurred in the beginning of this day, with a broadcast message to all agents. Only agents that were able to produce a hierarchical decomposition of the complex task and find out the subtasks and resource requirements were able to start planning the task. Some of the resources (*money and a building for bombmaking*) have been already located by the end of the day, and people with access to these resources will likely become anchors to the planning process of the terrorist attack.

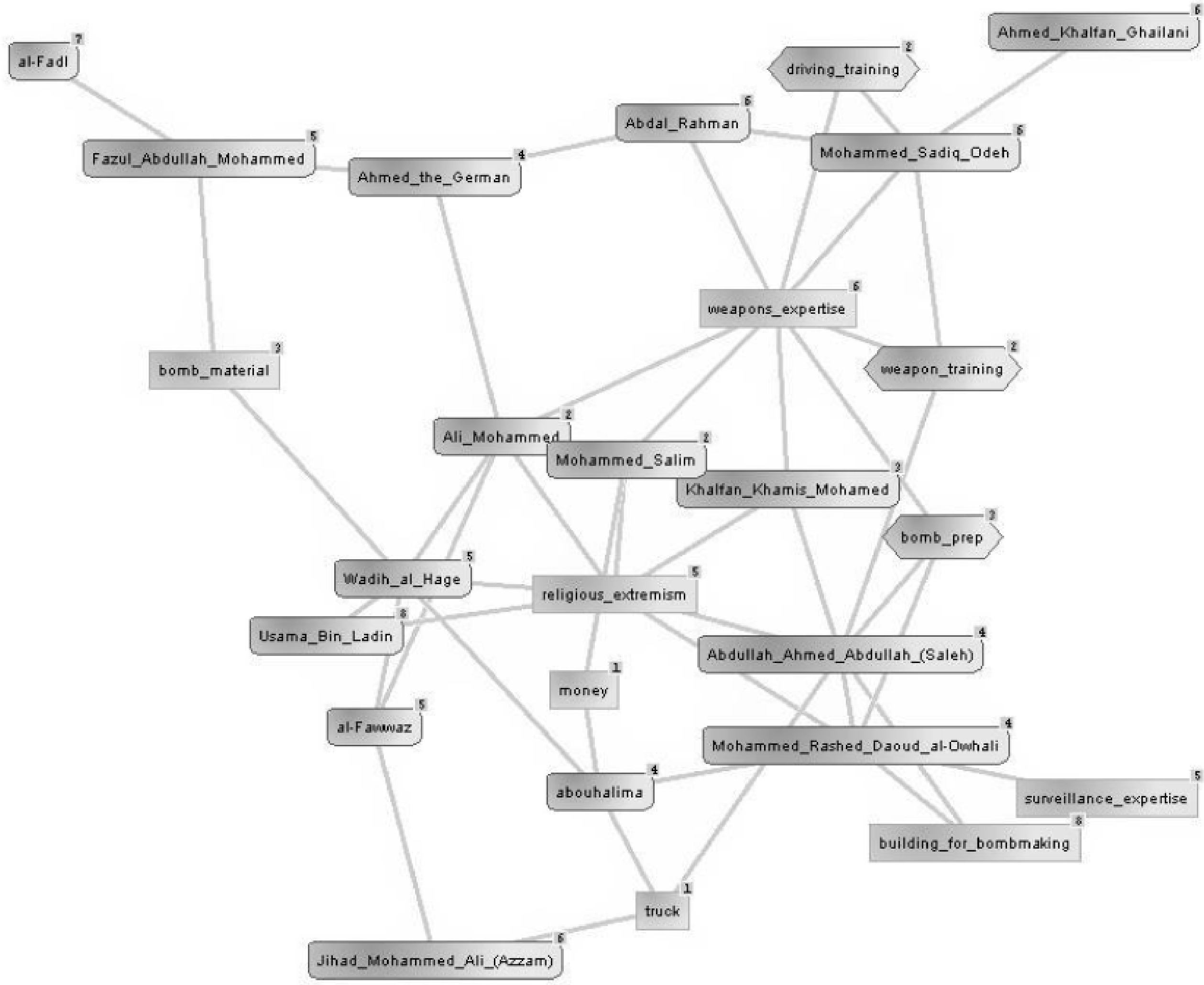


Figure 2(b): Day 2: Planning and Resource Procurement

Figure 2(b) shows the organization in the midst of planning. Note agents *Abdullah Ahmed Abdullah* (*Saleh*) and *Mohammed Rashed Daoud al-Owhali*. A day ago they had access to the building for bomb preparation and money. Now they also have purchased a truck from *Abouhalima* – i.e. a resource exchange process – with the money that they had during Day 1. At the end of the day, *Saleh* and *al-Owhali* engaged in weapons training and bomb preparation (subtasks on the critical path of execution of a bombing), and enlisted help of a weapons export *Khalfan Khalis Mohamed*.

During Day 3, preparations were well under way, but explosive material has not been yet procured. Transactive memory prompted *al-Owhali* to come back to *Abouhalima* as he was able to procure resources. *Abouhalima* was a familiar person to *al-Owhali* as *al-Owhali* bought a truck from him during Day 2.

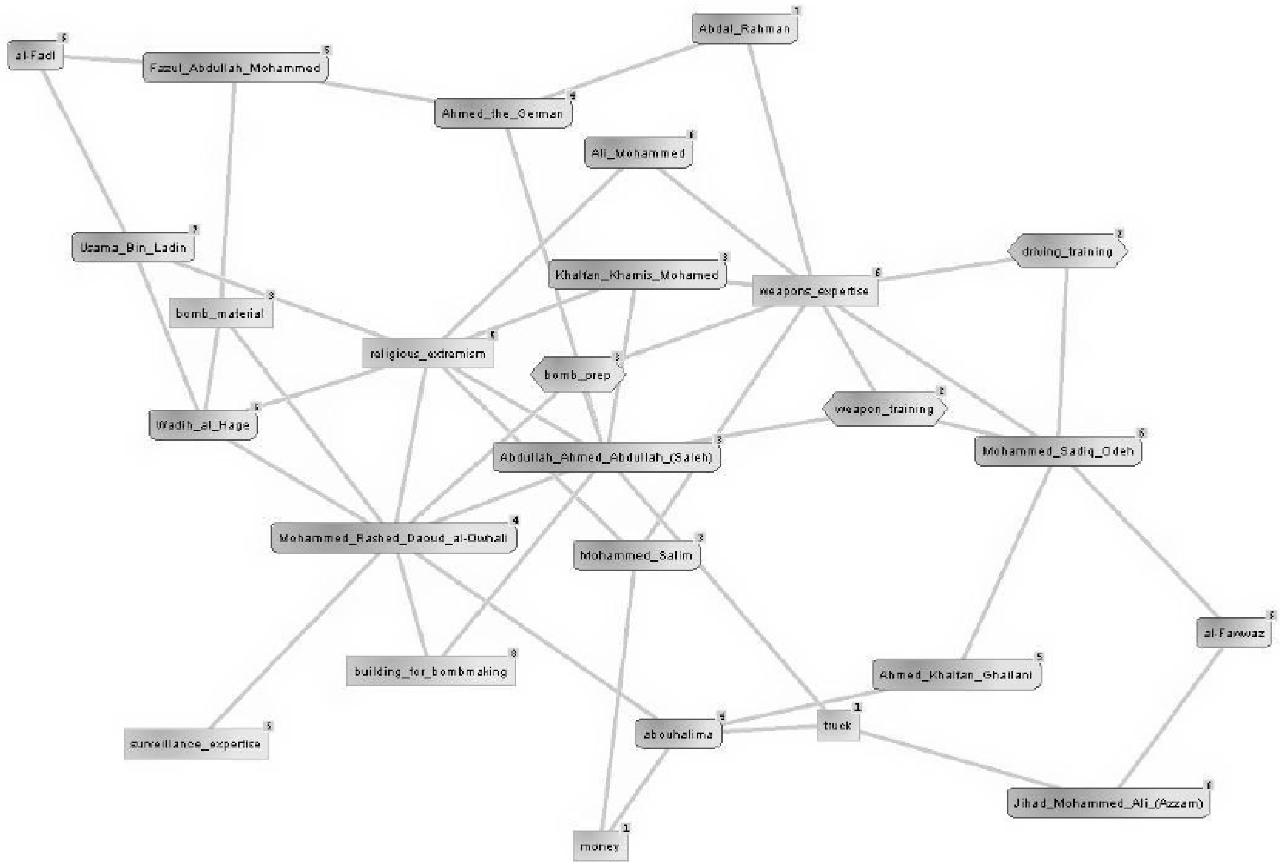


Figure 3(a): Day 3: Final Preparations

However, he did not have explosives. The closest place to obtain them was from *Wadih al Hage,* at a network distance of 2. *al-Owhali* was introduced to *al Hage* in the beginning of Day 3 (figure 3(a)), and procured explosives by the end of the day.

Meanwhile, *Saleh* has been engaged in *weapons training*. There he met *Mohammed Sadiq Odeh* who has had *driving training* and recruited him to drive the truck bomb.

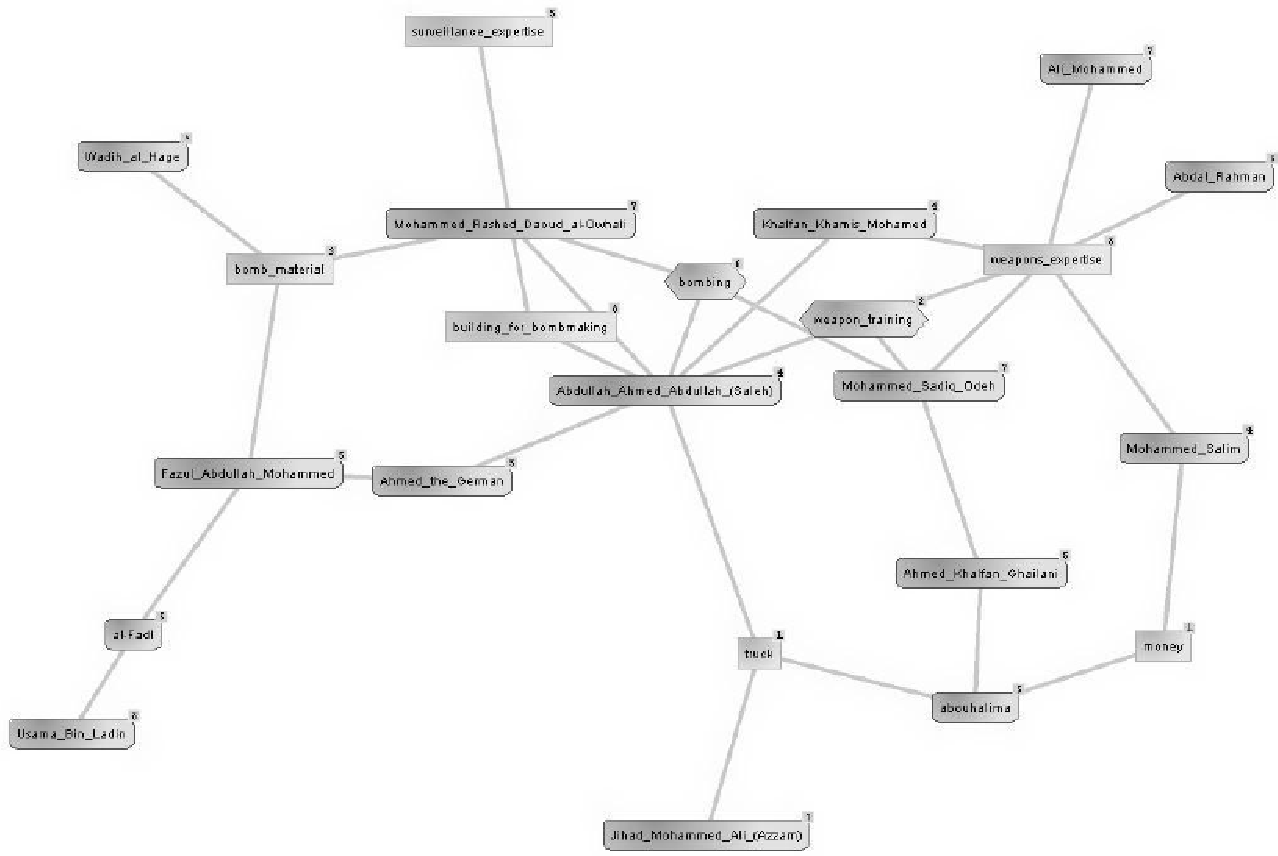


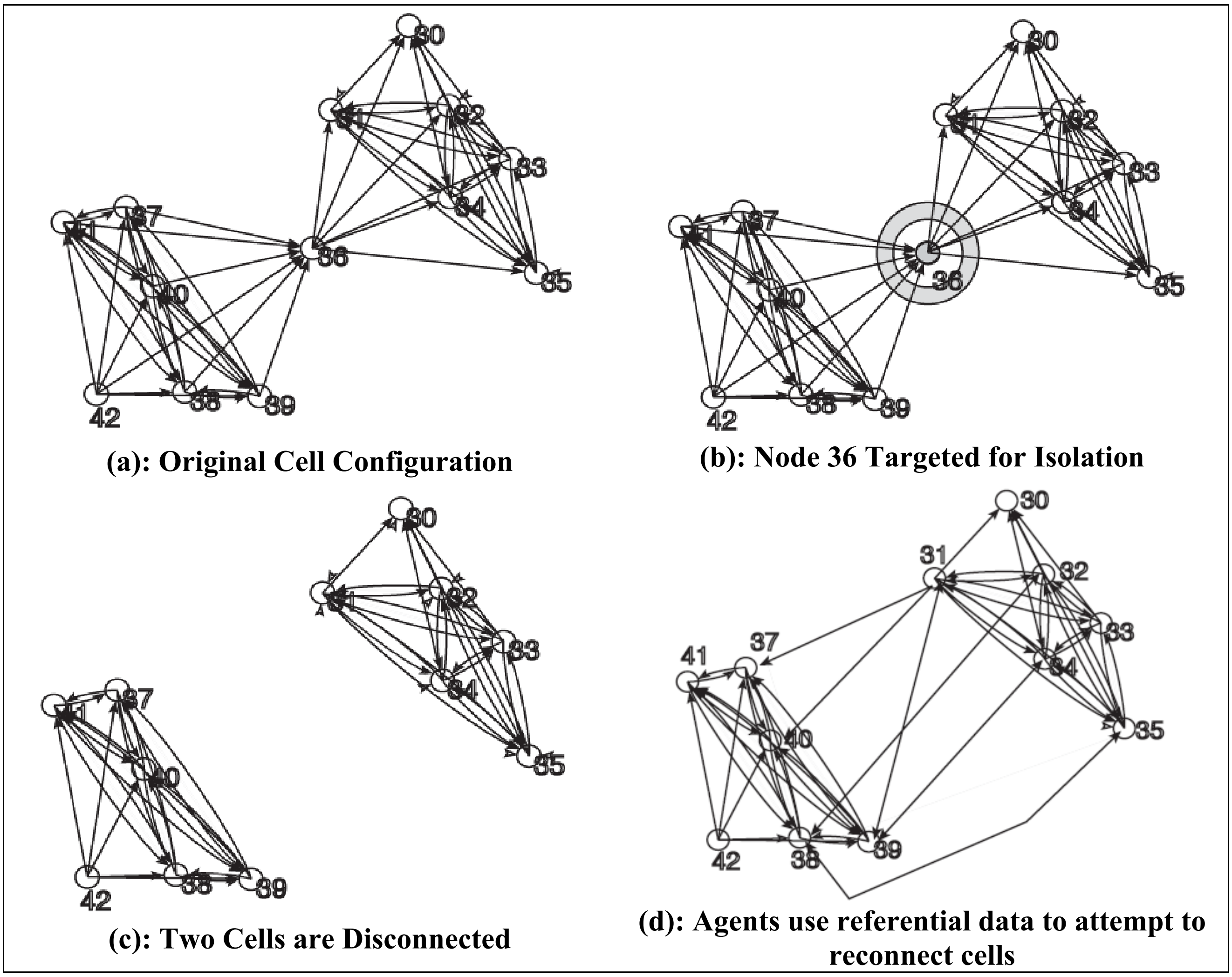
Figure 3(b): Day 4: The Bombing

The bombing itself happened on Day 4 (figure 3(b)). It was perpetrated by *al-Owhali*, *Saleh* and *Odeh*. The model used for NetWatch does not let us find out whether the perpetrators survived and got away or died in the blast.

This "dramatic reading" of the scenario illustrates in human terms how a set of intelligent agents goes about accomplishing a complex task - via planning, resource acquisition and knowledge exchange. While most of the simulation scenarios do not read like a paperback novel, the processes behind them stay as complex as the ones illustrated above. While we may only look at the top-level results, and condense dozens of runs into a single diagram, we must keep in mind this underlying complexity.

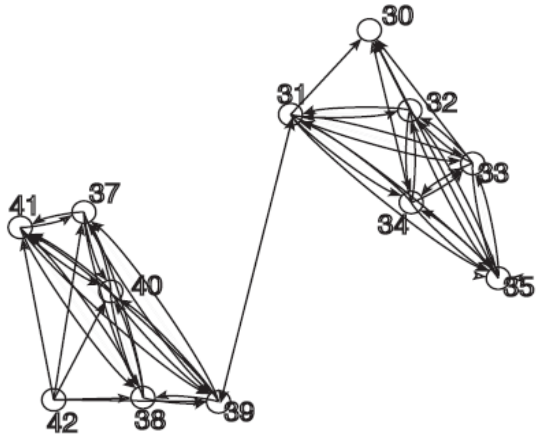
5 Recovery Mechanisms of Covert Networks

A priority in research on destabilization of covert networks has been finding key individuals removal of which will separate a cellular network into subparts. However, our experiments have shown that after a covert networks is separated into disconnected cells, the network will use its latent resources and quickly recover from damage.

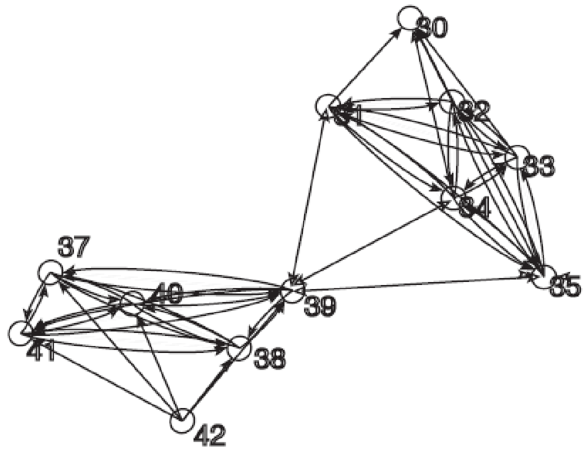


(a): Original Cell Configuration **(b): Node 36 Targeted for Isolation**

(c): Two Cells are Disconnected **(d): Agents use referential data to attempt to reconnect cells**



(e): One of the connections succeeds others are refused



(f): New Cell Leader Has Emerged

Figure 4: Recovery of a covert network from removal of central individual

The process of recovery is based on use of referential data to contact members of other cells bypassing a gatekeeper. However, in order for such connection to succeed, the referential data must be mutual - both parties of the conversation have to have referential knowledge of each other.

Such occurrences are fairly rare due to the very function of a gatekeeper, which insulates cells from each other by filtering information that passes through it. If the gatekeeper filters out 70% of referential data, the probability of successful connection between any two agents is < 10%.

Cell reconnection attempts fail (in approximately 32% of cases in our simulation) if no pair of agents finds mutual referential data on each other. In this case, the effect of disconnection on performance of the covert network depends on whether the newly disconnected cell possessed information or resources that were otherwise scarce in the organization. If the cell was close to self-sufficiency, it will continue to operate on its own. Otherwise, the cell will fall dormant until a new source of resources is found.

