

ICT/CI ASSISTED COMPLEX ECONOMIC NETWORK IN VIRTUAL REALITY

A Contribution to Emerging Theory of Virtual Complex Networks - Part I

Ladislav Andrášik

Abstract:

In the contemporary mainstream economics there is a persisting reckoning on mathematical apparatus of Newtonian Mechanics or in better case on the first (of Clausius) Thermodynamics. However the economy in objective reality isn't existing as a mechanical system but as such they are living in the form of complexly evolving social organism creating a complex network. De facto it is a spontaneous product of great population of Homo sapiens in a very long historical evolution. Problems and difficulties for economics scholar are consist in fact that such entities in objective reality are not directly observable and the less they are such ones as a wholeness effectively controlled from separate sole centre. Fortunately the progress in ICT and mainly in computational intelligence (CI) is bringing new possibilities for insight if not directly into objective economies thereabout at least into virtual ones. For such purposes we are constructed within relatively simple software called STELLA the primordial virtual economy which allows for the user directly in computer to observe the behaviour in it. Fever explanatory however is only a slide showing of snapshots passed from STELLA. For that reasons we must to expend the exposition by voluminous verbal commentaries. On the other hand we must emphasize that "reading" of snapshots from computer simulation is new very efficient modus of mining knowledge from complex economic process. In the Part II of this essay (in the next issue of ITA journal) we are bringing results of simulations and deep commentary to behaviour in virtual economy.

Keywords:

Complex systems, computational experimentations, constructive approach, complexity, decentralized market process, economies as artificial (computational) worlds, economics, economy, emergent organization, endogenous interactions, experiment, graph theory, idiosyncrasies, network, interaction structure, mainstream economics, ontological and methodical mistakes, STELLA software, virtual environment, virtual laboratories.

ACM Computing Classification System:

Network economics, network performance evaluation, network modelling, network simulation, network experimentation, network properties.

Introduction

The theory and application of advanced field of complex networks is promising approach, with devices and tools for building mental models on complex worlds and further resume applications in those bases certain virtual world in computers with suitable software. Our motives in this essay are to use these new possibilities for better understanding the behaviour of complex socio-economic organisms at least in using metaphors with virtual economies created in software environment of STELLA. Actually this is need because in the contemporary mainstream economics there is a persisting reckoning on mathematical apparatus of Newtonian Mechanics

or in better case on first (of Clausius) Thermodynamics. However the economies in objective reality do not exist as a mechanical system but they are living as complexly evolving social organism in the form of complex network. Unfortunately for economics scholar such entities in objective reality are not directly observable and the less they are such ones as a wholeness effectively controlled from separate sole centre. In this introduction we begin with concise explanation on complex network approach to economies.

1 Types of Complex Networks

From the point of view of purposes of this essay it is interesting to show certain types of complex networks. One of them is a *Scale-free network*. It is, as it is written in expertly sources a such network whose degree distribution follows a *Power Law*, at least asymptotically.

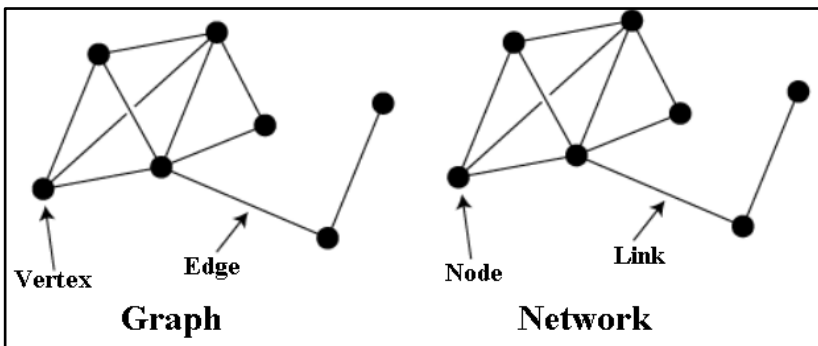


Fig.1. The different terminology between Graph and Network theories.

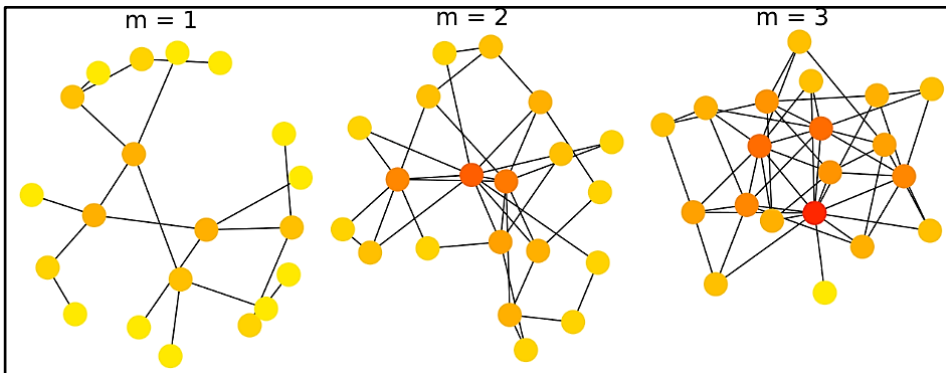


Fig.2. The insight of three Barabási-Albert models of scale-free networks.

That is, the fraction $P(k)$ of nodes in the network having k connections to other nodes goes for large values of k as $P(k) \sim k^{-\gamma}$ where γ is a parameter whose value is typically in the range $2 < \gamma < 3$ (wherein the second moment of $k^{-\gamma}$ is infinite but the first moment is finite), although occasionally it may lie outside these bounds. We are bringing typical examples of *Scale-free network*, which is descending from A-L. Barabási, [2]. The snapshot of (Fig.2) displays three graphs of his and Albert model.

Each has 20 nodes and a parameter of attachment m as specified. The colour of each node is depending upon its degree (the same scale for each graph). The second type of complex network which is interested for us is so called *Small-world network*. It is a type of mathematical graph/network in which most nodes are not neighbours of one another, but the neighbours of any given node are likely to be neighbours of each other and most nodes can be reached from every other node by a small number of hops or steps. We are bringing very simple example of such graph/network, (Fig.3).

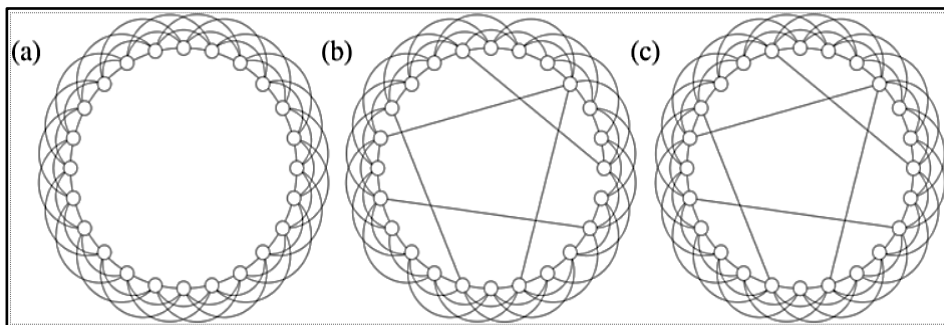


Fig.3. The type of network called Small world – three distinct graphs.

In the (Fig.3) there are three models: (a) A ring network in which each node is connected to the same number $l=3$ nearest neighbours on each side¹. (b) A Watts–Strogatz network [24] is created by removing each edge with uniform, independent probability p and rewiring it to yield an edge between a pair of nodes that are chosen uniformly at random. (c) The Newman–Watts [17] variant of a Watts–Strogatz network, in which one adds "shortcut" edges between pairs of nodes in the same way as in a WS network but without removing edges from the underlying lattice. This figure was appeared in Newman work, [7, (2003)]. In this essay we are using terminology due to software STELLA because it is very suitable for creating economic networks. In (Fig.4) we are showing a simple but abstract networks created by using STELLA building blocks.

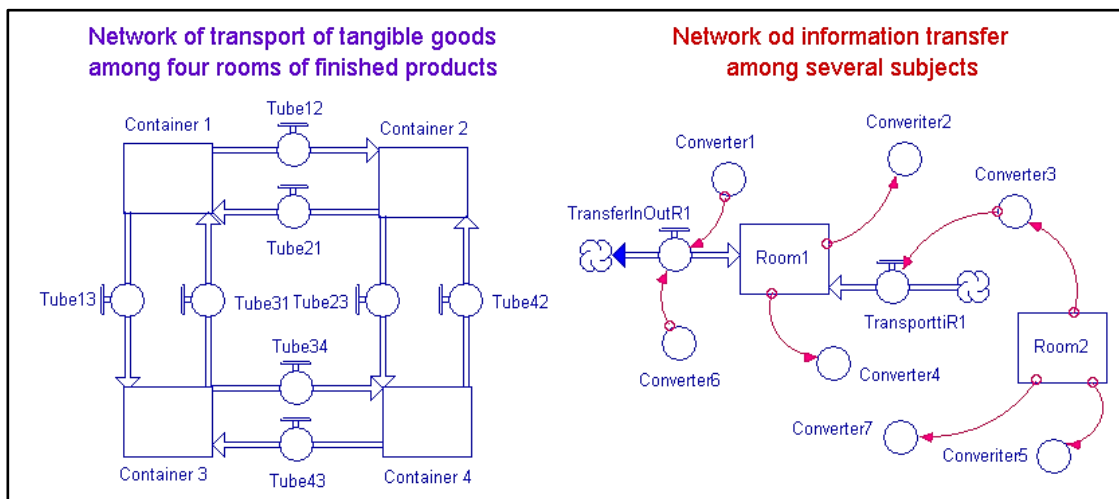


Fig.4. The snapshot of two different simple network scheme created in STELLA.

¹ This network resembles a one-dimensional lattice with periodic boundary conditions.

In recent thirty years there is a rising set of studies of networks from an economics perspective (Kirman (1997), Ioannidis (1997, 2002, 2004), Tesfatsion (1997), Weisbuch and Kirman and Herreiner (2000), Kranton and Minehart (2001), Corominas-Bosch [6, (2005)], Wang and Watts [14, (2002)]) and others. Actually recent surveillances are showing that there are several attitudes to focus attentions on complications with economies in objective reality from different side than in the mainstream economics namely from the side of theory of graphs and networks ones. The first approach to capture the global properties of such systems as complex network is to model them as graphs whose nodes represent the dynamical units, and whose links stand for the interactions between them.

The author O. Gomes in his essay on *Complex Networks in Macroeconomics* [9] published in 2014 is informing on using this new approach in different branches of contemporary science and he puts main focus on economics. He shows that even on first sight the socio-economic entities are looking like a *Complex Networks*. He has written that socio-economic phenomena might be approached, in many different contexts, through the construction of networks that highlight the local interaction among heterogeneous agents. We must to add onto this assertion that every agent is authentic and inherently heterogeneous so in his roles, functions and activities too. Real-world networks concerning human relations in the society or in the economy involve a large number of nodes, and large numbers and qualitative varieties of links connecting them and an evolving structure where both nodes and links may be generated or may disappear at each time period. He emphasizes that the economies are behaving as a *Scale-Free Complex Network*². A market for a given good, the financial system or the world economy, all display characteristics that allow to classify them as the complex network structures and, more specifically, as having property of *Scale-Free Networks*.

In other important example A. Kirman discusses resourceful problems, which are from the subject of our virtual economy, certain economic models in which agents interact directly with each other rather than through the price system as in the standard general equilibrium model. Actually in his chapter *Economies with Interacting Agents* [10] among others as contributor to the book *The Economics of Networks* [4] He is suggested that the relationship between micro and macro behaviour is very different from that in the standard model and that the aggregate phenomena and process too that can arise are rich. The models considered by A. Kirman include ones with global interaction in which all agents can interact with each other which is by our opinion an overambitious strong assumption and the one in which agents can only interact with their immediate neighbours which is more realistic approach. The author is considering both static and dynamic models and the latter includes the class of evolutionary economic models. In the last part of his chapter A. Kirman is discussing models in which communication networks evolve. Among others we are known that A. Kirman together with Oddou and Weber (1986) applied stochastic graphs to simple decentralized pure-exchange economies. The Kirman's contribution into *introductory theory and methodology of complex networking economies* is very significant and useful.

Other interesting for our investigation is a chapter in cited book: *Spatial Interactions in Dynamic Decentralized Economies: a Review*, due to the author G. Fagiolo [4], pp.53-91. He describes in his chapter dynamic models of decentralized economies with imagination that agents in economies are spatially distributed and interact directly and locally. He put more exactly that this means: (a) agents are located in a space as some graph or integer lattice that is seen in our essay perspective as a network; (b) the current choice of each agent is influenced by past choices of their neighbour.

² In recent literature the *Scale-free Networks* are described as a connected graph or network with the property that the number of links originating from a given node exhibit a *power law distribution*. A scale-free network can be constructed by progressively adding nodes to an existing network and introducing links to existing nodes with preferential attachment so that the probability of linking to a given node i is proportional to the number of existing links k_i that node has.

In this way we are obtaining belief that this approach is very congenial with economic evolution in objective reality and it is also a good inspiration for our work. We are owing oneself in this contexts to vigorously emphasize that it is a cardinal difference between if in one hand it is an economics of such sectors of economies as the networks are: networks of oil and other products pipelines, electrical networks, etc., that is sectorial economics, and the other side it is a general economics of fullness economy as a complex network.

Authors Newman, M. E. J., Watts, D. J. and Strogatz, S. H., describe in theirs essay with name *Random graph models of social networks* [12] some new exactly solvable models of the structure of social networks, based on random graphs with arbitrary degree distributions. They give models both for simple unipartite networks, such as acquaintance networks, and bipartite networks, such as affiliation networks. Authors compare the predictions of their models to data for a number of real-world social networks and find that in some cases, the models are in remarkable agreement with the data, whereas in others the agreement is poorer, perhaps indicating the presence of additional social structure in the network that is not captured by the random graph. Their works are also very inspirational in our endeavour to constructing virtual laboratories in STELLA in the form of complex networks.