If one reconnection attempt succeeds, the agents will find that the newly connected pair of agents is the lowest-cost communication path to the neighboring cells (as cost is measured in number of attempts required to get a message across), and thus use them as a conduit for external communication. The initiator of the successful connection will, thus, emerge as a new gatekeeper separating the two cells.

In about 5% of remaining cases, two or more reconnection attempts succeed simultaneously. This results in creation of multiple redundant paths between cells. This essentially results in one cell being absorbed in another. The combined cells function well on tasks that do not require much interaction, but the overhead of extra connection drives down performance on deliberation- intensive tasks.

6 Conclusion

While replicating well-validated results on the system level, NetWatch achieve greater face validity of the overall result. Due to the fact that behaviours of individual agents are explainable and verifiable at every step of the way, we can claim that the system-level results are more explainable as well.

Moreover, as individual agent behaviours and ranges of parameters that control them can now be justified through social-psychological, management or organization theory literature, we can gain a greater understanding of what the true result spaces of such simulations are.

A full mapping of the result space and the response surface of a complex simulation system is a fairly difficult problem, as it boils down to a Monte-Carlo process with a high number of dimensions. However, it is possible to derive a satisfactory response surface mappings by employing heuristics to navigate the parameter space.

The purpose of this paper has been a demonstration of power afforded to a social modeler through intelligence embedded in every agent. The main value of modeling human systems in this manner is the fact that the emergent behaviours are not only rooted in well-understood theories of individual behaviour, but also the fact that emergent behaviours are instantly recognizable and interpretable in human terms. Tracing communications inside a terrorist organization yields a picture of a bomb plot that is plausible and detailed, rather then merely demonstrating a similar level of complexity.

We make no claim that each of our agents is an accurate model of a human being. However, through increasing individual-level complexity and providing realistic low-levelmodels of individuals, our model of an organization achieves an incremental, yet important improvement in veridicality of multi-agent models.

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Hybrid of agent based model with 5 income groups of households and CGE model of Russian economy

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Introduction

Agent based models (ABM) – is a new tool to obtain knowledge and is currently being widely used in the social sciences, including economics. The major idea underlying the principle of ABM is to construct a “computation instrument”, which would combine a set of agents with a certain set of properties and would allow simulating phenomena of the real world. The final goal of agent based modeling is to estimate how the fluctuations of agents at the micro level influence the macro level indicators. The dominating methodological approach in this field is calculation of equilibrium or pseudo-equilibrium of the system, which contains the set of agents. Although ABM can use simple rules of behavior, they may produce extremely interesting results.

ABM consist of agents, dynamically interacting according to certain rules. The environment for their functioning may be rather complex.

The set of agents, which are the actors in ABM, is defined in the Russian language literature as artificial society (Makarov, 2006). The similar definition is used in international literature on ABM.

According to the above definitions, in this paper we consider artificial society as a set of micro level agents, included in ABM.

A great number of literature deals with various aspects of ABM. The most noted works are Schelling (1978), Yorke (1979), Poundstone (1985), Epstein and Axtell (1996), Wilensky (1998), Wilensky and Reisman (1999), Tesfatsion (2002), Wilensky (2004), Lee and Deguchi (2005), Upal (2005), Heppenstall, Evans, and Birkin (2006).

Listing the types and names of ABM could become endless, since the number of such developments increases very fast. Nonetheless, the following observations may be drawn from the ABM literature.

1. The majority of ABM are theoretical and are created in purely scientific purposes to test new instrument on artificial data.

2. In the small groups of models, considering real phenomenon or process, only few models are related to economics.

3. However, even this very limited number of models, considers only selected issues of microeconomic phenomena.

At the same time we do not know the example ABM of an economic system for the whole country, although the problem of modeling such a system is important in economic literature (see section 1).

Consequently, the ABM model developed in this paper is not only the first of this sort of models but also corresponds to the current tendency in the applied economic science.

As different from other models, the model in the paper, as is shown below, uses actual data and is capable of producing adequate results. The basic economic system is chosen to be CGE model. The models of this class are themselves a new direction in applied economics, which is becoming widely used around the world.

CGE models may be determined in the three key aspects. Firstly, they include economic agents with actions, which influence the whole economic system. Therefore, CGE models are called *general*. Usually the agents include households, maximizing their utility from consumed goods and services, and firms, maximizing their profit. Governments and trade unions may also be included in the number of agents.

Secondly, CGE models consist of a system of equations, the solution to which becomes the equilibrium at the market for each good, service and production factor. Consequently, the models are called *equilibrium*.

Thirdly, the models give quantitative results, which allows calling them *computable* (see details in Makarov, Bakhtizin, Bakhtizina, 2007).

To reflect the bounded rationality of human behavior according to one of ABM paradigms, we decided to use the totality of neural networks – one of the directions in Artificial Intelligence (AI).

Combination of CGE model and neural networks allows obtaining the mixture of economic system and human brain emulator for the agents in the "artificial society". Section 8 deals with creation of such societies.

It should be noted that the problem of "interbreeding" ABM and CGE in order to obtain a more adequate instrument is considered of current importance in international literature. The approach taken in this paper, however, differs in a number of aspects (sections 1 and 2).

1. Mixture of ABM and CGE modelling: international literature

Experiments on "interbreeding" the two instruments of measuring economic phenomena (CGE and ABM) have been taken since the beginning of this century (Cockburn, 2001), (Annabi, Cisse, Cockburn and Decaluwe, 2005), (Rutherford, Shepotylo and Tarr, 2005). These papers deals with correspondingly 3373 households of Nepal, 3278 households of Senegal and 55000 of households in Russia.

Nonetheless, the above models are not in the full sense ABM, despite using the household data.

The fundamental point is that processing macro level signals by households is accomplished via utility maximization which contradicts the major ABM paradigm – bounded rationality. In some models certain members of artificial societies may be endowed bounded cognitive possibility. For example, in "Sugar model" (Epstein and Axtell, 1996) an agent can not see below the certain horizon (regulated by the model developer). In "Life" game an agent can not "give birth to twins" (Conway, 1970). In the models dealing with economic system, individual agents can not know all the peculiarities of macro system and can not make the absolutely rational decision.

Consequently, it would be more correct to call the above models not ABM, but CGE ones with micro simulation models. Depending on the mechanism, which links macro and micro levels, these models can be classified in the following way:

1. CGE Models, Integrating Multiple Households (CGE-IMH). The special feature of this group is the fact that the maximal possible number of households is included. Usually this number corresponds to the number of respondents in the survey, conducted by national statistics agency. All the above described models belong to this group.

2. CGE Models with Sequential Micro-Simulation (CGE-SMS). This group includes the models, where micro and macro levels are not directly connected. In other words, at first macro parameters are calculated with the help of CGE. At the end of calculations the obtained data is submitted as an input in the mocro level model. The back recursion here is not permitted. Therefore, these weakly connected models do not necessarily guarantee the consequence of moving between the levels, since it is logical that micro agents should react to the changes of the environmental parameters before the equilibrium is reached.

Finally, it should be noted that while the urgency of creating the hybrid of CGE and ABM is being frequently mentioned (Brett, 2005), the existing and available literature does not yet offer the examples of the CGE and ABM hybrids, analogous to those developed in this paper (section 2).

2. The weak points of the conventionally used approaches and our solution for developing agent-based models

The analysis of various ABM published in the JASSS web-journal and other major Internet portals (e.g. http://www.econ.iastate.edu/tesfatsi/ace.htm), and presented at the First World Congress for Social Modeling (Kyoto, August 21-25,

2006) allows making an observation that most of existing models are mainly illustrative.

As for a hybrid of ABM and CGE, this approach is only being developed. Yet, since this research is the prerogative of applied economics, the existing papers employ official statistical data and are aimed at obtaining results of various impacts for economic systems.

Nonetheless, in the framework of the existing models household behavior is modeled through utility maximization which does not follow one of the concepts of ABM.

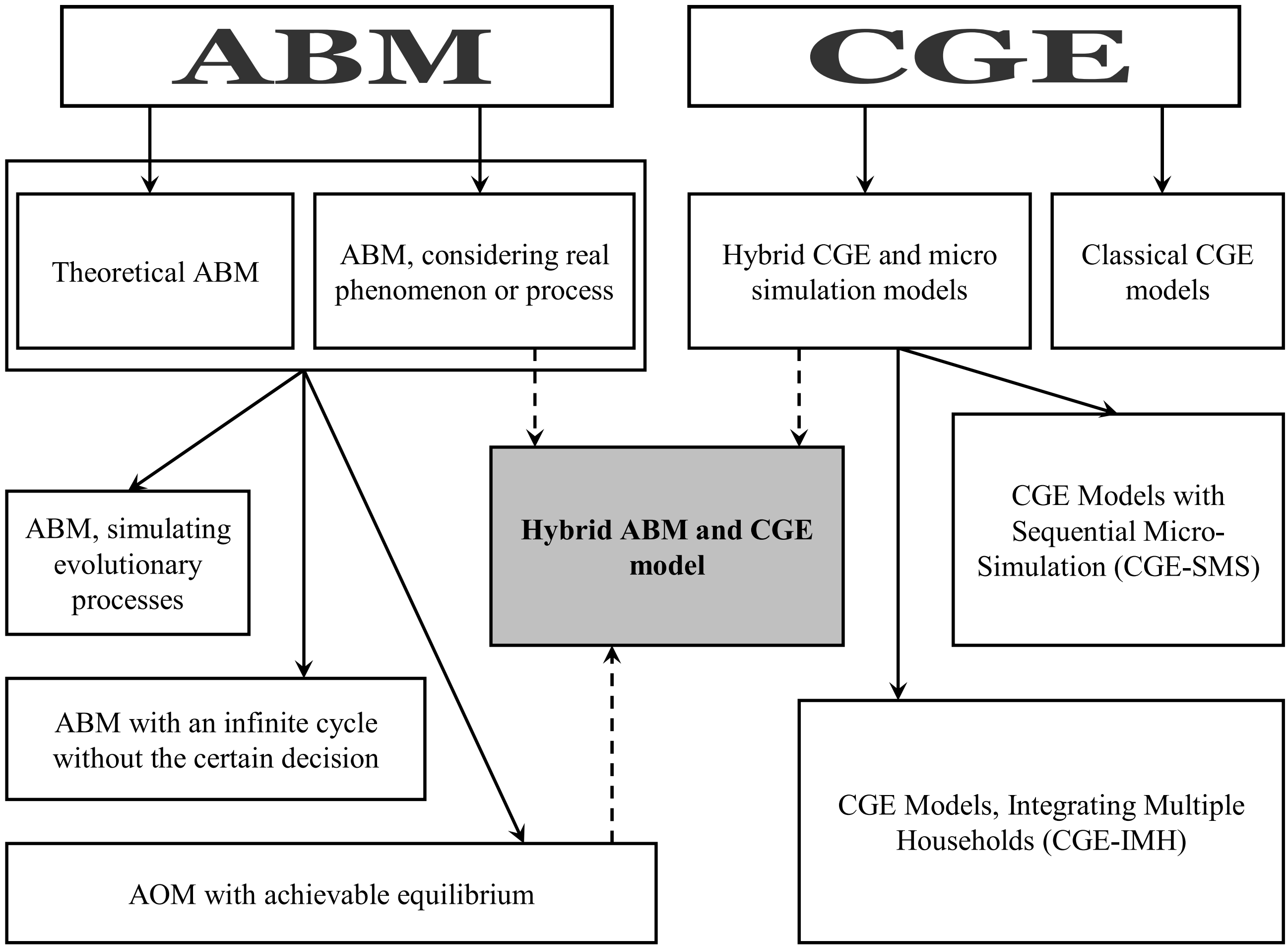
We also think that Sequential Micro-Simulation (CGE-SMS) has a number of drawbacks as an approach, as well, due to the absence of the consequent shifts from macro to micro levels.

Therefore, in developing our model we tried to solve the following tasks:

1. Correspond to the major requirements of ABM, namely, to micro level agent autonomy; bounded rationality, not allowing to acquire full knowledge of the environment (e.g. utility maximization is not allowed); functioning within certain environment.

2. Create models, aimed at applied results. Consequently, the micro level environment is economic systems, realized in CGE models.

The graph shows how the model in this paper fits in the set of the above mentioned models.



Graph 1 – The place of the developed model in the set of existing models

Below we note this hybrid ABM and CGE model as hybrid ABM model.

3. Developing hybrid agent based model with artificial societies, making decisions about their income.

In the process of the model conceptual design, the major goal of its creation was formulated to make the instrument, which would realistically reflect human behavior in budget spending according to varying economic situation.

On the other hand, this model also allows to obtain quantitative estimates of the impact of different disturbances to economic system on the following variables:

1) The volume of investment in capital stock of Russian enterprises and organizations,

2) The rates of VAR, profit tax, property tax, personal income tax and unified social tax[2];

3) The rates of deposits for enterprises and natural persons;

4) The volume of social transfers to Russian households (pensions, allowances etc.);

5) The volume of money supply in economics.

Therefore, the developed model is an attempt to describe bounded rationality and at the same time be an instrument to assess the consequences of financial and economics decisions of the government executing bodies.

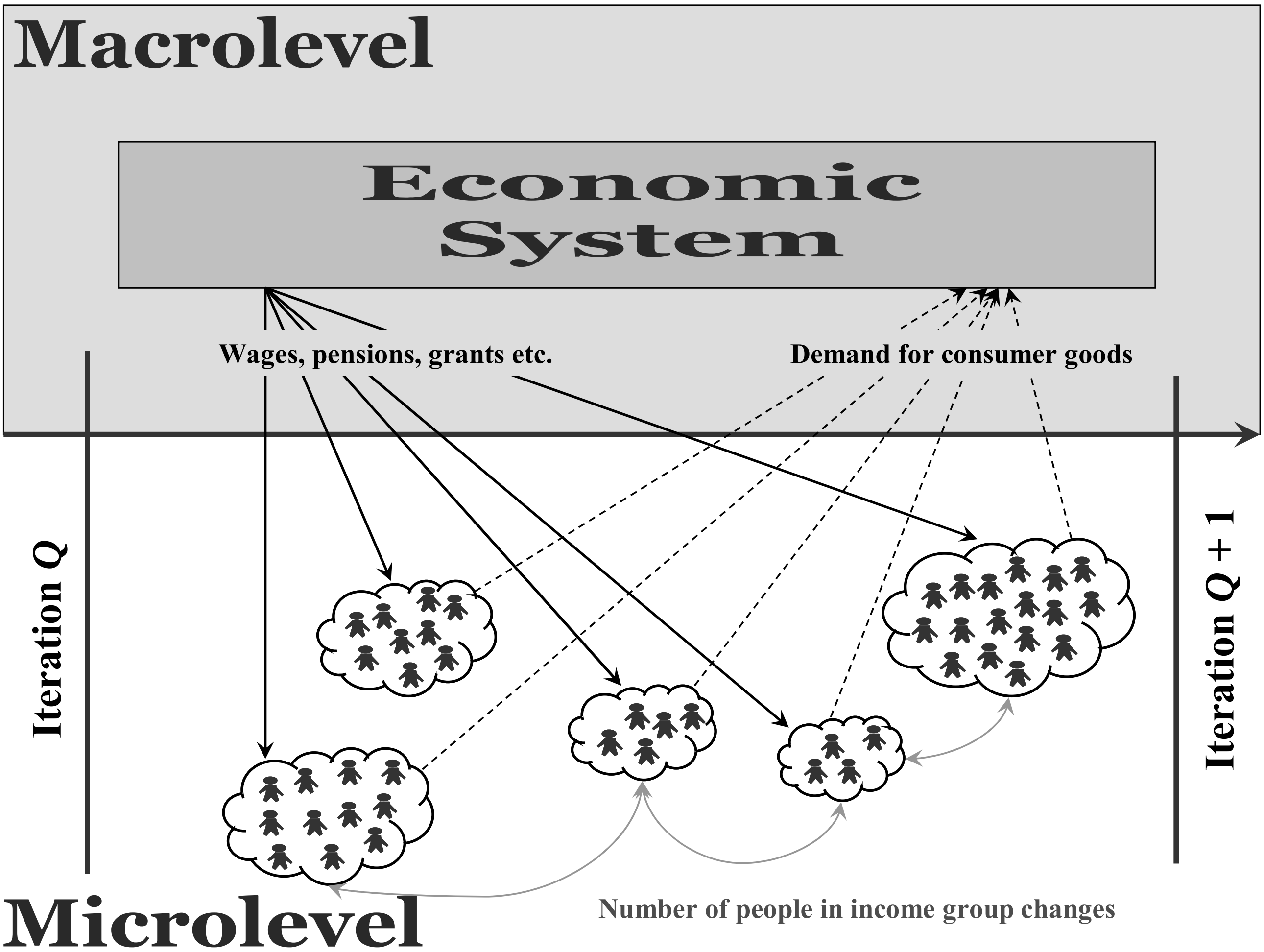
Below is the conceptual description of the model work.

4. Conceptual view at the model (interactions of artificial societies in the economic system).

The model deals with 5 artificial societies, which reflect the set of several thousand people, making decisions according to information they obtain from economic system. Technically, this decision is being made within neural network, that obtains input variable, characterizing the change in purchasing power of a member of artificial society.

In this way, individual decisions of various levels at the macro level in their totality have an influence on the macro level parameters. Here it is important, that the decisions are taken independently by individual agents, but aggregated result is reported back to the economic system. This process occurs at each iteration, until the aggregate demand equals aggregate supply at all the markets for goods and services (Graph 2).

[2] Employer payroll tax, which combines earmarked contributions to Pension fund, Mandatory health insurance funds, and Social insurance fund.



Graph 2 – Interaction of macro and micro levels in our ABM: conceptual view

In general, the members of 5 artificial societies, who differ in their income, buy final goods from the aggregated agent-producer. Agents in different income groups have different patterns in buying final goods. The iteration mechanism allows for the situation when the number of people in income group changes (e.g., it is possible to model the rise of salary for workers with lowest income or the rise in pensions).

When an agent moves to a different income group, her decisions become based on a different neural network, corresponding to her new income groups. Below is the detailed description of the model.

5. The description of the major blocks of the model (economic agents and main relations)

The models is represented by 5 economic agents.

Economic agent №1 – aggregate producer of goods and services. This included all legally registered participants of economic system, producing goods and services (see section 7.1).

Economic agent №2 – «artificial societies», representing Russian households, divided into 5 income groups (see section 8).

Economic agent №3 – the government (see section 7.2), represented by the totality of the federal, regional and local governments, as well as by off-budgetary funds. This sector included certain non-profit organizations, providing certain services for households (political parties, trade unions, public unions etc.).

Economic agent №4 – banking sector, which includes the Central Bank of Russia and commercial bank (see section 7.3).

Economic agent №5 – outside world (see section 7.4).

Graph 2 present the principal scheme demonstrating the work of the model in general terms.