Among others we want to focuses attention of readers to *Agent-based computational economics* (ACE) which is important further way, in the study of economies different from neoclassical approach. This approach is very congenial with our approach in this essay. ACE branch of economics is using agent-based modelling and simulation, in which an agent based model, is a one that comprising autonomous agents placed in an interactive social environment or network of socio-economic interaction among its nodes. Simulating these and similar models using appropriate software in common computers is very useful and most practical way to understand evolution of economies by visualizing the process running in virtual environment, see for example [13] or [15]. In these contexts worth mentioning the impact of theory and functional *computational neural networks* on reasoning in economics in direction to go to complex networks including such ones as *Multilayer Perceptron Neural Networks* and/or *Auto-associative Neural Networks*, [13]. In contemporary era the crucial role of development of socio-economic complex networks are playing the entirety of the Networks based on advanced ICT, and mainly the Internet among them, (Fig.5).

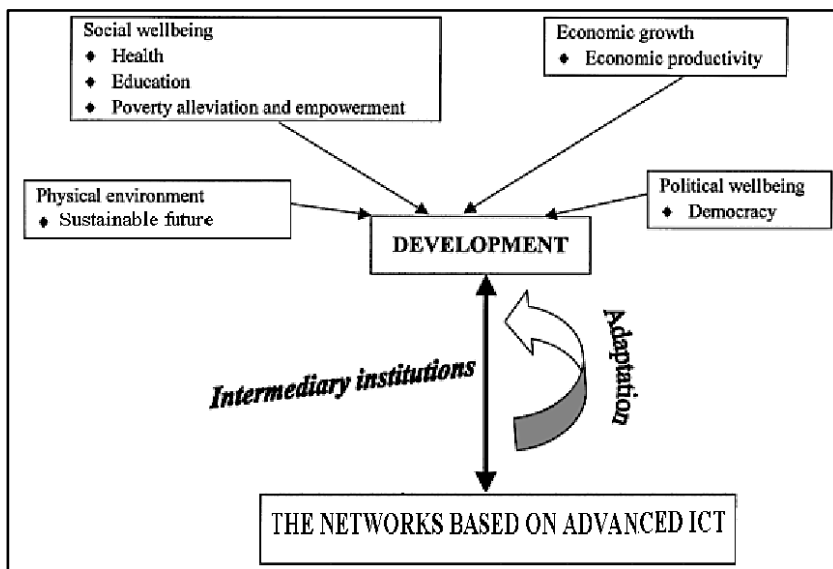


Fig.5. The schema of complex development influenced by ICT networks.

The construction of this schema was inspired by Shirin Madon, LSE Research Online London) The authors of *Job Information Networks, Neighbourhood Effects, and Inequality* [7] are focused their attention on the fact that considerable interest has emerged recently in the economic literature about social interactions and the ways in which social norms and structures are the conditions of individual behaviour. They emphasized that treatment of labour-market transactions being very different from trading in goods reflects the importance of *Idiosyncrasies* due to social effects, outcomes within social groups. One of typical example of where such idiosyncrasies play a prominent role is job-market search. Their research has already used network analysis to elucidate the origins of previous unexplained similarities in outcomes by qualitative differences such as race, ethnicity, and gender. Furthermore, they identify the source of some neighbourhood correlations in labour-market outcomes.

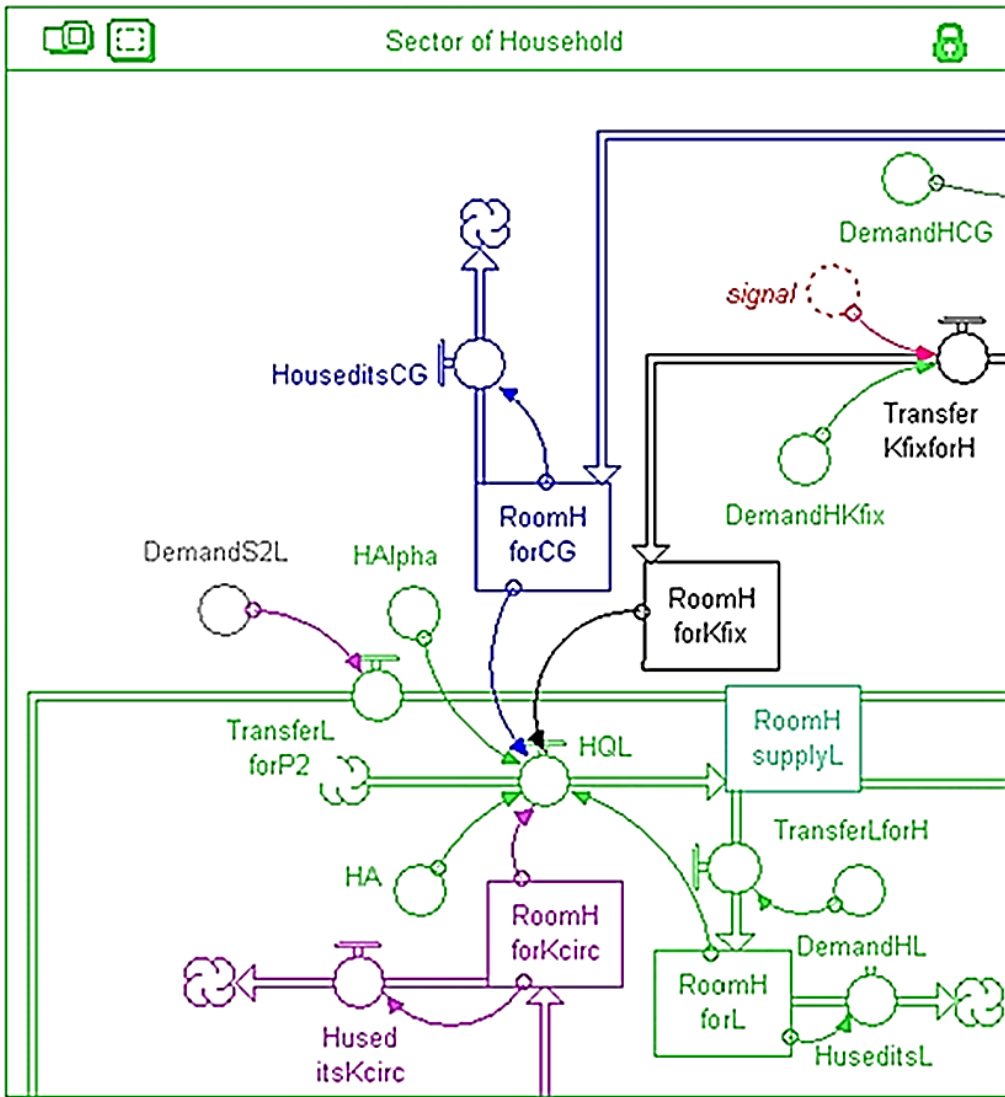


Fig.6. The snapshot of Households scheme created in STELLA.

At the same time they note that, there are a number of promising areas where research is needed. In particular, the importance of employer characteristics and the role of the internet in altering the role of informal contacts in the future are topics that deserve special attention³.

Among others scholars Margarida Corominas-Bosch with two co-workers [6] is considered a bargaining in a bipartite network of buyers and sellers, who can only trade with the limited number of people with whom they are connected. Such networks could arise due to proximity issues or restricted communication flows, as with information transmission of job openings, business opportunities, and transactions *not easily regulated by external authorities*. They are beginning with two separate simple networks, which are then joined by an additional link. Participants appear to quickly grasp important characteristics of the networks.

The results diverge sharply depending on how this connection is made, typically conforming to the theoretical directional predictions. Payoffs can be systematically affected even for agents who are not connected by the new link. They find evidence of a form of social learning - the shares (publicly) allocated to others in the past affect what one is willing to accept. They are performing an experimental test of a graph-theoretic model that allows them to decompose any two-sided network into simple networks of three types, with unique predictions about equilibrium prices for the networks in their works. These (noted above) contributions to subjects in question are from our view the most important and obvious applications of networks to approach in virtual economic models in economics where so many markets are not centralized, but rather consisting of a complex structure of bilateral trades and relationships.

However our approaches to build economies as complex network economies in virtual environment are differing from those they are cited in earlier passage in a good deal richer tools of STELLA building boxes and much brighter in discriminating qualitative and quantitative variability among nodes/stocks and interaction/flows of some created graphs. The snapshot of (Fig.6) is showing the Households part of Economic Network entirety created in STELLA environment. The vertices, converters and edges are coloured for better distinguishing the one sector from the others ones. For *Households* are chosen green colour. The primeval vertex of *Households* is a *Container* called *RoomHsupplyL*, which is supply of disposable *Labour Forces L* for all sectors of virtual economy; it departs as flows of performance the *Live Works* via four pipelines called *TransferLforH*, *TransferLforP1*, *TransferLforP2* and *TransferLforP3*. The intimately need for household is the supply of consumer goods and services called *RoomCGforH* for feeding the persons of *Population* living in *Households*. Some part of all *Population* is a supply charge of all *L*. The filling of *RoomCGforH* is coming as flow thru pipeline called *TransferCGforH*, blue colour, which however isn't shown as full in the snapshot of (Fig.6) (it is set to the snapshot of (Fig.7)). More details of links and values flowing among blocks of sectors are shown in (Tab.1a) and (Tab.1b).

There are certain differences between sector *S1* and of households *H* (and sectors *S2* and *S3* too), because of different character of their supplied and demanded products. The product of *S1* is investment goods, which is traded per years whereas with labour forces *L* and *Kcirc* and *CG* are traded per month. These time instance discrepancies are doing in network entirety some perturbations, which are introduced into flows fluctuations in one year frequencies. In Part 2 of this essay (next issue of this journal) we will bring snapshots with detail graphs of such *saw tooth waveform*.

³ For our research in economic problems of complex network and for this essay too the other two works of Ioannides are important [12] and [13].

Tab.1a. The fillings of building blocks of Household scheme – upper part.

Sector of Household	
<input type="checkbox"/>	$\text{RoomH_forCG}(t) = \text{RoomH_forCG}(t - dt) + (\text{TransferCG} - \text{HouseditsCG}) * dt$ INIT RoomH_forCG = 10 INFLOWS: ↻ TransferCG (IN SECTOR: Sector of Kfix Producers P1) OUTFLOWS: ↻ HouseditsCG = IF(TIME=0) THEN 0 ELSE RoomH_forCG
<input type="checkbox"/>	$\text{RoomH_forKcirc}(t) = \text{RoomH_forKcirc}(t - dt) + (\text{TransferKcirc_forH} - \text{Hused_itsKcirc}) * dt$ INIT RoomH_forKcirc = 10 INFLOWS: ↻ TransferKcirc_forH (IN SECTOR: Sector of Kcirc Producers P2) OUTFLOWS: ↻ Hused_itsKcirc = IF(TIME=0) THEN 0 ELSE RoomH_forKcirc
<input type="checkbox"/>	$\text{RoomH_forKfix}(t) = \text{RoomH_forKfix}(t - dt) + (\text{Transfer_KfixforH}) * dt$ INIT RoomH_forKfix = 10 INFLOWS: ↻ Transfer_KfixforH = signal_2*DemandHKfix
<input type="checkbox"/>	$\text{RoomH_forL}(t) = \text{RoomH_forL}(t - dt) + (\text{TransferLforH} - \text{HuseditsL}) * dt$ INIT RoomH_forL = 10 INFLOWS: ↻ TransferLforH = IF(TIME=0) THEN 0 ELSE HdemandL OUTFLOWS: ↻ HuseditsL = IF(TIME=0) THEN 0 ELSE RoomH_forL

Tab.1b. The fillings of building blocks of Household scheme – lower part.

<input type="checkbox"/>	$\text{RoomH_supplyL}(t) = \text{RoomH_supplyL}(t - dt) + (\text{HQL} - \text{TransferL_forP3} - \text{TransferLforH} - \text{TransferL_forP1} - \text{TransferL_forP2}) * dt$ INIT RoomH_supplyL = 0 INFLOWS: ↻ HQL = $\text{HA} * ((\text{RoomH_forKfix} + \text{RoomH_forKcirc})^{\text{HAlpha}} * (\text{RoomH_forCG} + \text{RoomH_forL})^{(1 - \text{HAlpha})})$ OUTFLOWS: ↻ TransferL_forP3 (IN SECTOR: Sector of Kfix Producers P1) ↻ TransferLforH = IF(TIME=0) THEN 0 ELSE DemandHL ↻ TransferL_forP1 (IN SECTOR: Sector of Kfix Producers P1) ↻ TransferL_forP2 = IF(TIME=0) THEN 0 ELSE DemandS2L
<input type="checkbox"/>	DemandHCG = 10
<input type="checkbox"/>	DemandHKfix = 2
<input type="checkbox"/>	DemandHL = 10
<input type="checkbox"/>	DemandS2L = 10
<input type="checkbox"/>	HA = 2
<input type="checkbox"/>	HAlpha = 0.5