Notations in the scheme:

▭ – economic agent;

◯ – markets for trade of corresponding goods among the economic agents studied in the model:

c – the market for final goods for artificial societies (households);

z – the market for intermediate goods;

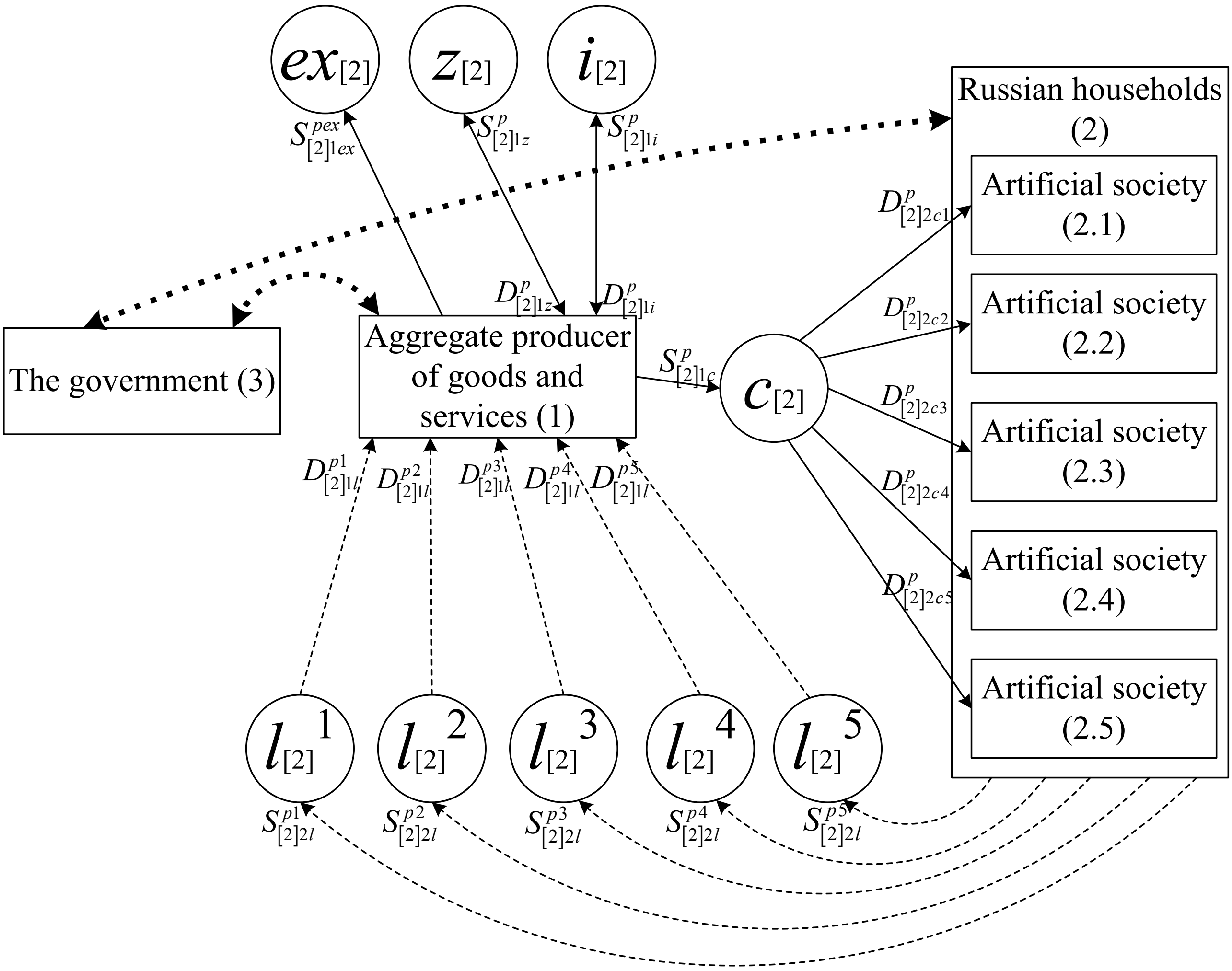
i – markets for investment goods;

l^1, l^2, l^3, l^4, l^5 – labor markets;

ex – the market for export goods.

Below each good is studied separately.

Arrow «in coming» to the market implies, that agent offers the god at the market, and arrow «out going» from the market , demonstrates that agent buys corresponding good. Thin broken line reflects the actions of agents, dealing with labor supply and demand, and thick broken line – shows the flows of tax payments and subsidies.



Graph 3 – Principle scheme of the ABM

As is shown on graph 3, producing sector makes product, which is distributed in the following 4 ways:

1) final goods for artificial societies $\left(S_{1c}^{p}\right)$, including consumer goods for current consumption (food etc.), durables (home appliances, cars etc.), and services;

2) intermediate goods $\left(S_{1z}^{p}\right)$, including goods and services, consumed during the accounting period as expenses for manufacture of the goods and services;

3) investment goods – the cost of perfecting produced and non produced material stock (i.e. the cost of creating fixed capital) – $\left(S_{1i}^{p}\right)$;

4) export goods – S_{1ex}^{pex}.

Hence, the model uses 4 types of goods.

To produce the above named goods agent-producer buys the following production factors:

1) labor – D_{1l}^{p1}, D_{1l}^{p2}, D_{1l}^{p3}, D_{1l}^{p4} and D_{1l}^{p5};

2) intermediate goods – D_{1z}^{p};

3) investment goods – D_{1i}^{p}.

Economic agent №3 sets tax rates, determines the share of budget, spent on subsidizing producers and on social transfers.

Banking sector determines interest rates for deposits and emits money for circulation.

Artificial societies (households divided into 5 income goods) buy final goods – D_{2c1}^{p}, D_{2c2}^{p}, D_{2c3}^{p}, D_{2c4}^{p} and D_{2c5}^{p}. This sector also determines labor supply, differentiated according to the salary level – S_{2l}^{p1}, S_{2l}^{p2}, S_{2l}^{p3}, S_{2l}^{p4} and S_{2l}^{p5}.

The following sections deal with behavior of each economic agent.

6. Markets

The number of markets in the models is the following: 1 market for final goods + 1 market for intermediate goods + 1 market for investment goods + 1 market for export goods = 4 markets.

The model also deals with 5 labor markets.

Consequently, the total number of markets in the model is 4 + 5 = **9**.

Below are the equations, dealing with the process for price changes.

For final goods for artificial societies:

(1) $$P_c\left[Q+1\right]=P_c\left[Q\right]+\left(D^{p}_{sc[Q]}-S^{p}_{sc[Q]}\right)/C;$$

For intermediate goods:

(2) $$P_z\left[Q+1\right]=P_z\left[Q\right]+\left(D^{p}_{sz[Q]}-S^{p}_{sz[Q]}\right)/C;$$

For investment goods:

(3) $$P_i\left[Q+1\right]=P_i\left[Q\right]+\left(D^{p}_{si[Q]}-S^{p}_{si[Q]}\right)/C;$$

For lower paid workforce (the first income group):

(4) $$P_{1l}\left[Q+1\right]=P_{1l}\left[Q\right]+\left(D^{p1}_{sl[Q]}-S^{p1}_{sl[Q]}\right)/C;$$

For employees with salaries below the average (second group):

(5) $$P_{2l}\left[Q+1\right]=P_{2l}\left[Q\right]+\left(D^{p2}_{sl[Q]}-S^{p2}_{sl[Q]}\right)/C;$$

For employees with average salary (third group):

(6) $$P_{3l}\left[Q+1\right]=P_{3l}\left[Q\right]+\left(D^{p3}_{sl[Q]}-S^{p3}_{sl[Q]}\right)/C;$$

For employees with salary above average (forth income group):

(7) $$P_{4l}\left[Q+1\right]=P_{4l}\left[Q\right]+\left(D^{p4}_{sl[Q]}-S^{p4}_{sl[Q]}\right)/C;$$

For high paid employees (fifth group):

(8) $$P_{5l}\left[Q+1\right]=P_{5l}\left[Q\right]+\left(D^{p5}_{sl[Q]}-S^{p5}_{sl[Q]}\right)/C.$$

Now we present equations which help determine aggregate demand and supply of goods for each of the price, used in the model. The final formulas for each of the agent are shown at the end of corresponding sections.

Since the model mainly deals with the behavior of 5 income groups and macro level is represented by one aggregate producer, aggregate demand and supply for production factors correspond to demand and supply of the latter one agent. Final groups for artificial societies, however, become an exception.

Aggregate demand for labor of different groups:

(9) $D_{sl}^{p1} = D_{2l}^{p1}$;

(10) $D_{sl}^{p2} = D_{2l}^{p2}$;

(11) $D_{sl}^{p3} = D_{2l}^{p3}$;

(12) $D_{sl}^{p4} = D_{2l}^{p4}$;

(13) $D_{sl}^{p5} = D_{2l}^{p5}$.

Aggregate supply of labor by different groups:

(14) $S_{sl}^{p1} = S_{2l}^{p1}$;

(15) $S_{sl}^{p2} = S_{2l}^{p2}$;

(16) $S_{sl}^{p3} = S_{2l}^{p3}$;

(17) $S_{sl}^{p4} = S_{2l}^{p4}$;

(18) $S_{sl}^{p5} = S_{2l}^{p5}$.

Aggregate demand for final goods for artificial societies:

(19) $D_{sc}^{p} = D_{2c1}^{p} + D_{2c2}^{p} + D_{2c3}^{p} + D_{2c4}^{p} + D_{2c5}^{p}$.

Aggregate supply of final goods for artificial societies:

(20) $S_{sc}^{p} = S_{1c}^{p}$.

Aggregate demand for intermediate goods:

(21) $D_{sz}^{p} = D_{1z}^{p}$.

Aggregate supply of intermediate goods:

(22) $S_{sz}^{p} = S_{1z}^{p}$.

Aggregate demand for investment goods:

(23) $D_{si}^{p} = D_{1i}^{p}$.

Aggregate supply of investment goods:

(24) $S_{si}^{p} = S_{1i}^{p}$.

Aggregate demand for export goods:

(25) D_{sex}^{pex} (set value).

Aggregate supply of export goods:

(26) $S_{sex}^{pex} = S_{1ex}^{pex}$.

Hence, we have 18 equations to determine aggregate demand and supply of the goods, studied in the model.

7. Economic agents of the macro level.

7.1. Aggregate producer of goods and services

The sector does the following actions:

On spending its budget:

- pays labor for its services. Technically, it is reflected in the fact, that economic agent determines the shares of budget, going to buying labor services: O_{1l}^{p1} , O_{1l}^{p2} , O_{1l}^{p3} , O_{1l}^{p4} , O_{1l}^{p5} ;
- buy intermediate goods: O_{1z}^{p} ;
- buys investment goods: O_{1i}^{p} ;
- pays taxes to consolidated budget and to off-budgetary funds: O_{1}^{t} , O_{1}^{f} ;

- determines the share of non-spent budget (i.e. how much to leave on bank accounts): O_1^s.

On dividing the produced product:

- determines the share of final good to be sold at the market for final goods for artificial societies (household): E_{1c}^p;
- determines the share of final good to be sold at the market for intermediate goods: E_{1z}^p;
- determines the share of final good to be sold at the market for investment goods: E_{1i}^p;
- determines the share of final good to be sold at the market for export goods: E_{1ex}^{pex}.

Now we come to equations, describing behavior of aggregate producer of goods and services.

The form of production function:

(27) $$Y_1 = A_1^r \cdot \left(\left(K_{1(t)} + K_{1(t+1)}\right)/2\right)^{A_1^k} \cdot \prod_{j=1}^{5}\left(D_{1l}^{pj}\right)^{A_1^{lj}} \cdot \left(D_{1z}^p\right)^{A_1^z},$$

where A_1^r, A_1^k, A_1^{l1}, A_1^{l2}, A_1^{l3}, A_1^{l4}, A_1^{l5} A_1^z – are production function parameters.

The arguments of production function are resources: capital, labor (5 groups of workers), intermediate product.

Below we describe sector demand for production factors:

Demand for labor:

First group (low paid workers):

(28) $$D_{1l}^{p1} = \left(O_{1l}^{p1} \cdot B_1\right)/P_{1l};$$

Second group:

(29) $D_{1l}^{p2} = \left(O_{1l}^{p2} \cdot B_1\right) / P_{2l}$;

Third group:

(30) $D_{1l}^{p3} = \left(O_{1l}^{p3} \cdot B_1\right) / P_{3l}$;

Fourth group:

(31) $D_{1l}^{p4} = \left(O_{1l}^{p4} \cdot B_1\right) / P_{4l}$;

Fifth group (high paid workers):

(32) $D_{1l}^{p5} = \left(O_{1l}^{p5} \cdot B_1\right) / P_{5l}$.

Demand for investment goods:

(33) $D_{1i}^{p} = \left(O_{1i}^{p} \cdot B_1\right) / P_{i}$.

Demand for intermediate goods:

(34) $D_{1z}^{p} = \left(O_{1z}^{p} \cdot B_1\right) / P_{z}$.

The following equations describe supply of goods, produced by economic agent №1.

Supply of final goods for artificial societies (households):

(35) $S_{1c}^{p} = E_{1c}^{p} \cdot Y_1$.

Supply of investment goods:

(36) $S_{1i}^{p} = E_{1i}^{p} \cdot Y_1$.

Supply of intermediate goods:

(37) $S_{1z}^{p} = E_{1z}^{p} \cdot Y_1$.

Supply of export goods:

(38) $S_{1ex}^{pex} = E_{1ex}^{pex} \cdot Y_1$.

Equation below calculates revenues of the sector:

(39) $Y_1^p = S_{1c}^p \cdot P_c + S_{1i}^p \cdot P_i + S_{1z}^p \cdot P_z + S_{1ex}^{pex} \cdot P_{ex}$.

These total revenues are comprised of the revenues from selling final, investment, intermediate, and export goods.

GPD in the base year prices:

(40) $Y_1^v = Y_1 - S_{1z}^p$.

GDP in current prices:

(41) $Y_1^{vp} = Y_1^p - S_{1z}^p \cdot P_z$.

Budget of the sector:

(42) $B_1 = B_1^b \cdot \left(1 + P_{b\%(t-1)}\right) + Y_1^p + G_3^s + M_4$.

Budget of an agent is formed from:

1) the money on bank accounts (with interest);
2) revenues, received in the current period Y_1^p;
3) subsidies from consolidated budget G_3^s;
4) money emission M_4.

Dynamics of money on bank accounts:

(43) $B_{1(t+1)}^b = O_1^s \cdot B_1$.

Dynamics of capital:

(44) $K_{1(t)} = \left(1 - R_{1(t-1)}\right) \cdot K_{1(t-1)} + D_{1i(t)}^p$.

The capital calculating equation takes into account capital depreciation. Investment into capital enters the formula with the “plus” sign.

The share of budget going to the taxes for consolidated budget:

$$O_1^t = \left(Y_1^{vp} \cdot T^{vad}\right) / B_1 + \left(\left(K_1 \cdot P_i\right) \cdot T^{prop}\right) / B_1 +$$

(45) $$+\left(\left(Y_1^p - \sum_{j=1}^{5} W_{2j} - D_{1z}^p \cdot P_z - K_1 \cdot P_i \cdot A_1^n\right) \cdot T^{pr}\right) / B_1 .$$

This accounts for VAT, property tax and profit tax. In calculating the share of budget going to profit tax, we subtract labor cost W_{21}, W_{22}, W_{23}, W_{24}, W_{25}, intermediate consumption $D_{1z}^p \cdot P_z$ and depreciation cost $K_1 \cdot P_i \cdot A_1^n$ from revenues.

The share of budget going to unified social tax to off-budgetary funds:

(46) $$O_1^f = \left(\left(\sum_{j=1}^{5} W_{2j}\right) \cdot T^{esn}\right) / B_1 .$$

The residual of the sector budget:

(47) $$O_1^s = 1 - \sum_{j=1}^{5} O_{1l}^{pj} - O_{1z}^p - O_{1i}^p - O_1^t - O_1^f .$$

7.2. Government

This economic agent is represented by the sum of federal, regional and local governments, as well as, by off-budgetary funds. It also includes non profit enterprising, providing services for households.

Economic agent №3 makes the following actions:

Sets the types of taxes and tax rates:

- VAT T^{vad};
- Enterprise profit tax T^{pr};
- Property tax T^{prop};
- Personal income tax T^{pod};

- Unified social tax T^{esn}.

The sum of the first 4 taxes, which make up the major part of tax revenues, goes to consolidated budget, while unified social tax goes to off-budgetary funds.

Spending its budget:

- Subsidizes aggregate producer of goods and services from consolidated budget: O_3^{s1};
- Spends the resources of off-budgetary funds: O_3^{f1}, O_3^{f2}, O_3^{f3}, O_3^{f4}, O_3^{f5};
- Determines the share of non spent budget: O_3^{s}.

Now we proceed to equations, determining behavior of economic agent №3.

Consolidated budget:

(48) $$B_3 = O_1^t \cdot B_1 + \sum_{j=1}^{5}\left(O_{2j}^t \cdot B_{2j}\right) + B_3^{other} + B_3^b \cdot \left(1 + P_{b\%(t-1)}\right).$$

This equation sums the money, collected as taxes from aggregate producer and from artificial societies. Exogenous value B_3^{other} demonstrates the sum of all other taxes (not included in the above list of taxes), non tax revenues and other revenues of consolidated budget. The money on bank accounts (with interest) are also included in the equation.

Dynamics of consolidated budget money on bank accounts:

(49) $$B_{3(t+1)}^b = O_3^s \cdot B_3.$$

Monetary revenues of off-budget funds:

(50) $$F_3 = O_1^f \cdot B_1 + F_3^b \cdot \left(1 + P_{b\%(t-1)}\right).$$

This equation calculates the money, collected for the following off-budgetary funds from aggregate producer of goods and services in the form of unified social tax:

- Pension fund;
- Social insurance fund;
- Federal and territorial mandatory health insurance funds.

The money on bank accounts (with interest) are also included in the formula.

Dynamics of off-budgetary fund's money on bank accounts:

(51) $F^{b}_{3(t+1)} = O^{s}_{3f} \cdot F_{3}$.

Subsidy to aggregate producer of goods and services:

(52) $G^{s}_{3} = O^{s1}_{3} \cdot B_{3}$.

The resources of off-budgetary funds for artificial societies:

The first income group:

(53) $G^{f1}_{3} = O^{f1}_{3} \cdot F_{3}$;

The second income group:

(54) $G^{f2}_{3} = O^{f2}_{3} \cdot F_{3}$;

The third income group:

(55) $G^{f3}_{3} = O^{f3}_{3} \cdot F_{3}$;

The forth income group:

(56) $G^{f4}_{3} = O^{f4}_{3} \cdot F_{3}$;

The fifth income group:

(57) $G^{f5}_{3} = O^{f5}_{3} \cdot F_{3}$.

These resources include the money from Pension fund and Social insurance fund, spent on pensions and benefits.

7.3. Banking sector

Banking sector includes Central bank and commercial banks. This economic agent has the following functions:

1) To emit money: M_4;

2) To set the interest on deposits for enterprises $P_{b\%}$ and natural persons $P^h_{b\%}$.

The actual functions of these structures in real life are much wider, but the model needs this sector only for the balance of money flows.

7.4. Outside world

All outside world parameters are set exogenously in this version of the model treats. This implies that all resource and financial flows are set for all the periods of time, on the basis of certain scenario of home and outside world producers' interactions.

8. Artificial societies – micro level economic agent

8.1. Aggregated meta data

This economic agent is presented in the model as the set of artificial societies, which make decisions about the ways of distributing their budget.

There are 5 artificial societies in the model, differing in per capita income (the first group with the lowest revenues and the firth – with the highest revenues).

This section provides equations for the model, while the procedures for calculating certain variables for these formulas are described in detail in sections 8.2-8.4. These sections also provide characteristics of each artificial society, pointing out the number of its members and mechanism for their selection.

The members of artificial society j (j = 1…5) make the following actions:

<u>On spending its budget:</u>

- Buy final goods: O^p_{2cj};

- Pay taxes to consolidated budget: O^{t}_{2j};
- Determine the share of non spent budget: O^{b}_{2j}.

The share O^{p}_{2cj} for each income group is determined by neural networks (see section 8.2).

The equations below describe behavior of artificial societies.

Demand of artificial societies for final goods:

The first income group:

(58) $D^{p}_{2c1} = \left(O^{p}_{2c1} \cdot B_{21}\right) / P_{c}$;

The second income group:

(59) $D^{p}_{2c2} = \left(O^{p}_{2c2} \cdot B_{22}\right) / P_{c}$;

The third income group:

(60) $D^{p}_{2c3} = \left(O^{p}_{2c3} \cdot B_{23}\right) / P_{c}$;

The forth income group:

(61) $D^{p}_{2c4} = \left(O^{p}_{2c4} \cdot B_{24}\right) / P_{c}$;

The fifth income group:

(62) $D^{p}_{2c5} = \left(O^{p}_{2c5} \cdot B_{25}\right) / P_{c}$.