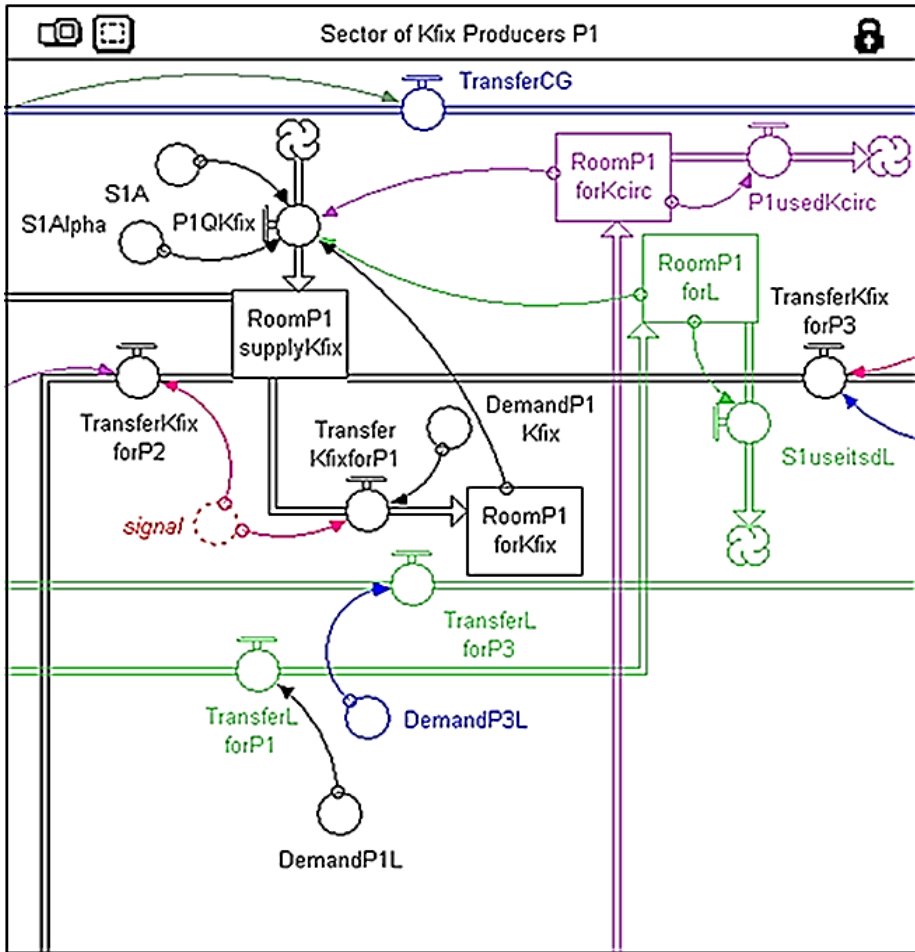


Fig. 7. The snapshot of sector P1 scheme created in STELLA.

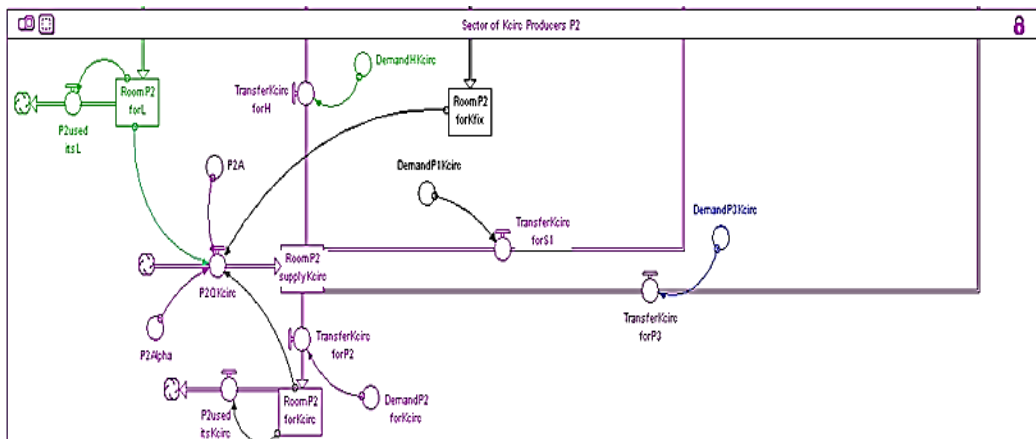



Fig. 8. The snapshot of sector P2 scheme created in STELLA.

Tab.2. The fillings of building boxes of sector P1.

Sector of Kfix Producers P1	
<input type="checkbox"/>	$RoomP1_forKcirc(t) = RoomP1_forKcirc(t - dt) + (TransferKcirc_forS1 - P1usedKcirc) * dt$ INIT RoomP1_forKcirc = 10 INFLOWS: → TransferKcirc_forS1 (IN SECTOR: Sector of Kcirc Producers P2) OUTFLOWS: → P1usedKcirc = IF(TIME=0) THEN 0 ELSE RoomP1_forKcirc
<input type="checkbox"/>	$RoomP1_forKfix(t) = RoomP1_forKfix(t - dt) + (Transfer_KfixforP1) * dt$ INIT RoomP1_forKfix = 10 INFLOWS: → Transfer_KfixforP1 = DemandP1_Kfix*signal_2
<input type="checkbox"/>	$RoomP1_forL(t) = RoomP1_forL(t - dt) + (TransferL_forP1 - S1useitsdL) * dt$ INIT RoomP1_forL = 10 INFLOWS: → TransferL_forP1 = IF(TIME=0) THEN 0 ELSE P1demandL OUTFLOWS: → S1useitsdL = IF(TIME=0) THEN 0 ELSE RoomP1_forL
<input type="checkbox"/>	$RoomP1_supplyKfix(t) = RoomP1_supplyKfix(t - dt) + (P1QKfix - Transfer_KfixforH - TransferKfix_forP2 - Transfer_KfixforP1 - TransferKfix_forP3) * dt$ INIT RoomP1_supplyKfix = 14 INFLOWS: → P1QKfix = signal_2*(S1A*((RoomP1_forKfix+RoomP1_forKcirc)^S1Alpha)*RoomP1_forL^(1-S1Alpha)) OUTFLOWS: → Transfer_KfixforH (IN SECTOR: Sector of Household) → TransferKfix_forP2 = DemandP2_Kfix*signal_2 → Transfer_KfixforP1 = DemandP1_Kfix*signal_2 → TransferKfix_forP3 = DemandP3_Kfix*signal_2
→	$TransferCG = IF(TIME=0) THEN 0 ELSE DemandHCG$ OUTFLOW FROM: RoomP3_supplyCG (IN SECTOR: Sector of CG Producers P3) INFLOW TO: RoomH_forCG (IN SECTOR: Sector of Household)
→	$TransferL_forP3 = IF(TIME=0) THEN 0 ELSE DemandP3L$ OUTFLOW FROM: RoomH_supplyL (IN SECTOR: Sector of Household) INFLOW TO: RoomP3_forL (IN SECTOR: Sector of CG Producers P3)
<input type="radio"/>	DemandP1_Kfix = 6
<input type="radio"/>	DemandP3L = 10
<input type="radio"/>	P1demandL = 10
<input type="radio"/>	S1A = 0.99
<input type="radio"/>	S1Alpha = 0.5

In production process in the sectors there can be emerging several other perturbations. Let we preserve simplicity of understanding: we were chosen only one of them namely in production process of investment goods where we have embedded perturbation into parameter API , in the form of $\Delta API = +\text{small value}$, but only in one time instance. This sole perturbation is caused increasing of investment goods production without change of other inputs and in container called *RoomP1supply Kfix*, begins to raise inventories of investment goods. This new situation force the CEO's of sector *P1* to lowering the price of investment goods called *PriceKfix*. The lower *PriceKfix* enables for sectors *H*, *P2* and *P3* to buy more investment goods and by these decisions of those sectors CEO's the emerging problem for *P1* is excided.

The scheme of Bank accounts network is seemingly parallel and independent from the four sectors of goods. However the networks are connected by several information links, which are carrying values of prices and goods. The software STELLA allows this via tool called *Ghost* . Because of emerged perturbation of values of investment goods we must introduced into model the so called *built in regulators*.

Tab.3. The fillings of building boxes of sector P2.

Sector of Kcirt Producers P2	
<input type="checkbox"/>	$RoomP2_forKcirt(t) = RoomP2_forKcirt(t - dt) + (TransferKcirt_forP2 - P2used_itsKcirt) * dt$ INIT RoomP2_forKcirt = 10 INFLOWS: ↻ TransferKcirt_forP2 = IF(TIME=0) THEN 0 ELSE DemandP2_forKcirt OUTFLOWS: ↻ P2used_itsKcirt = IF(TIME=0) THEN 0 ELSE RoomP2_forKcirt
<input type="checkbox"/>	$RoomP2_forKfix(t) = RoomP2_forKfix(t - dt) + (TransferKfix_forP2) * dt$ INIT RoomP2_forKfix = 10 INFLOWS: ↻ TransferKfix_forP2 (IN SECTOR: Sector of Kfix Producers P1)
<input type="checkbox"/>	$RoomP2_forL(t) = RoomP2_forL(t - dt) + (TransferL_forP2 - P2used_itsL) * dt$ INIT RoomP2_forL = 10 INFLOWS: ↻ TransferL_forP2 (IN SECTOR: Sector of Household) OUTFLOWS: ↻ P2used_itsL = IF(TIME=0) THEN 0 ELSE RoomP2_forL
<input type="checkbox"/>	$RoomP2_supplyKcirt(t) = RoomP2_supplyKcirt(t - dt) + (P2QKcirt - TransferKcirt_forH - TransferKcirt_forS1 - TransferKcirt_forP3 - TransferKcirt_forP2) * dt$ INIT RoomP2_supplyKcirt = 0 INFLOWS: ↻ P2QKcirt = $P2A * ((RoomP2_forKfix + RoomP2_forKcirt)^{P2Alpha}) * RoomP2_forL^{(1-P2Alpha)}$ OUTFLOWS: ↻ TransferKcirt_forH = IF(TIME=0) THEN 0 ELSE DemandHKcirt ↻ TransferKcirt_forS1 = IF(TIME=0) THEN 0 ELSE DemandP1Kcirt ↻ TransferKcirt_forP3 = IF(TIME=0) THEN 0 ELSE DemandP3Kcirt ↻ TransferKcirt_forP2 = IF(TIME=0) THEN 0 ELSE DemandP2_forKcirt
<input type="checkbox"/>	DemandHKcirt = 10
<input type="checkbox"/>	DemandP1Kcirt = 10
<input type="checkbox"/>	DemandP2_forKcirt = 10
<input type="checkbox"/>	DemandP3Kcirt = 10
<input type="checkbox"/>	P2A = 2.829
<input type="checkbox"/>	P2Alpha = 0.5

Tab.4. The fillings of building blocks of the sector P3.

Sector of CG Producers P3	
<input type="checkbox"/>	$RoomP3_forKcirt(t) = RoomP3_forKcirt(t - dt) + (TransferKcirt_forP3 - P3used_itsKcirt) * dt$ INIT RoomP3_forKcirt = 10 INFLOWS: ↻ TransferKcirt_forP3 (IN SECTOR: Sector of Kcirt Producers P2) OUTFLOWS: ↻ P3used_itsKcirt = IF(TIME=0) THEN 0 ELSE RoomP3_forKcirt
<input type="checkbox"/>	$RoomP3_forKfix(t) = RoomP3_forKfix(t - dt) + (TransferKfix_forP3) * dt$ INIT RoomP3_forKfix = 10 INFLOWS: ↻ TransferKfix_forP3 (IN SECTOR: Sector of Kfix Producers P1)
<input type="checkbox"/>	$RoomP3_forL(t) = RoomP3_forL(t - dt) + (TransferL_forP3 - P3used_itsL) * dt$ INIT RoomP3_forL = 10 INFLOWS: ↻ TransferL_forP3 (IN SECTOR: Sector of Kfix Producers P1) OUTFLOWS: ↻ P3used_itsL = IF(TIME=0) THEN 0 ELSE RoomP3_forL
<input type="checkbox"/>	$RoomP3_supplyCG(t) = RoomP3_supplyCG(t - dt) + (P3QCG - TransferCG) * dt$ INIT RoomP3_supplyCG = 0 INFLOWS: ↻ P3QCG = $P3A * ((RoomP3_forKfix + RoomP3_forKcirt)^{P3Alpha}) * RoomP3_forL^{(1-P3Alpha)}$ OUTFLOWS: ↻ TransferCG (IN SECTOR: Sector of Kfix Producers P1)
<input type="checkbox"/>	DemandP3_Kfix = 3*CorrDemKfix
<input type="checkbox"/>	P3A = 1
<input type="checkbox"/>	P3Alpha = 0.5

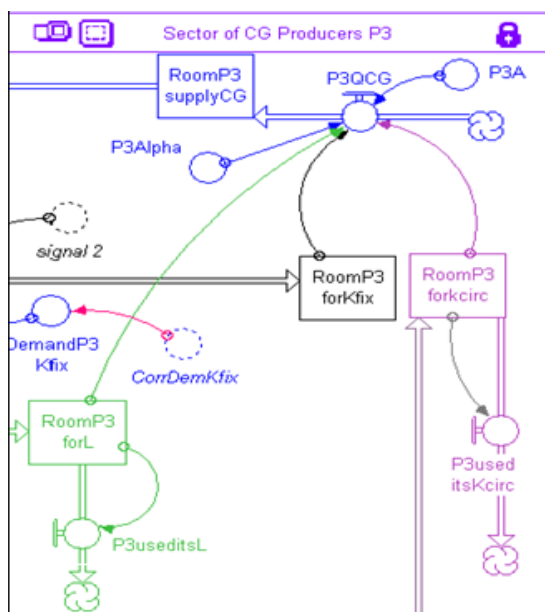


Fig.9. The snapshot of P3 scheme created in STELLA.