Salary of workers:

In the first income group:

(63) $W_{21} = D^{p1}_{1l} \cdot P_{1l}$;

In the second income group:

(64) $W_{22} = D^{p2}_{1l} \cdot P_{2l}$;

In the third income group:

(65) $W_{23} = D_{1l}^{p3} \cdot P_{3l}$;

In the forth income group:

(66) $W_{24} = D_{1l}^{p4} \cdot P_{4l}$;

In the fifth income group:

(67) $W_{25} = D_{1l}^{p5} \cdot P_{5l}$.

Budget of the *j* – th artificial society:

(68) $B_{2j} = B_{2j}^{b} \cdot \left(1 + P_{b\%(t-1)}^{h}\right) + W_{2j} + G_{3}^{fj}$.

The budget is formed from:

1) money saved on bank accounts;
2) salary;
3) pensions, benefits and subsidies, received from off-budgetary funds.

The number of households in *j* - th income group:

(69) $J_j = J \cdot \left(\psi_{2j} \Big/ \sum_{j=1}^{5} \left(\psi_{2j} \right) \right)$,

where ψ_{2j} – is the umber of households in each of 5 artificial societies calculated in equation (78), and J – is Russian population.

Per capita income in the 5 groups:

(70) $B_{2j(t+1)}^{i} = B_{2j} / J_j$.

Dynamic of money on bank accounts for the members of *j* – th artificial societies:

(71) $B_{2j(t+1)}^{b} = O_{2j}^{b} \cdot B_{2j}$.

The share of budget of the members of *j* – th artificial society, spent on income tax:

(72) $O_{2j}^{t} = \left(W_{2j} \cdot T^{pod} \right) / B_{2j}$.

The residual of money for the members of *j* – th artificial society:

(73) $O^b_{2j} = 1 - O^p_{2cj} - O^t_{2j}$.

8.2. Processing of RLMS sociological data

This section describes processing the data of Russian Longitudinal Monitoring Survey (RLMS) database, used for teaching neural networks.

RLMS is a series of representative national surveys, conducted in Russia in 1992 – 2003. The survey was realized in 2 stages for 2 different samples. The second wave of monitoring consists of 6 rounds. Each of them uses with more than 3000 questions grouped into 3 questionnaires (adult, child and family. On average about 10000 adults, 2000 children and 4000 households were surveyed in each round of RLMS. The data for RLMS second wave was used in our model.

Below we describe procedures for creating neural networks.

- Neural networks № 1 – 5, which determine the shares of budget spent on final goods, i.e. macro level variable for "aggregate representative" of each *j* - th group of households O^p_{2cj} .

The data on household expenditure on 92 groups of final goods, on household income and savings (RLMS family questionnaires), were used for constructing these networks. The obtained database (the matrix which rows are observations, and columns are variables) was processed in the following way:

Step 1. The new variable H^i_{2j} - the sum of *i* –th household from *j* – th group expenditure on all the above studied final goods and services was calculated. Therefore, the database at this stage includes 2 variables:

- The revenue of each household B^i_{2j} ;

- The sum, spent by this household on goods and services in the given year H^i_{2j}.

- Stage 2. The database obtained at the first stage is further processed in the following way:

1) Only those households which reported the amount of their income were selected;

2) For each round the variable B^s_2, which is the average income for all households, was calculated;

3) The following 2 new variables were amended to each round:

- V^i_{2j}, which equals to the household income divided by the average income of all households and may be called «*variable of human difference* »:

(74) $V^i_{2j} = B^i_{2j} \Big/ B^s_2$;

- O^{pi}_{2cj}, which equals to the sum of money spent on final goods and services in a year divided by household annual income:

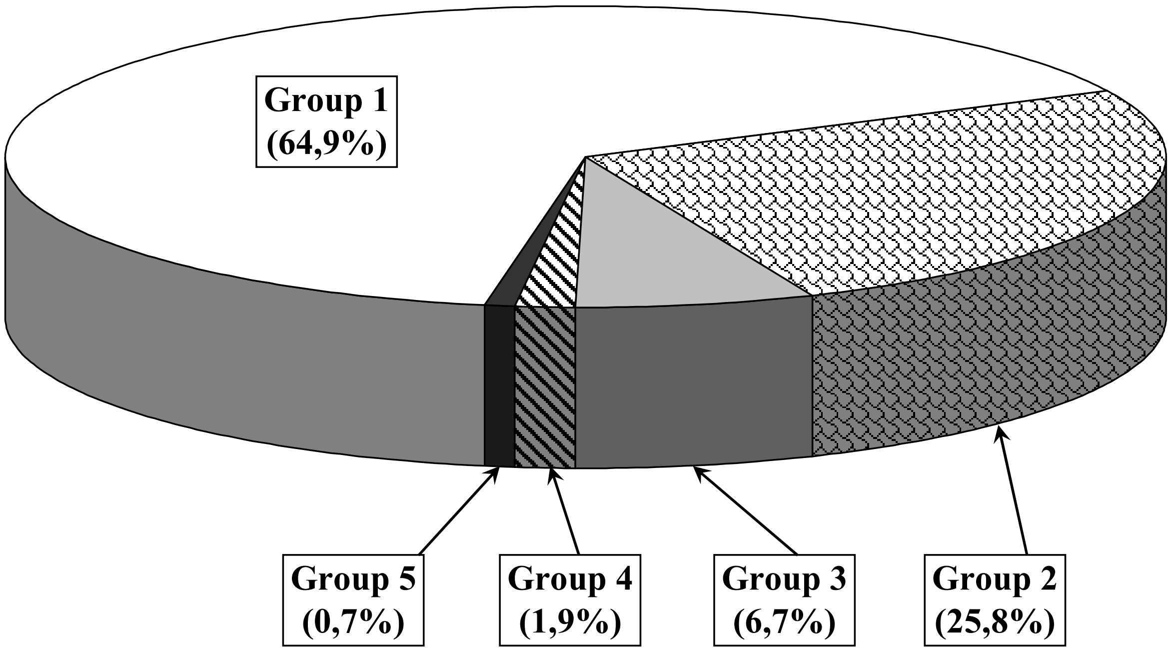
(75) $O^{pi}_{2cj} = H^i_{2j} \Big/ B^i_{2j}$

These 2 variables are all which is necessary for teaching neural networks №№ 1 – 5 to determine the shares of household budgets, spent on final goods. We combined these variables for the 6 rounds of RLMS in one database and then divided this database into 5 sets in the following way:

$$(76)\quad \begin{cases} V_{21}^i \in \left[\min\left(V_2^i\right); \min\left(V_2^i\right)+\Delta\right) \\ V_{22}^i \in \left[\min\left(V_2^i\right)+\Delta; \min\left(V_2^i\right)+2\cdot\Delta\right) \\ V_{23}^i \in \left[\min\left(V_2^i\right)+2\cdot\Delta; \min\left(V_2^i\right)+3\cdot\Delta\right) \\ V_{24}^i \in \left[\min\left(V_2^i\right)+3\cdot\Delta; \min\left(V_2^i\right)+4\cdot\Delta\right), \\ V_{25}^i \in \left[\min\left(V_2^i\right)+4\cdot\Delta; \max\left(V_2^i\right)\right] \end{cases}$$

where $\Delta = \left(\max\left(V_2^i\right) - \min\left(V_2^i\right)\right)/5$.

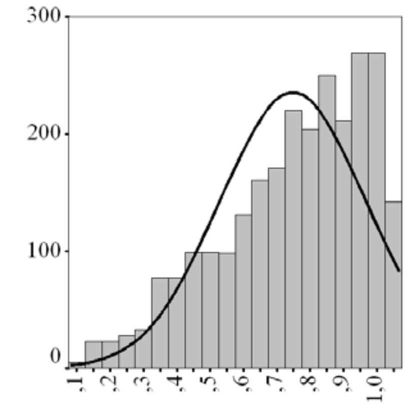
Graph 4 describes the sizes of corresponding sets.



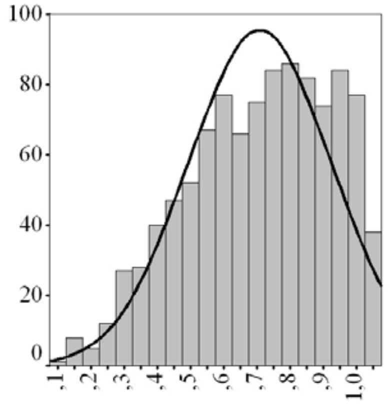
Graph 4 – V_{2j}^i for 5 groups of households (*j* = 1…5)

As might have been expected, the highest number of respondents may be seen in the group with lowest income.

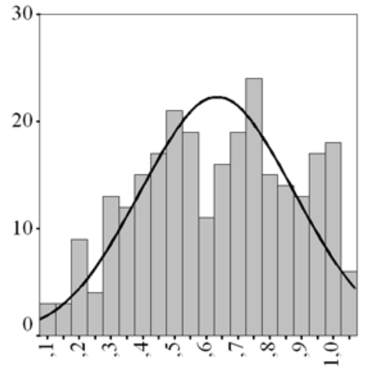
The graphs below show the distribution of the variables O^{pi}_{2cj}, which correspond to V^{i}_{2j} variables for each of the 5 income groups.



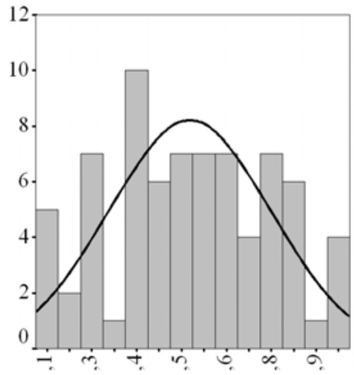
Graph 5 – Distribution of $O^{pi}_{2c1}\left(j=1\ldots 2589\right)$ for all rounds of the second wave (group 1)



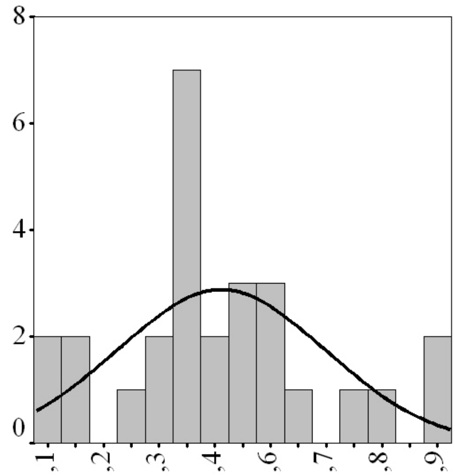
Graph 6 – Distribution of $O^{pi}_{2c2}\left(j=1\ldots 1030\right)$ for all rounds of the second wave (group 2)



Graph 7 – Distribution of $O^{pi}_{2c3}\left(j=1\ldots 269\right)$ for all rounds of the second wave (group 3)



Graph 8 – Distribution of $O^{pi}_{2c4}\left(j=1\ldots 74\right)$ for all rounds of the second wave (group 4)



Graph 9 –Distribution of $O^{pi}_{2c5}\left(j=1\ldots 27\right)$ for all rounds of the second wave (group 5)

As may be referred from the above graphs, for the lower income groups the expenditure on consumer goods and services constitute higher part of overall expenditure.

To sum up, the first neural network was taught on 2589 observations, the second – on 1030, тthe third – on 269, the fourth – on 74, the fifth – on 27.

8.3. Incorporating neural networks in CGE model

The observations used for teaching neural networks are interpreted in this ABM as correspondingly 2589, 1030, 269, 74 and 27 members of artificial societies. The number of these societies changes depending on the economic situation, with mechanism which is explained further in this section. The members of artificial societies make decisions about consumption of goods on the basis of changes in their purchasing power. Formally, each member of j – th artificial society receives the following information:

(77) $$U_{2j}^{i} = V_{2j}^{i} \cdot \left(B_{2j} / \psi_{2j}\right) \Big/ \left(B_{2j}^{f} / \psi_{2j}^{f}\right).$$

Equation (77) multiplies the variable for "human differences" on the fraction, reflecting the change of income for each member of the group j in the process of iterative recalculation. Exogenous variables B_{2j}^{f}, ψ_{2j}^{f} obtain fixed values B_{2j}, ψ_{2j} before computational experiments. Variable ψ_{2j} corresponds to the number of members in ach of the 5 artificial societies (income groups) and is calculated in the following way:

(78) $$\psi_{2j} = \sum_{i} \left(\frac{U_{2j}^{i}}{U_{2j}^{i}} \right).$$

In other words, in the course of iterative recalculation this equation computes the number of members in the j – th artificial society. This number depends on whether U_{2j}^{i} belongs to one of the 5 intervals (technically this is programmed with the help of logical condition for the value of the variable):

(79)
$$j = \begin{cases} 1; & U_{2j}^{i} \in \left[\min\left(U_{2j}^{i}\right); \min\left(U_{2j}^{i}\right) + \nabla\right) \\ 2; & U_{2j}^{i} \in \left[\min\left(U_{2j}^{i}\right) + \nabla; \min\left(U_{2j}^{i}\right) + 2\cdot\nabla\right) \\ 3; & U_{2j}^{i} \in \left[\min\left(U_{2j}^{i}\right) + 2\cdot\nabla; \min\left(U_{2j}^{i}\right) + 3\cdot\nabla\right) \\ 4; & U_{2j}^{i} \in \left[\min\left(U_{2j}^{i}\right) + 3\cdot\nabla; \min\left(U_{2j}^{i}\right) + 4\cdot\nabla\right) \\ 5; & U_{2j}^{i} \in \left[\min\left(U_{2j}^{i}\right) + 4\cdot\nabla; \max\left(U_{2j}^{i}\right)\right] \end{cases},$$

where $\nabla = \left(\max\left(U_{2j}^{i}\right) - \min\left(U_{2j}^{i}\right)\right) / 5$.

Output variables for neural networks №№ 1 – 5 N_{2j}^{i} (see equation 86) are transformed in order to be used in the macro economic system (CGE model) in the following way:

(80) $$O_{2cj}^{p} = \left(\sum_{i} N_{2j}^{i} \cdot \left(\frac{U_{2j}^{i}}{U_{2j}^{s}}\right)\right) \Big/ \psi_{2j},$$ where U_{2j}^{s} – is the average value of U_{2j}^{i} for all members of j – th group.

For each i – th member of the group this neural network parameter is then multiplied by U_{2j}^{i} and divided by the number of members in the group. Such correction is necessary for computing the aggregated share of budget for the whole group of households.

(Since each group uses its own network, the iteration recalculation process may lead to a result when a member of one artificial society started earning more and thus shifted to other income group and artificial society. Therefore, in making consumer decisions, this member begins to use another network).

The shares received at this stage are used in determining household demand of final goods in equations (58) – (62).

8.4. Neural networks used in the agent based model

The values of network input parameters may belong to various intervals, while the sensitivity of logistic function for sigmoid activation (activation function is used very frequently) is just slightly wider than $(-1;1)$ interval. Output parameters for sigmoid also belong to narrow interval $(0;1)$.

To correct these inconsistencies it is possible to apply various scaling methods to input and output values. The neural networks constructed in this paper used mini-max algorithm, which transformed each variable, multiplying it on scaling coefficient and adding the value of bias.

Therefore, the zero activation level corresponds to the minimum value, present in the database for teaching neural networks. Activation level equal to one corresponds to the maximum value in the database.

The neural networks used in ABM have the same architecture of three layer preceptors. Difference arise from the number of neurons of the hidden layer, the values of scaling coefficients and the bias for income and outcome variables, and the values of synapse weights and the thresholds for neurons activation.

As was above described, input variables for neural networks are U_i^j, where j is the member of artificial society and i is the number of neural network, which processes input signal. Each input varibale U_i^j is scaled by multiplying the scaling coefficient $r_{(i)scale}^{in}$ and adding the bias $r_{(i)shift}^{in}$:

(81) $\theta_i^j = U_i^j \cdot r_{(i)scale}^{in} + r_{(i)shift}^{in}$.

Then, each neuron of the second layer receives the values of scaled variable θ_i^j, corrected by the corresponding synapse weigh w_i^{2k} and threshold value τ_i^{2k}:

(82) $x_i^{jk} = \theta_i^j \cdot w_i^{2k} - \tau_i^{2k}$, where k is the number of neuron in the second layer.

Threshold τ_i^{2k} is a special numeric criterion for further determination of activation level.

Obtaining x_i^{jk} as the argument, sigmoid for each neuron of the second layer looks in the following way:

(83) $$f_i^{jk}\left(x_i^{jk}\right) = \frac{1}{1+e^{-x_i^{jk}}}$$

The aggregate impulse, coming to a neuron of the output layer, is calculated as the sum of the values of activation functions of each second layer neuron, corrected by synapse weight w_i^{3k}, with subtraction of the threshold τ_i^3, which determines the activation level of the linear function for output neuron:

(84) $$\pi_i^j = \sum_k \left(f_i^{jk}\left(x_i^{jk}\right) \cdot w_i^{3k} \right) - \tau_i^3$$

Finally, the value of output neuron π_i^j is transformed in the output value of neural network N_i^j by subtracting the bias $r_{(i)shift}^{out}$ and then dividing the obtained residual on scaling coefficient $r_{(i)scale}^{out}$ (reverse scaling):

(85) $N_i^j = \left(\pi_i^j - r_{(i)shift}^{out} \right) \Big/ r_{(i)scale}^{out}$.

All transformation in (81) – (85) may be written as one equation:

(86) $$N_i^j = \frac{\sum_k \left(\frac{1}{1 + e^{-\left(\left(U_i^j \cdot r_{(i)scale}^{in} + r_{(i)shift}^{in} \right) \cdot w_i^{2k} - \tau_i^{2k} \right)}} \cdot w_i^{3k} \right) - \tau_i^3 - r_{(i)shift}^{out}}{r_{(i)scale}^{out}}$$

The numeric values of neural network parameters are not so important, since the emphasis in this paper is made on methodological approach to ABM development. Therefore, we do not concentrate on technical issues of neural networks realization and will just list the function of networks in the framework of the model.

- Neural network № 1 determines the share of budget for each member of the *first income* group, spent on final goods.
- Neural network № 2 determines the share of budget for each member of the *second income* group, spent on final goods.
- Neural network № 3 determines the share of budget for each member of the *third income* group, spent on final goods.
- Neural network № 4 determines the share of budget for each member of the *forth income* group, spent on final goods.
- Neural network № 5 determines the share of budget for each member of the *fifth income* group, spent on final goods.

9. Adequacy of the model – retrospective forecast

Before conducting computational experiments (described in section 10), it was necessary to test the adequacy of the model in order to test its ability to give plausible forecasts.

The model was calibrated for the period from 2000 to 2004. To test the adequacy of the model, its exogenous parameters were prolonged for the year 2005.

Since the exact values of the integral parameters in the model (GDP, consumer price index) are known from national statistics, it is possible to compare the estimated value of endogenous parameters in the year 2005 with the corresponding actual values.

The table below provided the estimated and actual values of GDP and consumer price index in Russia.

Table 1 – The major macroeconomic parameters of Russia (2000-2004 – calibration period, 2005 – test period)

	2000	2001	2002	2003	2004	2005
GDP in the base year (2000) prices						
Estimated value	7305,6	7677,6	8041,8	8632,7	9249,4	9909,2
Actual value	7305,6	7677,6	8041,8	8632,7	9249,4	9841,4
Consumer price index, percent of the previous year						
Estimated value	20,2	18,6	15,1	12	11,7	11,2
Actual value	20,2	18,6	15,1	12	11,7	10,9

As may be referred from the table, the estimated value differ very slightly from actual ones. This allows make an assumption that the model is capable to provide plausible prediction fro the longer period (the model deals with midle-term forecasts till 2015).

10. Modelling the consequences of corruption and shadow economy

The study analyzed the relation between certain components of shadow economy and major macroeconomic parameters of the country (GDP and consumer price index).