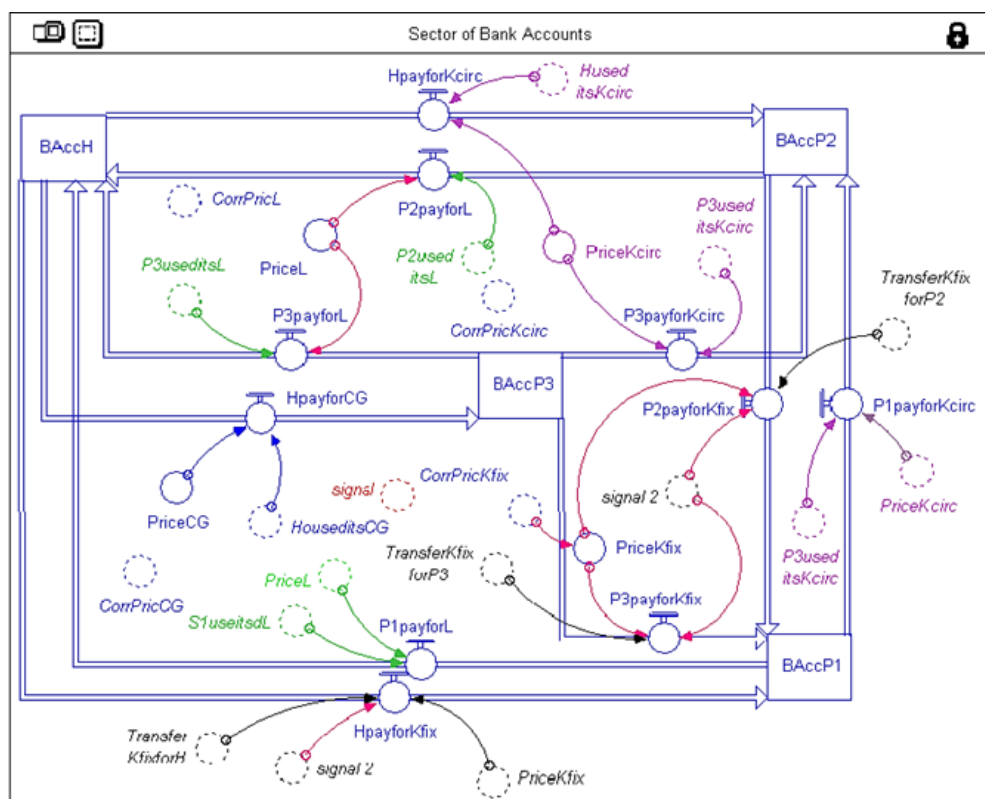


Fig.10. The snapshot of Bank accounts scheme created in STELLA.

Tab.5. The fillings of building boxes of sector of Bank accounts.

Sector of Bank Accounts	
<input type="checkbox"/>	$B_{AccH}(t) = B_{AccH}(t - dt) + (P3_{payforL} + P2_{payforL} + P1_{payforL} - H_{payforKcirc} - H_{payforCG} - H_{payforKfix}) * dt$ INIT $B_{AccH} = 500$ INFLOWS: <ul style="list-style-type: none"> $\otimes P3_{payforL} = PriceL * P3_{useditsL}$ $\otimes P2_{payforL} = PriceL * P2_{useditsL}$ $\otimes P1_{payforL} = PriceL * S1_{useitsdL}$ OUTFLOWS: <ul style="list-style-type: none"> $\otimes H_{payforKcirc} = PriceKcirc * H_{useditsKcirc}$ $\otimes H_{payforCG} = PriceCG * H_{useditsCG}$ $\otimes H_{payforKfix} = PriceKfix * signal_2 * Transfer_KfixforH$
<input type="checkbox"/>	$B_{AccP1}(t) = B_{AccP1}(t - dt) + (P3_{payforKfix} + P2_{payforKfix} + H_{payforKfix} - P1_{payforKcirc} - P1_{payforL}) * dt$ INIT $B_{AccP1} = 500$ INFLOWS: <ul style="list-style-type: none"> $\otimes P3_{payforKfix} = PriceKfix * signal_2 * Transfer_Kfix_forP3$ $\otimes P2_{payforKfix} = PriceKfix * signal_2 * Transfer_Kfix_forP2$ $\otimes H_{payforKfix} = PriceKfix * signal_2 * Transfer_KfixforH$ OUTFLOWS: <ul style="list-style-type: none"> $\otimes P1_{payforKcirc} = PriceKcirc * P3_{useditsKcirc}$ $\otimes P1_{payforL} = PriceL * S1_{useitsdL}$
<input type="checkbox"/>	$B_{AccP2}(t) = B_{AccP2}(t - dt) + (H_{payforKcirc} + P1_{payforKcirc} + P3_{payforKcirc} - P2_{payforL} - P2_{payforKfix}) * dt$ INIT $B_{AccP2} = 500$ INFLOWS: <ul style="list-style-type: none"> $\otimes H_{payforKcirc} = PriceKcirc * H_{useditsKcirc}$ $\otimes P1_{payforKcirc} = PriceKcirc * P3_{useditsKcirc}$ $\otimes P3_{payforKcirc} = PriceKcirc * P3_{useditsKcirc}$ OUTFLOWS: <ul style="list-style-type: none"> $\otimes P2_{payforL} = PriceL * P2_{useditsL}$ $\otimes P2_{payforKfix} = PriceKfix * signal_2 * Transfer_Kfix_forP2$
<input type="checkbox"/>	$B_{AccP3}(t) = B_{AccP3}(t - dt) + (H_{payforCG} - P3_{payforKfix} - P3_{payforL} - P3_{payforKcirc}) * dt$ INIT $B_{AccP3} = 500$ INFLOWS: <ul style="list-style-type: none"> $\otimes H_{payforCG} = PriceCG * H_{useditsCG}$ OUTFLOWS: <ul style="list-style-type: none"> $\otimes P3_{payforKfix} = PriceKfix * signal_2 * Transfer_Kfix_forP3$ $\otimes P3_{payforL} = PriceL * P3_{useditsL}$ $\otimes P3_{payforKcirc} = PriceKcirc * P3_{useditsKcirc}$
<input type="radio"/>	PriceCG = 4.15
<input type="radio"/>	PriceKcirc = 1.04
<input type="radio"/>	PriceKfix = 49 * CorrPrickfix
<input type="radio"/>	PriceL = 2

Tab.6. The fillings of building units of regulators.

Sector of calculations for built in regulators	
<input type="radio"/>	$CorrDemCG = IF(TIME > 0) THEN IF(P3QCG > 14.14) THEN (SupplyKfix_3 / P3Qnul) ELSE 1 ELSE 1$
<input type="radio"/>	$CorrDemKcirc = IF(TIME > 0) THEN IF(P2QKcirc > 40.01) THEN (SupplyKcirc) / P2Qnul ELSE 1 ELSE 1$
<input type="radio"/>	$CorrDemKfix = (SupplyKfix / P1Qnul) / 1.2$
<input type="radio"/>	$CorrDemL = IF(TIME > 0) THEN IF(HQL > 40) THEN (SupplyL) / HQnul ELSE 1 ELSE 1$
<input type="radio"/>	$CorrPricCG = IF(TIME > 0) THEN IF(P3QCG > 10) THEN P3Qnul / SupplyKfix_3 ELSE 1 ELSE 1$
<input type="radio"/>	$CorrPricKcirc = IF(TIME > 0) THEN IF(P2QKcirc > 40.01) THEN P2Qnul / SupplyKcirc ELSE 1 ELSE 1$
<input type="radio"/>	$CorrPricKfix = (P1Qnul / SupplyKfix) * 1.2$
<input type="radio"/>	$CorrPricL = IF(TIME > 0) THEN IF(HQL > 40) THEN HQnul / SupplyL ELSE 1 ELSE 1$
<input type="radio"/>	HQnul = 38
<input type="radio"/>	P1Qnul = 14
<input type="radio"/>	P2Qnul = 38.01
<input type="radio"/>	P3Qnul = 13.14
<input type="radio"/>	$SupplyKcirc = IF(RoomP2_supplyKcirc > 0) THEN RoomP2_supplyKcirc ELSE 1$
<input type="radio"/>	$SupplyKfix = IF(RoomP1_supplyKfix > 0) THEN RoomP1_supplyKfix ELSE 1$
<input type="radio"/>	$SupplyKfix_3 = IF(RoomP3_supplyCG > 0) THEN RoomP3_supplyCG ELSE 1$
<input type="radio"/>	$SupplyL = IF(RoomH_supplyL > 0) THEN RoomH_supplyL ELSE 1$