The first series of computational simulations was an imitation of the process of redirecting an amount of sources from consolidated budget to households. This was aimed to be an imitation of the direct theft or “legal” means of using budgetary money. These “legal” means include buying equipment fro public institutions with announcing a competition between possible sellers, while the actual winner of the competition is known from the very beginning. After this winner receives the amount of resources, he returns a part of the money in cash back directly to government officials.

The model deals with the following ways of withdrawing budgetary sources with further redirecting them to households:

- Scenario №1: extracting 10% of consolidated budget;
- Scenario №2: extracting 20% of consolidated budget;
- Scenario №3: extracting 30% of consolidated budget;
- *Scenario №0 is the basic scenario of economic development*.

We should note here the limitations of the model. We supposed that the monetary sources come only to the 5th group of households (the 5th neural network). In reality, however, this may be different. Nonetheless, since in practice it is very hard to single out the income group related to misappropriation of public money, we supposed that only the highest income group is involved in the shadow economy. Consequently, as for resulting macroeconomic parameters, instead of analyzing income in each income group, we will concentrate on GDP and consumer price index. The same limitation is applicable to the second series of computational experiments.

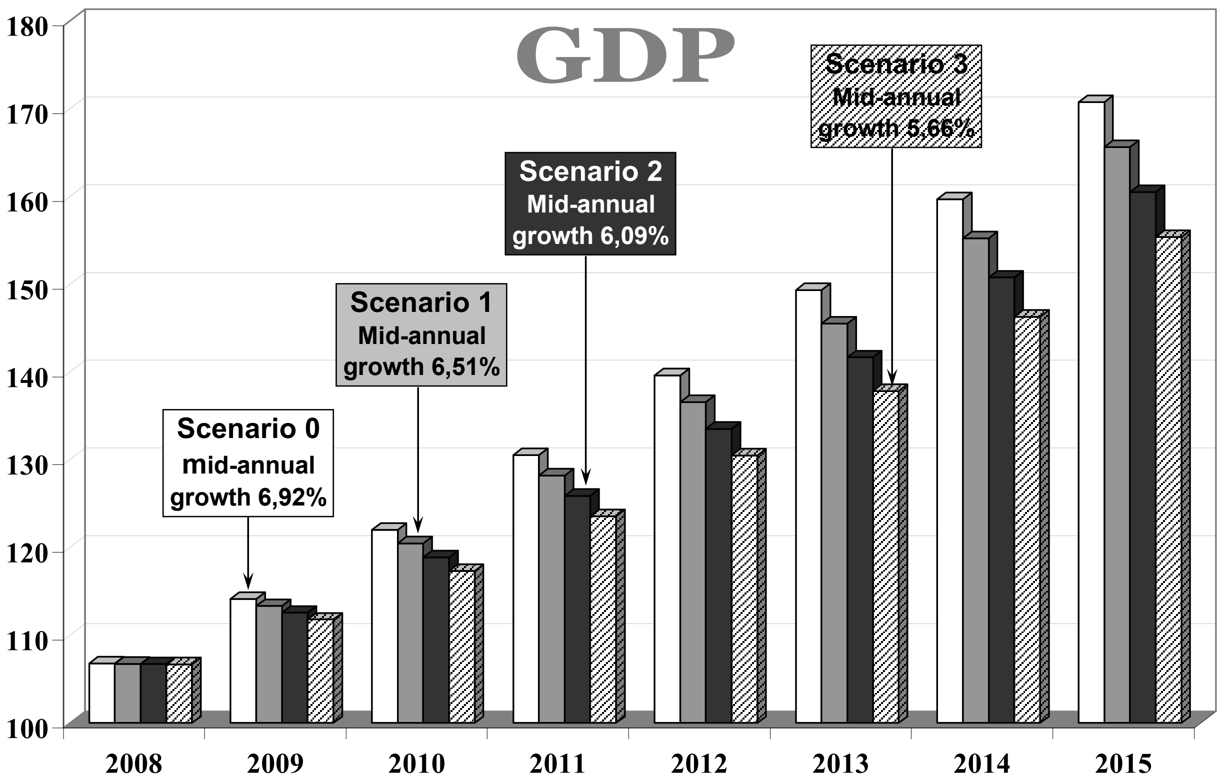
The revenues of consolidated budget in 2005 were 6820,6 billion rubles. The above mentioned sums equal to 10%, 20% and 30% of consolidated budget are correspondingly 682 billion rubles ($26 billion), 1364 billion rubles ($53 billion) and 2046 billion rubles ($78 billion). The model simulates the scenario of economic development fro the years 2008-2015. Prolonged values of the extracted money equal correspondingly to $43 billion, $87 billion and $130 billion in 2008. the money is assumed to be extracted annually, including extraction in the final year 2015.

The table below provided the results of the calculations.

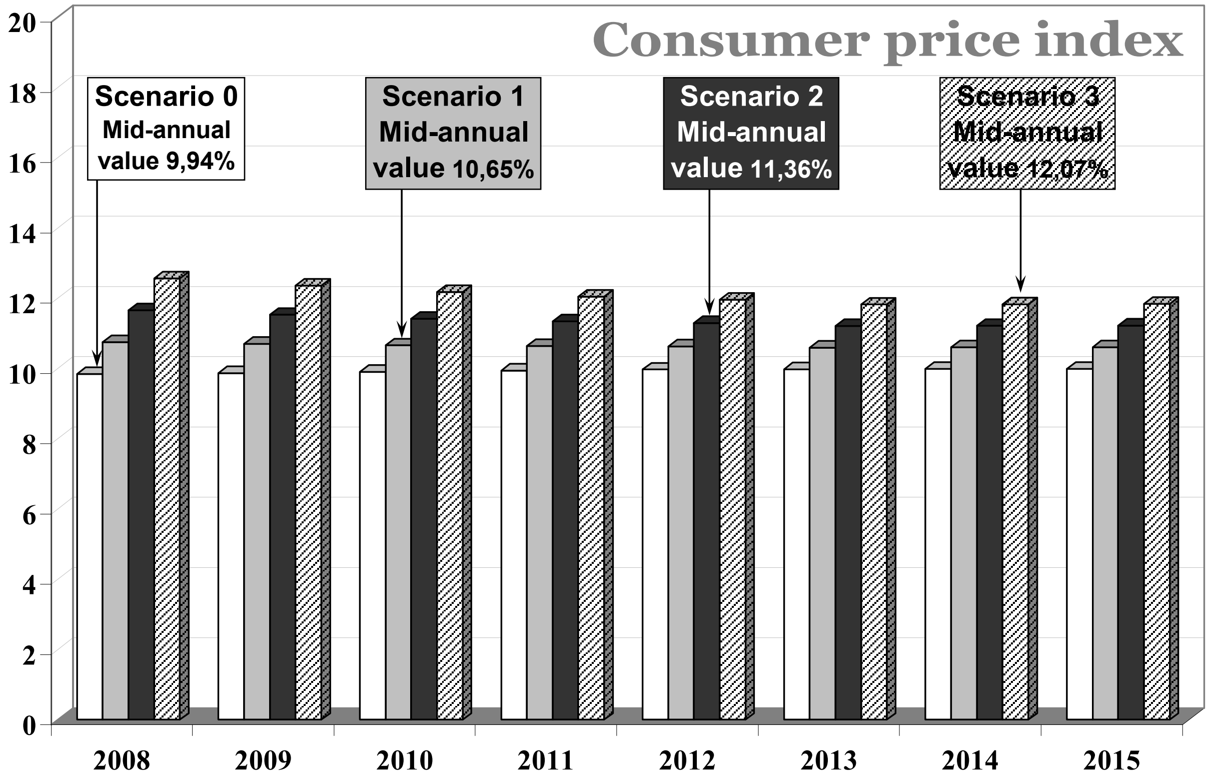
Table 2 –The consequences for extracting money from consolidated budget and transferring it to households

	2008	2009	2010	2011	2012	2013	2014	2015
Russian GDP (2007 = 100%)								
Scenario 0	*106,78*	*114,12*	*122,03*	*130,51*	*139,61*	*149,33*	*159,68*	*170,74*
Scenario 1	106,75	113,34	120,46	128,19	136,56	145,50	155,22	165,62
Scenario 2	106,72	112,57	118,89	125,87	133,52	141,67	150,76	160,50
Scenario 3	106,69	111,79	117,32	123,55	130,47	137,84	146,30	155,38
Consumer price index, percent of the previous year								
Scenario 0	*9,84*	*9,87*	*9,90*	*9,94*	*9,97*	*9,98*	*9,99*	*9,99*
Scenario 1	10,75	10,70	10,66	10,64	10,63	10,59	10,60	10,61
Scenario 2	11,65	11,53	11,42	11,34	11,30	11,20	11,22	11,22
Scenario 3	12,56	12,36	12,17	12,05	11,96	11,82	11,83	11,84

To make it more visual, we present the above results in the form of graphs.



Graph 10 – Forecast of GDP growth, percent of the 2007 value (extracting money from consolidated budget and transferring it to households)



Graph 11 – Forecast of consumer price index, percent of the previous year (extracting money from consolidated budget and transferring it to households)

To sum up the analysis we can make the following observations. Budgetary money, which went to households, provoked the increase in private expenditures and this, in its turn, resulted in the rise in prices. The growth in consumer price index may be explained by increase in demand combined with decrease in production, since producers did not receive the due amount of expected subsidies from the budget.

Consequently, under the scenario №3 the economy witnesses the decrease in the average annual GDP growth rate from 6,92% (basic scenario) to 5,66%. Therefore, by the year 2015 non realized potential growth of GDP (with 2007 as the base year) will be 5,12%, 10,24% and 15, 26%correspondingly for the three simulated scenarios.

AS for the rise in consumer price index, the average annual values increase correspondingly 0,71%, 1,43% and 2,14%.

The second series of calculation deals with extraction of money from producers and transferring it to households. It imitates giving bribes by producers and receiving bribes (the final recipients of these bribes are households). The examples of such a scheme may be opening a new business by entrepreneurs, obtaining a license for construction, “made up” fines etc. The bribes paid by producers are reflected in the increase of commodity prices, which influences the budgets of households.

On the other hand, a certain part of households benefits from this scheme, leading to the rise in demand fro consumer goods and services. The increase in demand causes the rise in prices. The situation is worsened by extracting the money from producers, since the latter now lack the chance to invest in production.

The sources, extracted in this series of calculations, are larger than those in the previous series and equal to $70 billion, $140 billion and $210 billion for the following 3 cases:

- Scenario №1: extracting 10% of sources from producers of goods and services;
- Scenario №2: extracting 20% of sources from producers of goods and services;
- Scenario №3: extracting 30% of sources from producers of goods and services;
- *Scenario №0 is the basic scenario of economic development.*

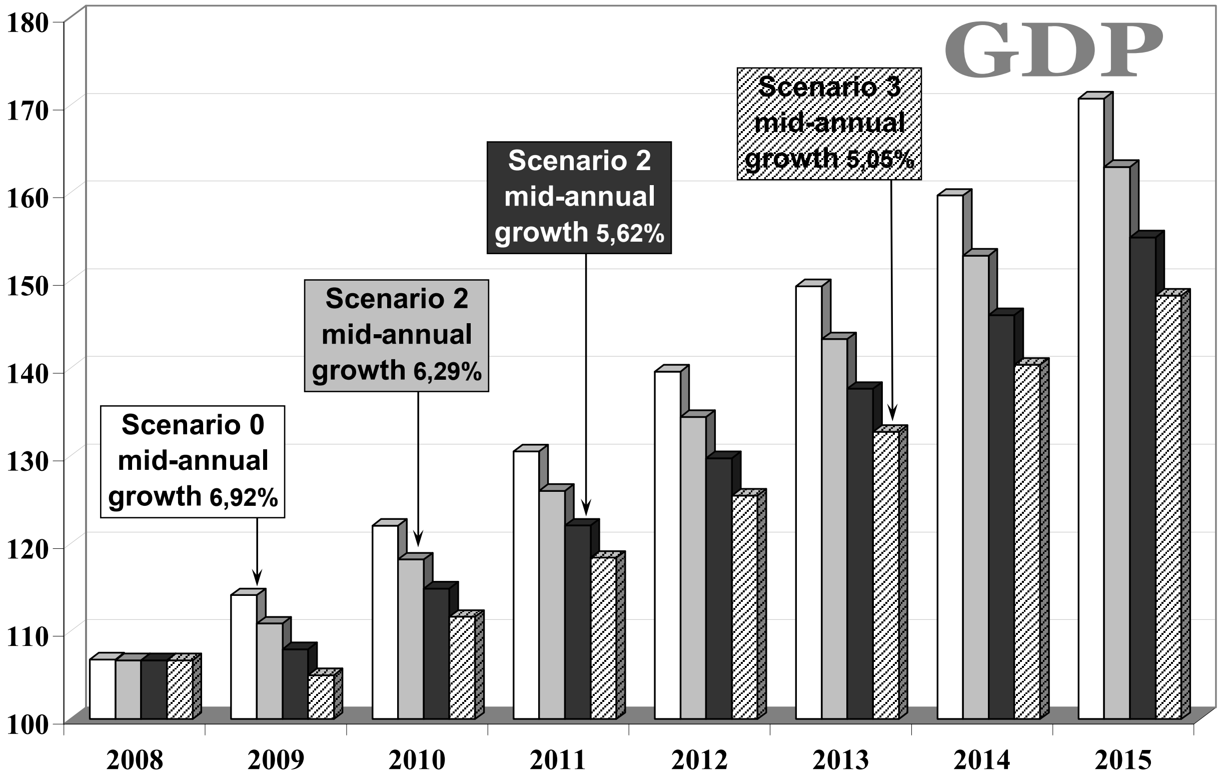
The table below shows the results of calculations.

Table 3 – The consequences of extracting money from producer and transferring it to households

	2008	2009	2010	2011	2012	2013	2014	2015
Russian GDP (2007 = 100%)								
Scenario 0	*106,78*	*114,12*	*122,03*	*130,51*	*139,61*	*149,33*	*159,68*	*170,74*
Scenario 1	106,70	110,89	118,19	126,00	134,45	143,32	152,82	162,94
Scenario 2	106,70	107,95	114,89	122,07	129,72	137,65	146,06	154,92
Scenario 3	106,69	105,02	111,66	118,38	125,49	132,75	140,38	148,29
Consumer price index, percent of the previous year								
Scenario 0	*9,84*	*9,87*	*9,90*	*9,94*	*9,97*	*9,98*	*9,99*	*9,99*
Scenario 1	16,58	11,82	10,33	10,41	10,38	10,54	10,52	10,53

Scenario 2	23,31	14,88	10,55	10,88	10,97	11,23	11,26	11,33
Scenario 3	37,42	18,15	10,69	11,19	11,34	11,69	11,80	11,95

Similarly to the previous calculations, we demonstrate the results in the form of graphs, too.

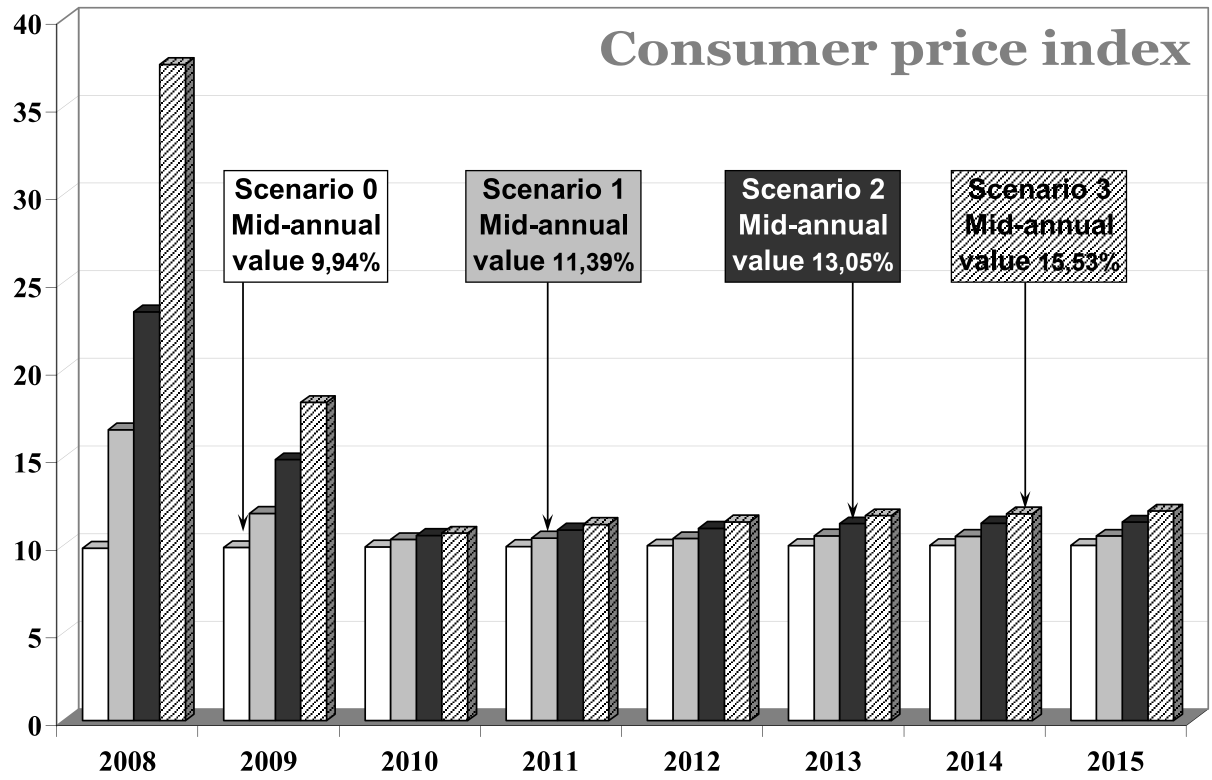


Graph 12 – Forecast of GDP growth, percent of the 2007 value (extracting money from producer and transferring it to households)

As may be referred from the above tables and graphs, extracting the money from producers leads to particularly negative results. Non realized cumulative potential growth of GDP reaches for the 3 analyzed cases correspondingly 7,80%, 15,81% and 22,45% by the year 2015.

Moreover, in the 3 scenario there is almost 1% decrease of GDP in the year after the extraction of money.

As for inflation, economy witnesses considerable growth of average annual values by 1,45%, 3,12% and 5,59% fro the studied cases. In the first year there is a strong outburst of inflation, but then the gradual adjustment of economic system is observed. By the year 2015 the growth of consumer price index for scenario №3 (as for the most extreme scenario) becomes 1,96% of that of the base year.



Graph 13 – Forecast of consumer price index, percent of the previous year (extracting money from producer and transferring it to households)

To sum up, it should be noted that the two analyzed aspects of shadow economy (budgetary theft and bribes) lead to extremely negative results for the country's economy. The both cases see the rise in consumer demand leading to growth in consumer prices. It is also that the producer often transfers the cost of bribes to the price of the product, which contributes to the increase of prices, as well. In any case, in the end the burden is born by the largest part of population, non related to distribution of budgetary resources or giving and receiving bribes.

Conclusion

The articles proposes the approach of constructing hybrid agent based models, which combine micro level, represented by a set of agents with bounded rationality, and macro level, realized with the help of CGE modeling.

The developed ABM allowed analyzing the relations between certain components of shadow economy and major macroeconomic parameters of the country (GDP and consumer price index).

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Modeling Competition with Evolution of a Multi-Agent System

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Introduction

Agent-based modeling (ABM) is a very efficient tool for analyzing socio-economic systems (Makarov, 2006). One of important directions of multi-agent model studies (Tarasov, 2002) is the research of competition between different agents. Two types of competition: constructive and aggressive may be considered. It is particularly crucial to analyze situations when aggressive competition disappears, for it allows understanding conditions of coordinated cooperative agent work. Full elimination of competition is not profitable since constructive competition could and should lead to contest, search for new decisions and progressive development. Aggressive competition, when aggression leads to cruel fight between the agents, wars, and murders of some agents by the other, demands elimination and shift to constructive competition.

The theories of competitive behavior, incorporating competitive interrelation between the agents, historically started from the models of classic population genetics (Wright, 1945, Hamilton, 1964, Wilson, 1975). Then game theory became the major instrument in this field (Axelrod, Hamilton, 1981, Eshel, Cavalli-Sforza, 1982). While the first models studied the co-evolution of the two strategies – altruist and egoist – and did not concentrate on the emergence of cooperative behavior, recently there is the tendency of more detailed study of the latter. Cooperative behavior evolution models usually incorporate special effects and population structure. They are represented by computer models, in most cases based on game theory (Nowak, May, 1992, Wilson, Dugatkin, 1997, Riolo, Cohen, Axelrod, 2001).

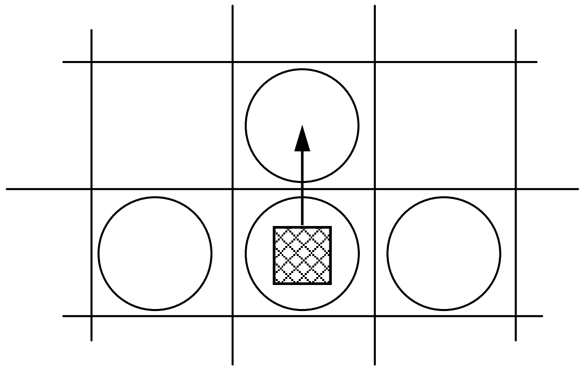
Analytic models of cooperative behavior evolution allow receiving visual results. However, the cost of this visual feature is introduction of many assumptions in the models. These assumptions include the following: infinite population size, limited number of possible strategies, neglecting special structure of population. Modern computer models, on the other hand, allow getting rid of most of these limitations. Yet, scenario of inter-agent relations is very simplified in all currently proposed models. Usually the agent can choose one of the two actions – cooperate or not cooperate with the current partner. Therefore, studying cooperation and competition with the help of ABM, where agents have a large set of strategies and interact in space, is particularly interesting.

This paper characterizes the studies of agent-based modeling with competing agents, who lost “aggressiveness genes” in the course of evolution. This led to the growth of multi-agent population size (Burtsev, 2002, Burtsev, Redko, 2002, Redko, 2004). The paper analyses the perspectives for developing these studies.

Competing Agents Evolution Model

Burtsev (2002), Burtsev and Redko (2002) build and study ABM of purposeful adaptive behavior emergence. The model is an artificial society in a 2-dimension closed space. The space is separated into cells, containing agents and their food. One cell can not contain more than one agent. The food consumed by agents appears in cells with a certain probability. Each agent has inner energy resource R ($R \geq 0$). Resource is being renewed with eating and, possibly, with fighting with other agents. Resource is being spent within other actions.

Below is the description of an agent work. Sensor system of the agent provides for agent’s perception of outside world (Graph 1) and gives the agent information about its inner condition. Agent is oriented in space. The agent has “forward” direction, and the field of vision is oriented with regard to this direction. The actions made by the agents are determined. The agent’s field of vision consists of the 4 cells: the cell, where the agent is situated, and the cells on the left, on the right and in front of the agent. The agent can see the food and other agents in its field of vision. Apart from the information about the cells and their condition, the agent receives information about its inner resource R and the change of this resource ΔR.



Graph 1. Field of Vision of the Agent. The arrow demonstrates the "forward" direction, the circumferences mark the cells, from which agent receives information. The square marks the cell where agent is situated.

We analyze the discreet time case, $t = 0,1,2,...$ In each period of time agent makes only one action. These actions are the following: 1) eat, 2) move one cell forward, 3) turn to the left, 4) turn to the right, 5) rest (not do anything), 6) multiply (reproduce itself), 7) hit the agent in front (attack), 8) defend itself.

Reproduction is one of the actions the agent can make. The agent's heir inherits changed with mutations self-ruling system of its parent and a part of parent's energy. If energy resource of the agent falls to 0 in the course of its life, the agent dies.

Let us denote: ΔR – the change in agent's resource in one period of time; k_i – parameters of inner resource change ($k_i \geq 0$). Agent's resource is limited: $R \leq R_{max}$, where R_{max} – is maximal (rather high) value.

Accomplishing different actions leads to the following changes of agent's resource R:

1) Resting: $\Delta R = - k_1$.

2) Moving: $\Delta R = - k_2$.

3) Turning (to the left or to the right): $\Delta R = - k_3$.

4) Eating: $\Delta R = - k_4 + k_5$.

5) Reproducing: $\Delta R = - k_6$.

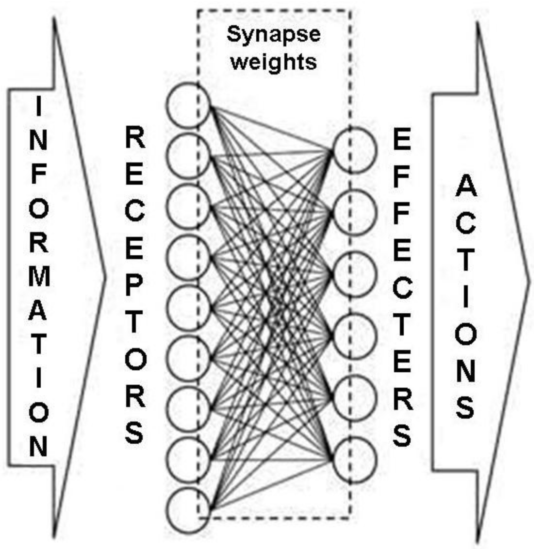
When an heir appears the parent gives ita part of own energy: $\Delta R_p = - 0.5R_p$. Initial heir's resource R_o equals to energy received from the parent $R_o = 0.5R_p$. Here *p* and *o* denote respectively the parent and the heir.

6) Attacking other agent: $\Delta R = 0.5k_7$, if the victim does not protect itself and $\Delta R = - k_7$ if the victim protects itself.

7) Defending itself from the other agent: $\Delta R = - k_8$.

If in the course of the action it turns out that $R > R_{max}$, we let $R = R_{max}$.

The system of agent self-ruling is one-layer neural network with receptor (input) and effecter (output) modules (Graph 2). Receptor signals come to the input of neural network, signals from the outputs – to network effecters. The set of modules and parameters of link between them are set by agent's genome. Agent's genome **G** consists of two chromosomes **G** = (**W**, **M**). The first chromosome contains the neural network synapse weights. The presence or the absence of the module in the network structure is determined by the value of the corresponding binary number (1 or 0) in the second chromosome. Agent's genome **G** does not change in the course of its life.



Graph 2. The Structure of Agent's Neural Network.

The following signals are sent at the entry (input) of agent's neural network:

1) signal about the presence of food in the agent's field of vision (in agent's cell, in front, on the left, on the right);

2) signal about the presence of other agents in the filed of vision (in front, on the left, on the right);

3) current value of the inner energy resource R;

4) the difference between resource's maximum R_{max} and current R values;

5) resource change ΔR;

6) additional constant input signal.

The output values y_j for the neural network are set as:

$$y_j = \Sigma_i W_{ij} x_i \ ,$$

where x_i – inputs of the j neuron, and W_{ij} – its synaptic weights. The number of inputs for each neuron equals to 11, i.e. the number of different sensor signals. The number of output neurons in neural network equals to 8 – the number of its actions. Agent accomplishes the action which implies the maximum value of y_j .

All agents constitute population. Population of agents goes through evolution within time due to the two factors: the changes of structure and weights of synapses in the ruling neural network and the selection of agents who gain resource and reproduce fast.

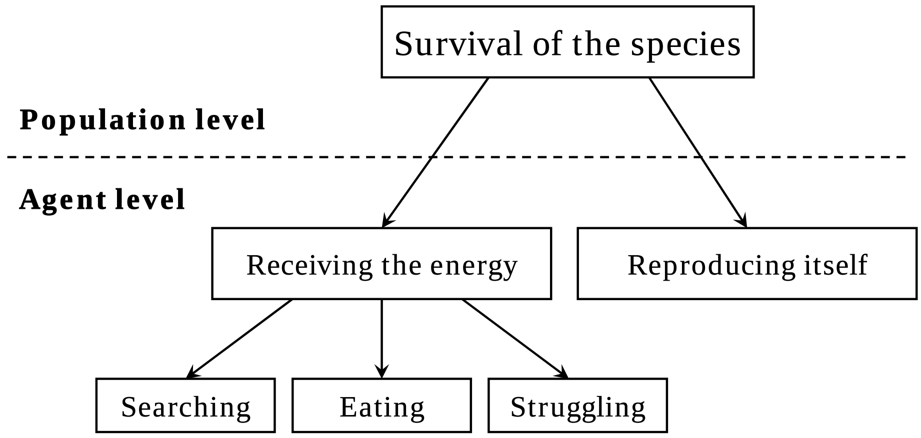
Genome variation happens due to the below described mutations:

1) Adding to each weight W_{ij} stochastic value, uniformly distributed on the interval [-p_m, p_m], where p_m – intensiveness of weight synapses' mutation;

2) Changing of the value M_j, which determines the presence or the absence of the module. Under this mutation there is removal or adding of sensor or effecter with the possibility p_s.

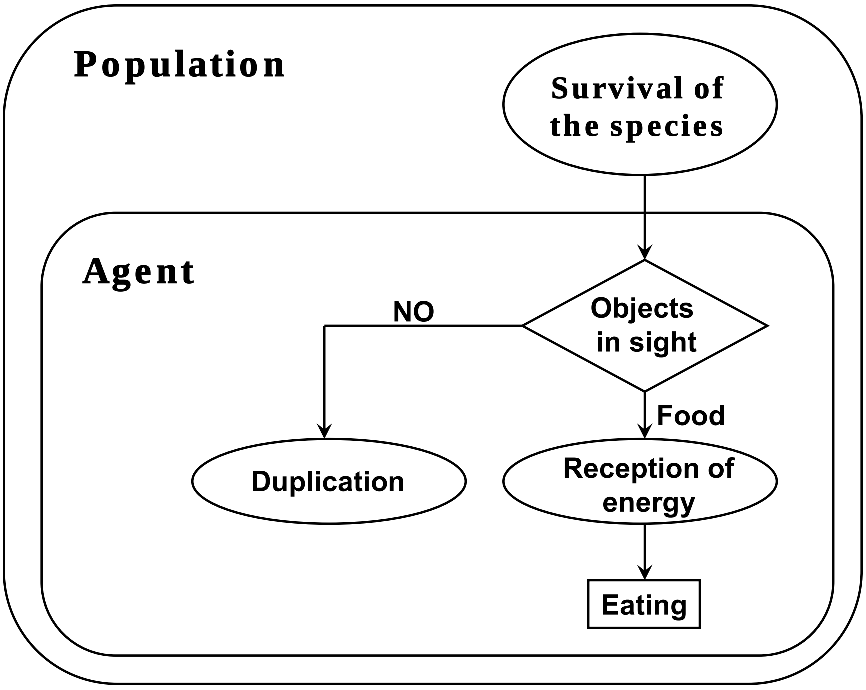
Results of the Modeling

In the course of computer experiments we showed the possibility of agents' goals hierarchy emergence in the course of artificial evolution. "Meta goal" for each agent in evolutionally stable population is "survival of the species". Meta goal determines the goals of agent's existence – to receive energy and to reproduce itself. These two goals may be in turn divided into subgoals. Simplified goal hierarchy for population and agents is described in the Graph 3.



Graph 3. Goal Hierarchy, Emerging in the Course of Computer Experiment.

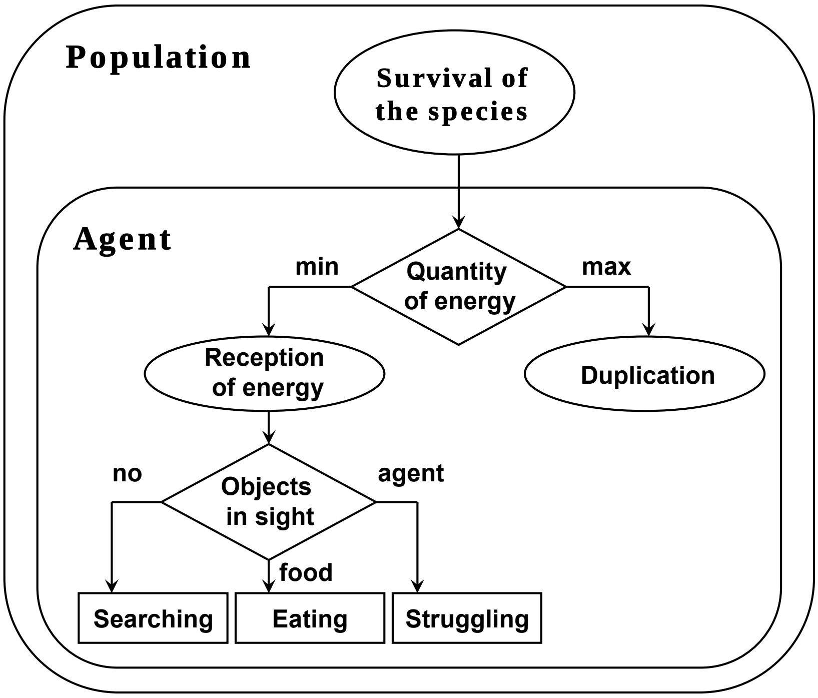
In the beginning of each experiment the world is being settled by population of agents, who have minimal set of receptors and effectors: the agent can see food in the cell where agent is situated and in the cell in the front. The agent can make the following actions – eat, move, and reproduce itself. The weights of the synapses are set in order to provide the two initial instincts for the agent – eating and reproduction. If agent sees the food in its cell, the agent should make the action "eat". If the food is seen in the neighboring cell, the agent should move to this cell. If the agent does not see anything, it should reproduce itself. These agents of initial population have primitive strategy, taking into consideration only the presence of food in the field of vision. The structure of agents' goals is demonstrated in Graph 4.



Graph 4. The Scheme of Subgoals for the Agent in Initial Population.

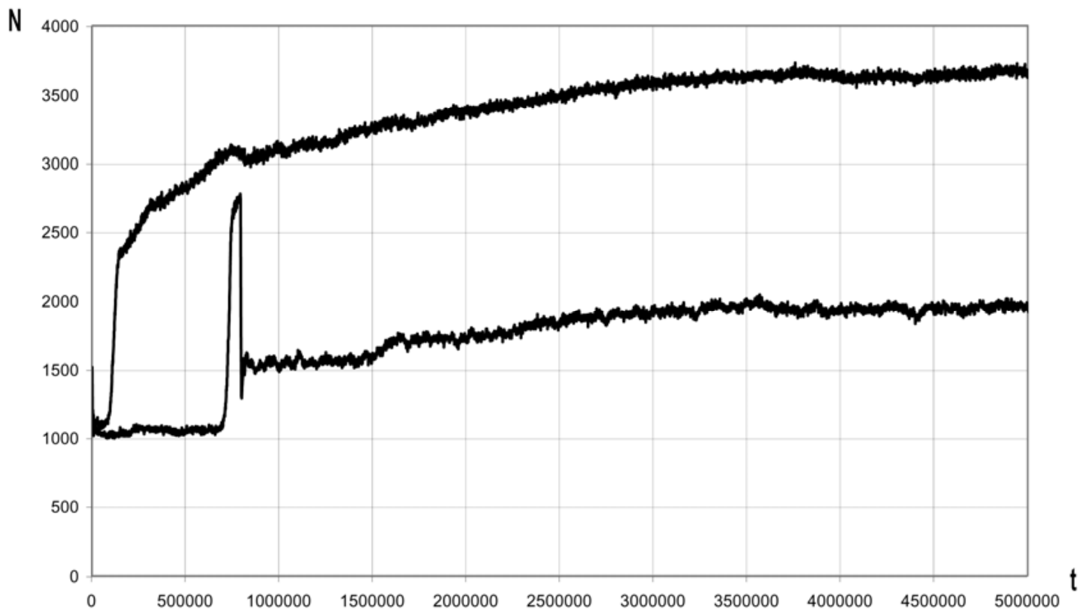
In the process of evolution the population of agents sees emergence of behavior, which corresponds to a more complex goal hierarchy with sensors and effecters (Graph 5).

The most interesting finding in analyzing this model is the possibility of studying effects, dealing with aggressive competition between agents. In certain computer experiments the unexpected peaks in the change of population size with time were present (Graph 6, lower curve). The analysis of agent's self-ruling system demonstrated that peaks corresponded to those periods of time, when effecters responsible for the fight between agents were absent in the neural network. To prove this effect we compared the full model (with the fight between agents) with the model, where fight effecters were totally eliminated from agents' ruling system (Graph 6, upper curve). It can be seen that in case of "global pacifism" the stable size of population was approximately 2 times higher, than for usual agents, fighting one with another. This may be explained by the fact that the presence of aggressive competition led to consuming the resource *R* for the very fight with each other.



Graph 5. The Scheme of Subgoals Choice, Formed in the Course of Agents' Evolution.

These agents lacked resource for "creative" life, for active accumulating of resource and for spending it on the processes of reproduction, which could lead to the rise in population size. Consequently, elimination of the fight between agents and disappearance of "aggressiveness genes" lead to increase in the size of population.



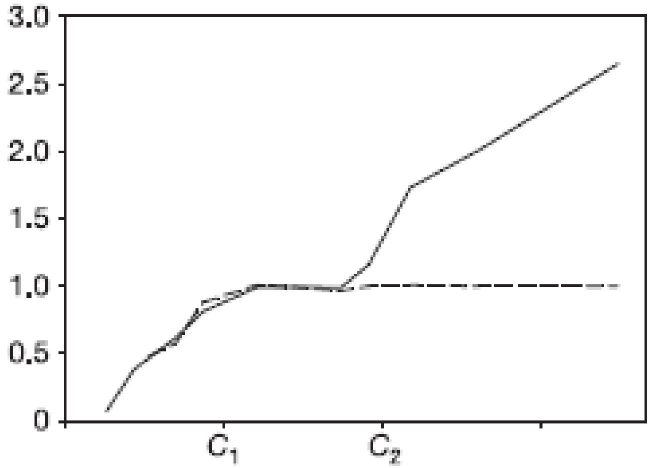
Graph 6. The Change of Population Size *N* in Time *t* in the Full Model (Lower Curve) and in the "Global Pacifism" Case (Upper Curve).

It should be noted that the observed effect of "aggressiveness genes" disappearance was present only in the short period of time (lower curve in Graph 6). This short-term feature is observed due to the fact that mutational appearance of new agents leads to active fight of aggressive agents with "peaceful agents" (those, not having fight effecters). Therefore, peaceful agents are being driven out of population. Aggressive competition led to destruction of peaceful agents. Only agents having the means for aggressive competition could survive.

Nonetheless, in modification of this model we observed formation of population where peaceful agents could exist within a long period of time. Indeed the agents modeled in Burtsev (2005), Burtsev and Turchin (2006) had marker vectors, which were initially stochastically set. It was also assumed that several agents could not be in one cell simultaneously. Markers changed from parents to heir only with minor mutations. Therefore, agents-heirs have markers similar to those of their parents. In the process of evolution due to mutations and selection there is the similarity of markers for the heirs of the same parent. Therefore, in the course of competition these agents with similar markers have similar tactics. Agents-relatives do not benefit from fight with each other. This disadvantage of fight between the agents-relatives appeared by itself in the course of evolutional self-organization of agents' population.

Several types of agents with different markers were observed in evolving population. They can be called "hawk", "pigeon", "crawl", "bourgeois", and "starling". "Hawks" and "pigeons" are analogues of predator and victim in evolution game theory. Other strategies can be attributed to more complex forms of behavior. "Crawls" do not attack agents of their own species, but can attack agents of different species ("Crawl does not peck the eye of another crawl"). The strategy of "starling" is most unusual. "Starlings" are moderately aggressive birds, who as a flock can cooperatively protect themselves from aggressive predators of other species. When the amount of joint food resource *C* was large, the model demonstrated the emergence of “starling” subpopulations, non aggressive to each other. The size of population in this case increased considerably if compared to the size of population without markers (Graph 7).

Consequently, the use of agents with markers, when the amount of food resource *C* is large, allows forming the species on non-aggressive agents, such as “starlings”. Agents-starlings aggressive agents could appear due to mutations and could destroy peaceful ones. Nonetheless, it was shown that when *C* is very big peaceful agents form the largest part of population.



Graph 7. The Dependency of Average Population Density on the Size of Resource *C* (Burtsev, 2005, Burtsev, Turchin, 2006). Stroke line demonstrates the case of agents without markers, thick line denoted population with makers. The latter has a lot of non-aggressive “starlings”.

Conclusion

The study of computer models demonstrates that emergence of peaceful non-aggressive agents is achievable in evolution of multi-agent system population. These peaceful agents appear in population with markers. In this case the heirs have markers similar to those of their parents and hence behave in the way their parents behave. In fact there is formation of the species of similar agents. As a result, peaceful, non-aggressive agents do not spend their resource on the fight with each other. Therefore, the populations of rather large size are being formed in the process of evolution.

There are interesting directions for developing the above outline models. Firstly, one could exploit the already developed models and study evolution processes in detail. This research may include: 1) the analysis of general characteristics of multi-agent system evolution by the means of constructing generalized models of differential equations, 2) replacing neural network of self-ruling by simpler classifying systems (Holland et al, 1986, Butz, Hoffmann, 2002).

Secondly, there are possibilities for studying the processes of aggressive competition disappearance for various socio-economic applications: populations of competitive firms, regions, and countries. In the second case it is important to study not only the markers, allowing evolutional formation of similar agents' subpopulation, but "conscientious" forms of eliminating aggressive competition. In other words, markers determining similarity between agents-relatives, should be replaced by certain forms of self-understanding in order to eliminate aggressiveness between groups of agents, representing firms, nations, and states.

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Agent-Based Investment Technology (Part 1. Original Data)

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Global economy offers new tools for understanding socio-economic development in the light of scientific interpretation of social interactions. Once criticized, fundamental theories gained rational and very reasonable shapes, reflecting the essence of human dynamics in time and space. They provide infinite opportunities for research of past and present. These enormous studies determine major tendencies and eliminate inconsistencies due to the power of Science – an instrument of reaching the goals of the society. Over half a century ago the mankind has changed the view on the flow of time and established new relations on the basis of means of communications and qualitative perception of information.

Agent-based calculations, as the currently forming scientific paradigm, allow creating economic and social design for in-depth study and applications. This paper employs agent based modeling to deal with information technology of chain non stock market market investment as innovative model of human development. The first part of the study reflects certain results of theoretic research. The second part characterizes the major features of technology. The third part explains results of various modeling.

1. The View of the Basis

Marx wrote: «…Whatever are the public forms of production, the work and the means of production always remain production factors. However, being at the distance from each other, the former and the latter are only potential production factors. In order to produce, they must meet. The special character and the way, by which this interconnection is accomplished, reflect the different economic epochs of public systems». Modern researchers have outlined the very production factors analyzed by Marx. They are labor (human activity with its features considerably changing in the course of modern development) and information (human knowledge as the means of production significant for socio-economic progress), e.g. Toffler, 1990, Inozemtsev, 1999. The above studies however, do not indicate how these production factors must unite. Information as the unique substance has another special task – to be the basis of economic relations. It is the link between the mankind which possesses unique knowledge and the information itself, which is the essence of this knowledge according to personal value estimates. Hence knowledge becomes available to consumers and creates the value, i.e. exists for uniting production factors and is the medium for economic agents. These "mediums" are represented in the real word in different forms and must have the chance to unite satisfying certain conditions.

In the study about information society Schienstock, Bechmann and Frederichs (1999) see 2 directions for perspective technologic methods of information communication technology research. Treating information technology either the "process" or as the "structure" leads to ambiguous results. On the one hand, communication technologies become strong determinants of the work process. On the other, the stress is being made on the need to enlarge applicability of technology and implies that communication technology does not determine the work process, but just becomes available for a long existing object. Hence, the possibility to unite the process and the structure allows avoiding such contradictions.

Recent studies in economic experimental modeling and computer projecting of economic systems turn to macro processes. The research of agent-based computational economics, defined as computational study of economic processes and modeled dynamic systems of interacting agents, becomes particularly interesting. Defining the term "agent", Tesfatsion (2006) attributes it to linked data and behavioral methods, treating the object as the part of created computational world. The examples of such agents include people, social groups, institutions, biological and physical objects. The agents may be formed from other agents, thus creating hierarchical constructions. Commentator offers the methods of public interconnection for all other agents. Some of these interconnections are defined as private and therefore, they are not publicly available, and some – as secured from the access of all but a certain subset of agents. Agents can communicate with each other through their own public and protected methods. Tesfatsion (2006) outlines potential advantages of agent-based modeling as compared to standard methods of economic modeling. Firstly, here events are controlled exclusively by agent interconnections, as long as initial conditions are set. Therefore, instead of concentrating on the system equilibrium conditions, the research analyzes whether the certain equilibrium form is developing within a long period of time. The goal is to achieve better understanding of system status, i.e. the possibility of equilibrium condition for the corresponding volumes of jointly attracted agent information. In this case there is the advantage of concentrating on the process and not on the equilibrium. Therefore, modeling can continue even if equilibrium is computationally complicated or unachievable. Secondly, the growing possibility of agent usage of instrumental means provides for their participation in flexible social communication. Agents can communicate with other agents, interconnecting in time so that they could create adaptive scenarios. The third and the most important advantage, is the fact that instrumental means of modeling facilitate agents' projects with relatively increasing autonomy, implying the possibility of self-control. Tesfatsion (2006) indicates that the modeled economic system should be in the state of development for a long period of time exclusively on the basis of agents' interconnection, without participation of model creator.

2. Description of Technology

Technology of chain non stock market investment is created at the interfaces between economics, mathematics and nuclear physics. Its essence is the concentration of uniform economic information of various gods and services producers in the format of TURBO software calculations (Marchenko et al., 2005). These calculations are the complete list of necessary components for producing the given volume. The list includes main labor, additional labor, raw materials, energy, production possibilities, and payments identification entries and has the number, date and web address. Calculation includes the information about the direction and the amount of monetary transaction. The process of information accumulation creates technologic megapolis – containing digital information databank or just the set of files with software. It combines calculations in which the chains of payments are being formed according to chain interconnection algorithms. These chains of payments allow for multiple circulation of initial investment sum. Technologic megapolis is not institution or organization, it does not demand maintenance cost, does not create profit, and does not have permanent address or bank account. The ways of organizing technologic megapolis may be any types, consistent with TURBO format software (producer calculations registration, accumulating information through mail, Internet or other means). Technologic megapolis may merge with any number of other technologic megapolises or disintegrate into any number of new technologic megapolises.

The critical mass of trade object (synthesized chains of investment payments) is concentrated within technologic megapolis. There are lossless financial casino, capable of making payments of any volume from any place. Financial casino may be a number of calculations, interlinked in payments chains through non stock market investment algorithms. They may also be information software for technology at the intermediate stage, allowing for configurations of investment profitability by organizing the consequences of financing goods and services production processes. This dialog regime of investor work with algorithms by software of chain non stock market investment provides for imitation of various combinations for the outcomes of monetary investment at the accounting, profitability, goods deposit quality and other levels. The main task of financial casino is to reach the consensus between investor, producer and credit resource organizations. Similarly to technologic megapolis, financial casino is not institution or organization, it does not demand maintenance cost, does not create profit, and does not have permanent address or bank account. Financial casino may be organized on any computer with technologic megapolis. The consequence of directing investment funds from one chain into the other is the combination of different possibilities for capital growth. In each case investor knows the results of investment in advance. Goods deposit by the nomenclature and volume is set by investor with the possibility of visual control and any payments configuration. Thus the agreement with producer about financing production is reached.

To implement calculations financial conglomerate is created. Financial conglomerate electronically delivers payments and notifications to all the members of chain non stock market investment. This can also be just the programmed computer function not implying human work participation. Financial conglomerate receives financial resources from investor (bank) and distributes them according to chain investment rules. Producers get cashless net profit, the planned sum of their financial costs for production, and notification of their interest payments. Investor receives net profit, as estimated in producer calculations. The bank gets net profit, receives as the interest for the use of credit funds. The tax authorities receive taxes from all the sides: producer profit tax, VAT, investor profit tax, bank profit tax. Conglomerate does not make transit operations and is based exclusively on debit transactions to all the participants. These debit calculations are made by the chain investment algorithms so that the issues of producers' dislocation, the parties' responsibilities, and the process of their fulfilling do not become its function or competence. Conglomerate does not have the functions of governing or control, it does not bear responsibility for reliability of information used in chain investment algorithms, it is not responsible for the quality and the timing of producer obligation fulfillment. This proves the confidential feature of relations according to the contracts. The longevity of conglomerate's life is set by the speed of computer transmitting functions.

Financial technologic conglomerate provides for confidentiality of all responsibilities at the individual producer level by destructing all information about itself and payments, without the possibility of reconstructing this information. Structurally, conglomerate may consist of a set of separate financial conglomerates, so that each of them provides for one chain of payments and is not connected with the other. Financial conglomerate accomplishes the large amount of accounting operations and payments.

The technology itself is based on prepayment of all parties' interests, including taxes, and on financing a set of production processes by one sum. Each buying and selling transaction is automatically transformed into investment processes, which exceed this transaction in capacity. This leads to chain reaction and fastening economic development. Technology does not have problems with the guarantee of financial resource reimbursement, their profitability and payback. It provides for simultaneous transformation of financial resources combined with the capital growth.[1] The major task of the program is to reach consensus between investor, producers and credit resource bearing organizations. The quality, the timing and the fact of interest representation are the task of customer interest. Producer does not bear any moral responsibility for non sanctioned investment in the calculations (Philippovsky, 2006a). The optimal perspective work of the proposed technology is assumed to be in the case of interconnection of all producers in one information process of technological megapolis and in the presence of their consensus about joint investment activity without extracting profit outside of the space, where own production fully satisfies own consumption. There is the possibility of investing each new calculation, given it leads to creating certain chains, complying with the rules of chain investment (Philippovsky, 2006b).

The safety stock, which is the property of investor or credit organizations, is created as the result of chain investment. All the parties (producers, investor, credit organization, tax bodies) satisfy their interests by prepayment. The goods produced in the form of safety stock are not used as consumption value and are offered as value mass in the market. This value mass does not require workers and facilities to be stocked or sold. It is not interlinked with payback of the costs for its production

[1] Traditional way of investing the unit of production using 100 units of capital (calculated, for example, as the cost of production funds – 50 units, labor costs – 40 units, and additional capital – 10 units) in the period T creates the corresponding gross product – 100 units. Non stock market investment provides for the whole production process (e.g. under 50% dissimulation depth (the relation between the cashless payments (transit funds volume) to the whole value of good), and distribution between 3 producers in chain. Gross product is (1)100+(2)50+(3)25=175 units, by the means of information concentration and simultaneous capital non cash distribution. The need for capital in order to accomplish chain investment does not change and is (1)[100-50]+(2)[50-25]+(3)25=100 units.

(since all the interests have been satisfied), it is not goods deposit for credit resources and may be easily written off by the owner (or sold at the very low price).

Agents of Technology

The chain non stock investment may be used in all the industries of the economy. Any users, including those without special experience of working with computers, can be interacting economic agents.

With regard to Tesfatsion's (2006) conclusion, let us stress that active autonomous agents of investment technology are the very producers – legal and physical persons; investors, making financial decision; banks – in credit issues. Passive agents are tax and stock institutions, receiving obligatory payments, indicated by producers. Goods and labor obligations with the finite number of calculations, arising in the simultaneous investment capital distribution in the whole production cycle, may also be called agents. The usage of technology is publicly available for all parties concerned. At the same time all relations are confidential functions of each party. Such functions of technology create behavioral confidence of autonomous agents, leaving the necessary information for interactions in certain format for calculating possibilities and the needs of the whole totality of agents. Disseminating this technology requires time. However, simple access and usage conditions, joint study, and free basis of technology use may easily adapt these relations for social systems.

As for uniform economic information of technologic megapolis, created by agents, the process of achieving equilibrium condition of the whole economic system is being reached. Therefore the contradiction indicated by Schienstock et al. (1999) may be solved. Finally, the analyzed technology as the basis for merging labor and information opens new frontiers for economic relations, establishing direct production communications within one information space of technologic megapolis.

Applicability Scenarios

The 4 scenarios of chain reaction depending on the selected criteria were developed in the study. They are denoted as initial, local, total, and global. The first two are aimed at macroeconomic level. They provide for collection of all taxes into one place, avoiding all intermediate structures and transform financial control function into calculation control. Therefore, accounting becomes unnecessary procedure (Philippovsky, 2006c). Local chain reaction, as opposed to initial, collects VAT as well, and has starting regime, under which the taxes are not collected, there is no bank or investor profit, and the depth of dissimulation is 100%. Total chain reaction is aimed at the retail investment, provides for tax payments at the producer dislocation and is aimed at any organizations with financial resource for buying goods or goods deposit. Global chain reaction does not collect taxes and provides payments to businessmen in monetary units of the producing country. This reaction is transactional. On the whole all chain reactions give considerable growth and differ just slightly. The best figures for GDP growth are seen in starting, initial, and global regimes. However, to employ these reactions the special government decision would be necessary. Total regime has rather high figures and does not require special orders, i.e. it treats tax system as it is.

3. Computational Experiment

To reveal the possibilities of chain investment application use and its dependence on different factors, this study created the technologic megapolis of 1000 calculations with the following initial cost data:

- Major salary, 750 thousand rubles;
- Additional salary, 250 thousand rubles;
- Extra salary (social security payments and bonuses), 50%
- Major raw materials, 75% of the sum of major and additional salary;
- Additional materials, 25% of the sum of major and additional salary;

- Transportation expenditures, 10% of materials cost;
- Maintenance of equipment, 10% of major salary;
- Workshop expenditure, 30% of major salary;
- All plant expenditure, 20% of major salary;
- Off production expenditure, 10% of major salary;
- Profit, 30%;
- VAT, 20%;
- Profit tax, 30%.

5 places for paying the interests of producer with the depth of up to 100% are set. Each consequent calculation is lower than the previous by 10%. Calculations of the salary lower than 100 thousand rubles imply decrease in the volume of producer work of 1%. Graph 1 present the structure of main expenditure by producer. Imitation is accomplished by «test.exe» software.

The initial unit of investor interest (participation) in profit is 50%. The value of credit resources is set at the level of 5% of the sum provided. Potential possibilities of chain non stock market investment are set by the means of calculations according to accounting balances by the whole modeled system and individual payments.

After technologic megapolis imitation the following parameters were determined:

- By the types of chain reactions (initial, global, total, starting regime);
- By dissimulation depth (the share of transit payments in the whole sum of calculations), x=10%, 20%, 30%, 40%, 50%;
- By the cost of credit resources, k=5%, 10%, 15%, 20%, 25%;
- By the share of profit in the product value (profit according to calculation), p=10%, 20%, 30%, 40%, 50%;
- By the share of investor interest in profit, e=10%, 20%, 30%, 40%, 50%;
- By the value of profit tax, n=10%, 20%, 30%, 40%, 50%..

The data in Graph 3 demonstrates that initial and global chain reaction provide for GDP of 763 million rubles. Total and local reaction decrease the possibilities of non stock market investment till 513 million rubles. The starting regime allows receiving 1306 million rubles. The value of credit resources is 154 – 155 million rubles, in the starting regime it is 150 million rubles. The interest (percentage payments) for the use of credit resources in all the types of chain reactions (later denoted as working regimes) are the same and equal to 7 million rubles under the credit resource cost of 5%. This means that the creditor is indifferent to the ways his/her monetary funds are being used and receives stable profit.

The whole turnover for initial and global reactions is 570 million rubles. Total and local reaction provide for 335 million rubles. In the starting regime it equals to 1068 million rubles. The interests of investor, producers and tax authorities vary from 23 to 60 million rubles. In total regime producer profit is 28 million rubles, investor profit is 23 million rubles, all taxes are 55 million rubles. Compared to initial reaction, financial cost of producers in total regime rises from 36 million to 74 million rubles.

Imitating technologies with the dissimulation depth of 50%, 40%, 30%, 20% and 10% reveals dependency of chain investment on transit payments of producer interests. For example, under the same volume of attracted financial resources of 154 –155 million rubles, 50% of dissemination depth give GDP of 300 million rubles. With 40% GDP becomes 258 million rubles. It decreases till 171 million rubles with dissemination depth of 10%. At the same time there is the sharp fall in producer profit from 17 million rubles to 10 million rubles. Financial costs rise from 106 million rubles to 127 million rubles. Investor profit decreases from 12 million rubles to 4 million rubles; tax payments fall from 14 million rubles to 8 million rubles. The interest of credit organization is stable for any dissemination depth and equals to 5 million rubles.

The growth of credit cost from 5% to 10%, 15%, 20% and 25% leads to decrease in demand for credit resources from 155 million rubles to 130 million rubles. The profit of credit organization increases from 5 million rubles to 18 million rubles. Turnover falls from 570 million rubles to 525 million rubles, GDP decreases from 886 million rubles to 663 million rubles. The values of almost all the parameters decrease: producer profit - from 42 million rubles to 37 million rubles, financial costs – from 36 million rubles to 22 million rubles. Investor sees decrease in his/her profit from 36 million rubles to 20 million rubles, tax authorities see fall in their tax collections from 36 million rubles to 32 million rubles. The cost of bank credit does not influence the potential possibilities of non stock market investment. Consequently, this cost is determined by the supply and demand. On the one hand, credit organization has additional revenue of 13 million rubles, on the other – producer, investors and tax authorities bear total loss of 25 million rubles.

In the analysis of non stock investment parameter dependency on the value of profit in the cost of goods and services, we imitated technologies with the profit of 50%, 40%, 30%, 20% and 10%. The results demonstrate that calculations with the lowest share of profit in the cost of goods and services are preferable for chain investment. Indeed, the decrease of profit share from 50% to 10% provides for the GDP growth from 561 million rubles to 1162 million rubles and turnover growth from 374 million rubles to 554 million rubles. However, this scenario implies considerable decrease in producer profit from 43 million rubles to 29 million rubles. Investor profit decreases from 37 million rubles to 24 million rubles, bank profit – from 6 million rubles to 5 million rubles. Tax collection falls from 36 million rubles to 25 million rubles, too. This pattern creates situation when at the macro level it is better that producers have minimal profit, while for the producer, investor and for the bank it is better to obtain the maximum profit possible. In other words, this is absolutely contrary to the actual situation in Russia. The value of total revenue total loss of 39 million rubles (43-29+37-24+6-5+36-25) proves this conclusion.

To estimate the influence of investor interest in producer profit on the potential possibilities of chain non stock investment we imitate technologies with investor interest of 50%, 40%, 30%, 20% and 10%. The results demonstrate that the share of investor interest practically does not influence GDP and turnover. Indeed, the 50% share leads to GDP equal to 763 million rubles, the 10% - to 686 million rubles. The turnover falls from 570 million rubles to 525 million rubles.

As for the interests of all the parties, the low share of investor interest in producer profit does not serve to anybody's advantage. Producers loose profit from 42 million rubles to 29 million rubles, under 50% and 10% correspondingly. The bank sees decrease in its revenues from 5 million rubles to 2 million rubles. The taxes fall from 36 million rubles to 32 million rubles, investor profit decreases from 36 million rubles to 2 million rubles. The need in credit resources decreases from 154 million rubles to 130 million rubles, producer financial costs fall from 36 million rubles to 32 million rubles. It should be noted that the share of investor interest lower than 10% is critical under the cost of financial resources equal to 5%. After this value there is the sharp fall of all the parameters due to unavailability of attracting financial resources. Obviously, consensus between the parties will be found and this parameter would not be able to have a considerable influence on non stock market investment process.

Imitating technologies with profit tax of 50%, 40%, 30%, 20% and 10%, in all the cases we obtain GDP of 763 million rubles, turnover of 570 million rubles, producer financial cost of 36 million rubles, the volume of attracted financial resources of 154 million rubles. One can make the conclusion that the current tax system does not influence potential possibilities of chain non stock investment. Decreasing tax level from 50% to 10% leads to decrease of tax amount from 60 million rubles to 12 million rubles. At the same time the profit of producer rises from 30 million rubles to 54 million rubles. Investor profit increases from 26 million rubles to 47 million rubles, bank profit – from 4 million rubles to 7 million rubles. The value of profit tax is compensation of the state and is not the issue of consensus for the parties, participating in non stock market investment.

Summarizing the results of the analysis on Graph 3, let us study the GDP dynamics according to the above outlined factors. Total chain reaction leads to 513 million rubles, initial – to 763 million rubles, global – to 591 million rubles, the starting regime allows for 1306 million rubles, with similar need for credit resources of about 155 million rubles. The depth of dissimulation or transit cost, is the only parameter influencing chain investment. In the absence of dissimulation depth there is no chain reaction and no technology efficiency. With dissimulation depth equal to 10% GDP is just 171 million rubles, with 20% - 193 million rubles. The value of 50% leads to GDP of 300 million rubles, which realizes the opportunities of non stock investment.

The change in profit size in the corridor of 10% to 50% does not decrease the possibilities of chain investment and keeps GDP at the levels 561 million rubles and 1162 million rubles. The fall of profit share in the goods value from 50% to 10% increases GDP from 561 to 1162 million rubles. The values of credit resources do not have an influence on non stock investment. Indeed, under the 5% value GDP equals to 763 million rubles, under 25% - to 686 million rubles. The share of investor interests (10%, 20%, 30%, 40% and 50%) in the producer profit does not change GDP considerably. GDP equals to 763 million rubles for 30%, 40%, and 50% values, and 716 million rubles for 20% value. GDP decreases till 685 million rubles under 10% value. Possibilities of non stock investment are not interrelated to the tax rate (10%, 20%, 30, 40%, 50%) and provide GDP of 570 million rubles.

The change in goods stock and the volume of attracted credit resources creates insurance stock. If it is positive, the amount of gods produced is greater than the need for chain investment. Thus the mass produced would not have consumer value in the course of real investment and there will be problems with its realization. If insurance stock is negative, the amount of goods is smaller than the volume of attracted monetary resources, and this leads to inflation. Naturally, there is no direct coincidence but in chain investment the insurance stock varies just a little (3 orders lower than the amount of production). It changes from 77 thousand rubles to 320 thousand rubles positively, and to –1457 thousand rubles negatively. Insurance stock is negative when the credit costs 15% and more, the profit equals to 10% and investor interests equal to 10% and 20%.

In the end of demonstrating the possibilities of chain non stock investment algorithms applicability we analyze the interests of all the parties (Graph 4). In choosing the type of chain reaction the interests of investor and producers are maximum for global chain reaction and equal correspondingly to 52 million rubles and 60 million rubles. The starting regime assigns numerical value of interest only to producers - 26 million rubles. Initial and local chain reactions are more advantageous to investor and producer (whose profits are 35 million rubles and 42 million rubles), than total reaction (profits are 28 million rubles and 23 million rubles).

The tax agency is interested only in initial, local and total reactions. The first and the second give it 36 million rubles, the third - 55 million rubles and therefore is more preferable. Banks (credit organization) have maximal interest in global reaction - 7 million rubles. In local and initial they receive only 5 million rubles. They demonstrate no interest in starting regime. The starting regime is preferable only for macro level, for it gives the highest GDP growth and possibilities for money emissions.

All the parties except for the bank are interested in increasing the depth of dissimilation. The bank interests are stable and equal to 5 million rubles. Other parties receive correspondingly (under 10% and 50%): producers 10 million rubles and 17 million rubles, investor 4 million rubles and 12 million rubles, tax authorities 8 million rubles and 14 million rubles. This indicator is the determinant of chain investment.

The creditor interests in the cost of credit resources (bank percentage) are negatively related to the interests of producer, investor and investment authorities. The increase of credit resources (5%, 10%, 15%, 20%, 25%) increase the creditor profit from 5 million rubles to 18 million rubles. Producer interests fall from 42 million rubles to 37 million rubles, investor interests – from 36 million rubles to 20 million rubles. Tax collection also decreases from 36 million rubles to 33 million.

As for the size of profit, the interests of the parties coincide to the maximum extent. In the corridor 10%, 20%, 30%, 40% and 50% the interests of all parties stably rise. Producers receive 43 million rubles against 29 million rubles, investor has 37 million rubles against 24 million rubles. The inflow of taxes is 36 million rubles against 25 million rubles. Even the creditor increases his/her revenues from 5 million rubles to 6 million rubles. The credit organization is indifferent to the share of investor interests in producer profit. The interests of credit organization are constant and equal to 5 million rubles. The investor pays special attention to the share of his/her profit. With the value of this parameter equal to 10% investor interests are 2 million rubles, with 20% - 11 million rubles, with 30% - 20 million rubles, with 50% - 36 million rubles.

Interests of tax authorities are inversely related to the interests of other parties with the decrease of tax rate. With the rise of profit tax rate in the corridor of 10%, 20%, 30%, 40% and 50%, tax revenues increase from 36 million rubles to 60 million rubles. The producer interests fall from 54 million rubles to 30 million rubles, investor interests – from 47 million rubles to 26 million rubles, creditor interests – from 7 million rubles to 4 million rubles.

Producer and investor consensus about profit distribution has good perspectives. With the rise of investor profit share from 10% to 20% producer profit increases from 29 million rubles to 63 million rubles. In other cases, with the share equal to 30%, 40% and 50%, the investor and producer interests are opposite. Producer profit falls from 58 million rubles to 50 million rubles and 42 million rubles. In other words, up to the value 20% investor and producer gain mutual understanding of the profit. After this value investor profit is the issue of compromise between the demand and supply, and is determined by the market.

Final Remarks

Chain investment is in fact modeling not ending in time, it is directed to infinite number of economic agents with finite capital distribution between interacting autonomous agents. The equilibrium in such system is reached by the means of micro equilibrium for individual agents on the basis of full automation of accounting (the most prevalent economic form of exact computable equilibrium).

This research of informational contents of chain non stock market investment allows for the conclusions, that given technology determines the process of uniform economic information collection for justified division of capital between economic objects. Therefore, there is the development of certain global out sorting and information management. The usage of this technology provides for acceleration of production processes by redistributing maintenance time and directing it into production. The precondition for this is full prepayment of all economic relations in non cash form. This also leads to the decrease of costs due to calculations automating and decrease of maintenance personnel. The free workforce may be relocated into other sphere of economic activity. Self regulation of own obligations becomes the major regulation factor at the micro level. This is assured by information transparency of all the changes and confidentiality of all the relations of the participants. The possibilities of information megapolises division and merging would stimulate the due fulfillment of obligations by each economic agent. The usage of the same electronic currency would decrease the volume of information for the exchange. Further development and dissemination of technology will determine perfection of social relations with constant learning, perfection of information system, and decrease of information and other costs. This will serve the basis for forming the new technologic level of economy.

«TURBO» software allows for autonomous work with up to 150 thousand producer calculations (the modules bux.bat, bux.exe). In creating this technology we used the Clipper language in DOS. Currently we consider the possibilities of creating analogue in other languages.

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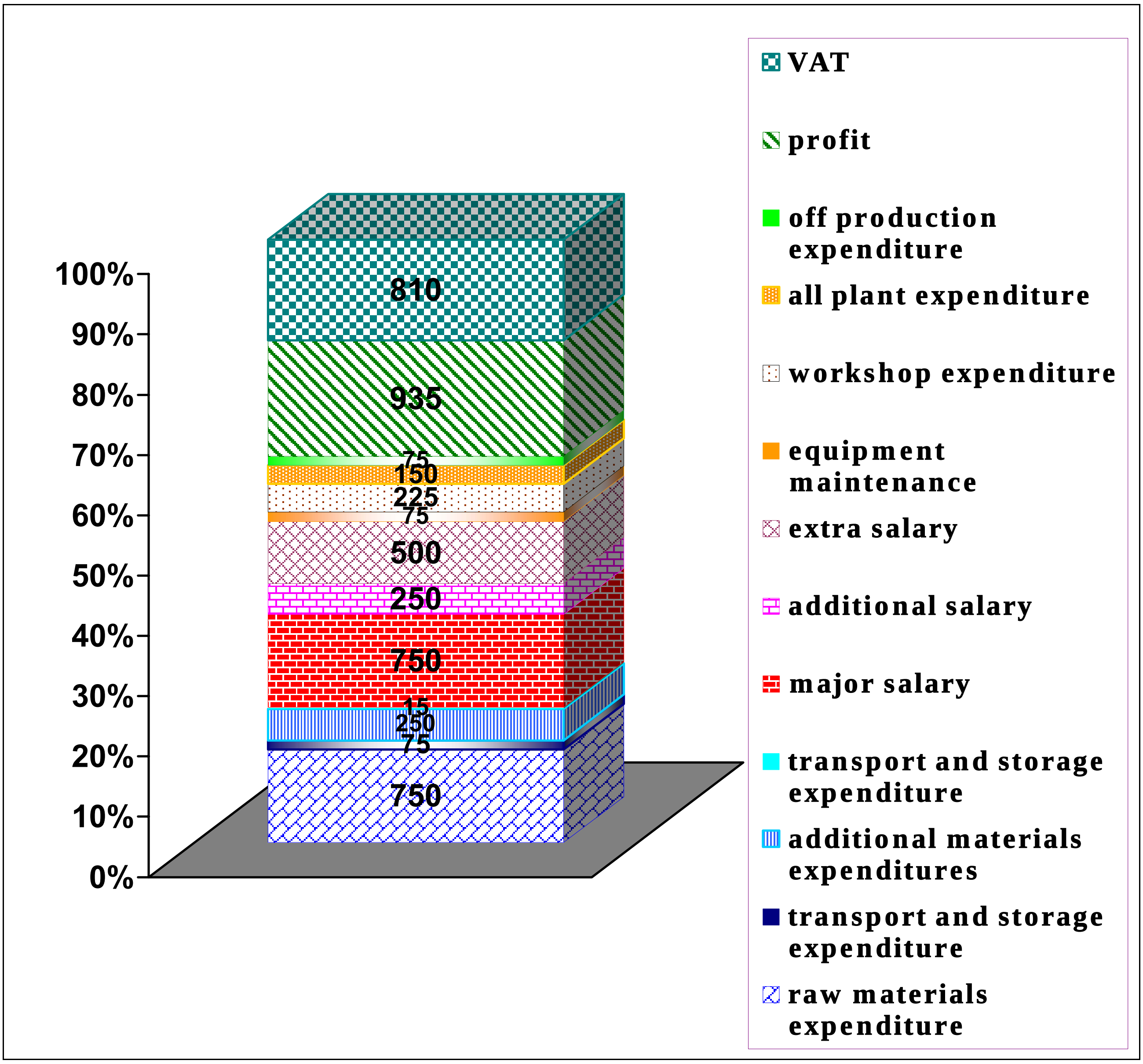
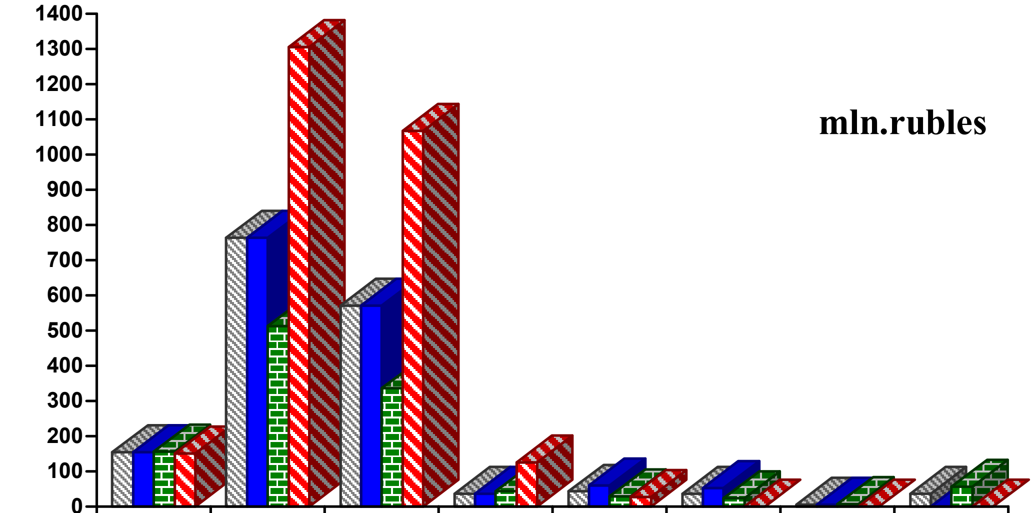
Appendix

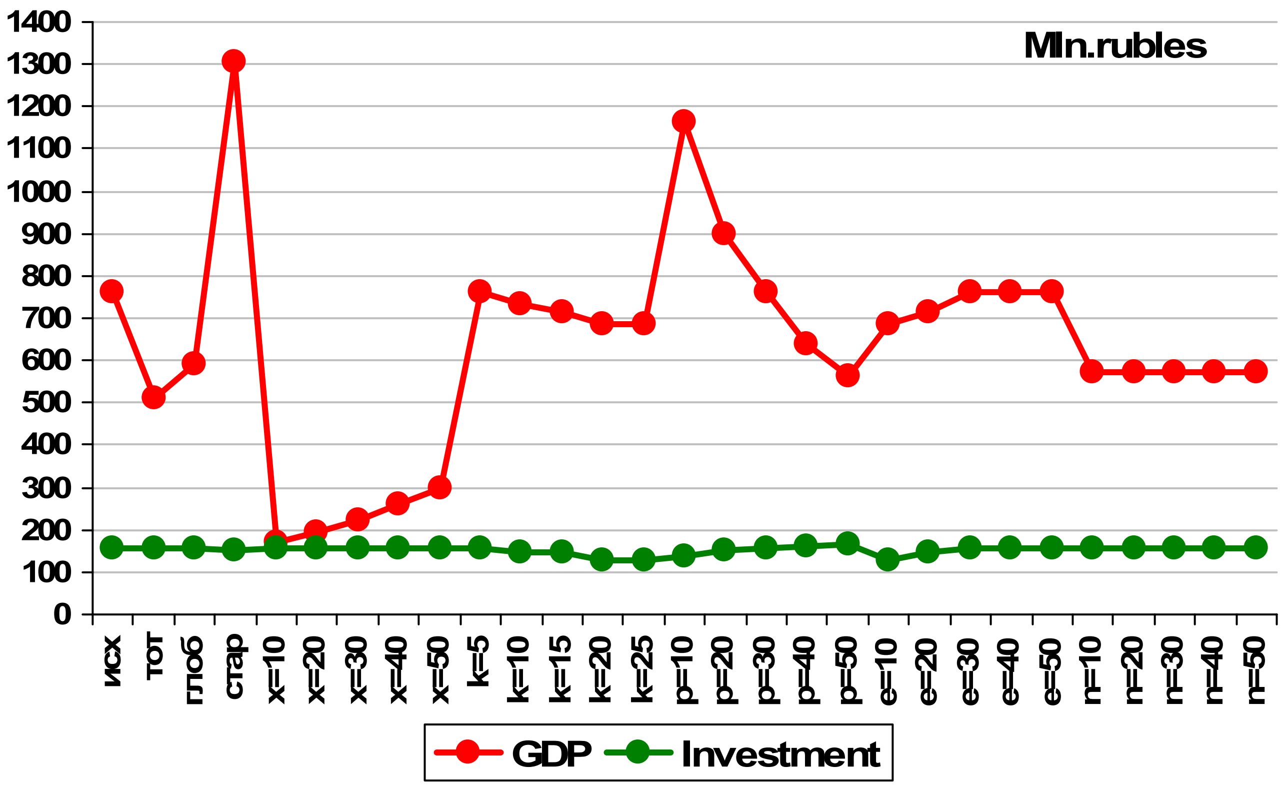


Graph 1 – Prime Cost Structure of Products according to Calculation

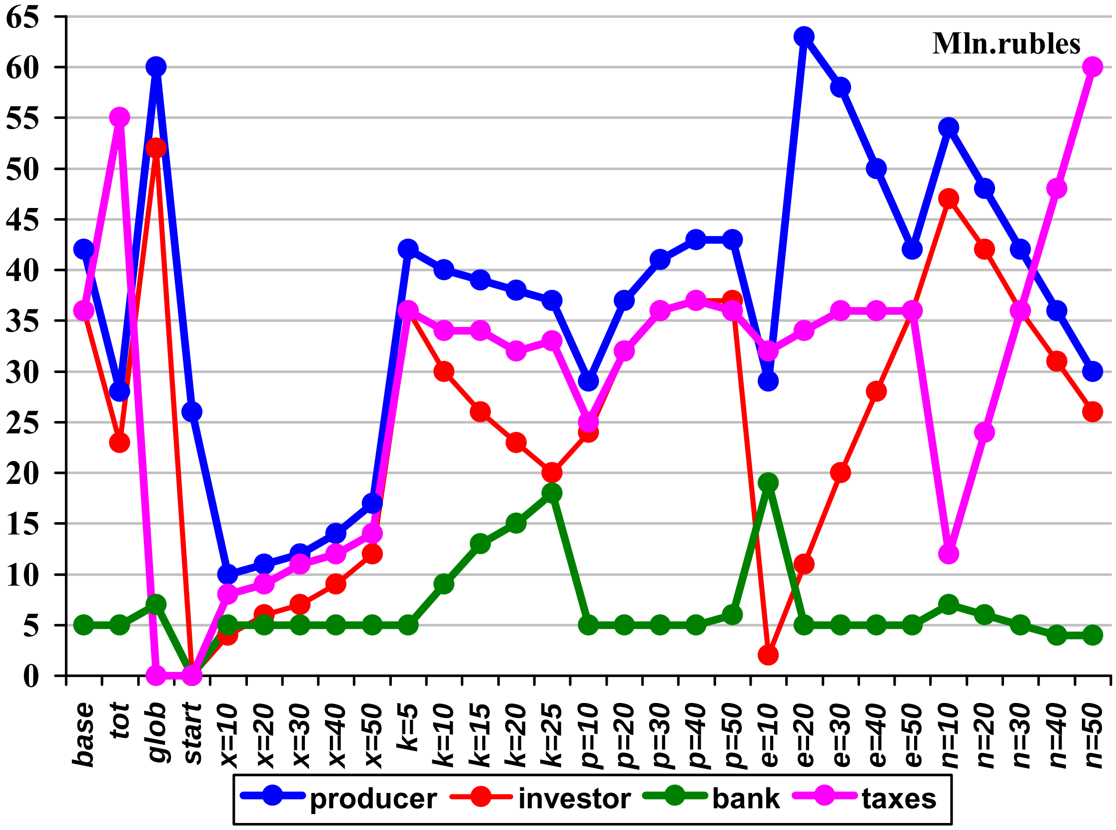


	Credit	GDP	Goods turnover	Financial Cost of Production	Profit	Profit	Profit	Taxes
Base	154	763	570	36	42	36	5	36
Global	154	763	570	36	60	52	5	0
Total	155	513	335	43	28	23	7	55
Start	150	1306	1068	124	26	0	0	0

Graph 2 – The Parameters of Chain Reaction (1000 Calculations)



Graph 3 – The Dependency of GDP Growth on Different Factors (1000 Calculations)



Graph 4 – Dynamics of Interests for all the Parties Concerned (1000 Calculations)

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