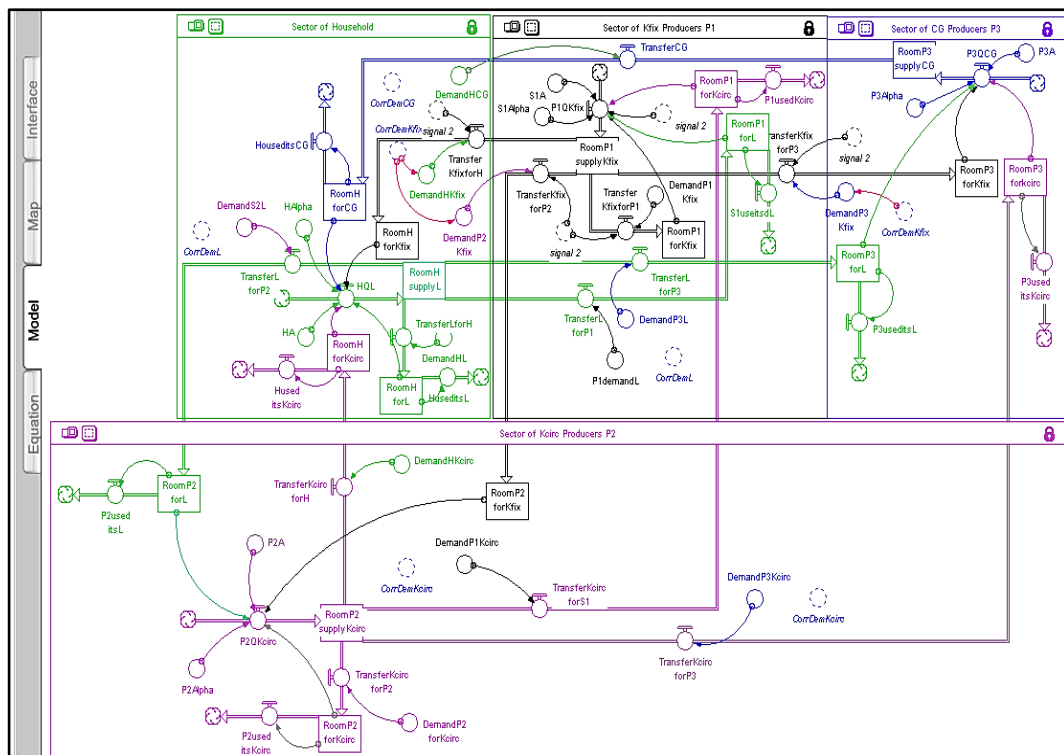


Fig.11. The snapshot of entirety scheme of Virtual Economy created in STELLA.

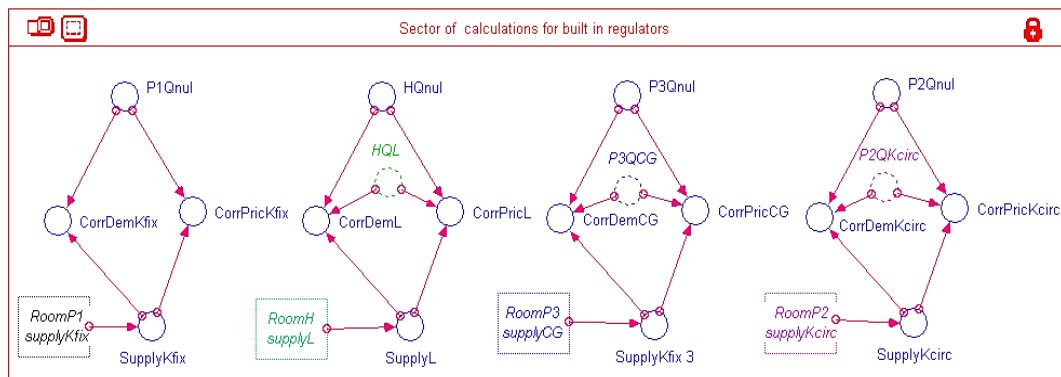


Fig.12. Sector of calculations from outside of model.

Conclusion

In this essay we are trying to focus attentions on imperfections in mainstream economics by the use for attestation of unconformity the objective reality example of economic growth. For those purposes we are using construction of virtual economy in environment of software STELLA in the form of complex economic network. Although we have choose relatively simple models for construction in STELLA, the simulation runs show clearly that the emergence of complexities in these constructed network don't allow to describe economic growth with simple abstract formulas as it is in neoclassical theory. This is because economy is not a mechanical system similar to Newtonian mechanics not to thermodynamics due to R. Clausius, but complex in network evolving social organism. We are attempting to deeper permeate to spontaneous human construction of economies in objective realities using metaphors of virtual economies constructed in STELLA environment.

Our primeval endeavour was to remark on inconsistent approaches of mainstream economics to economies in objective realities based on immoderate simplifications, abstractions and to use not suitable mathematical formalism for such complex evolutionary social organism the economy essentially is. We are emphasizing that economies in objective reality are evolving not only as a whole but unforeseeable they are discretely changing theirs values and qualities of all participants in network. For the purpose of understanding these complexities in economies we are in traducing several not only verbal but first of all graphical informations. Mainly the graphical "language" is the newest mode of better understanding such complex phenomena as economy is. This unconventional approach is needed from concerned readers to have a great patience for "reading" scheme of STELLA networks and the snapshots from realised runs in computer.

Among other within the contexts between network metaphor and real economies the basic impulse and driving engine of economic growth in present global dimension is still the natural seminal instinct of Homo sapiens, formalized as a difference between birth rate and dead one for simplicity. However in matured societies where the birth and death rates are equal to null or are a little lower they govern on economic growth with scientific advances and technologic progress. We have included into STELLA virtual economy the event of positive population growth. For that reason the growth of labour forces L in the model is caused by two driving forces: the first one is natural seminal instinct (extensity) and the second one is the growth of consumed with them goods and services (intensity). We have not embedded into model all three usually used neutral technological progresses but only one of type of Hicks (a progress which raises the marginal productivity of labour and capital in the same proportion that is in our model called by symbols A_i). The random change of the value in random time instance of A_i is the only perturbation force in our STELLA models of virtual economy. On the overall conclusion we are need to emphasize that models presented in this essay are no more than a rough metaphor of economy in objective reality but they are a little nearer than pure neoclassical formulas ones.

References

- [1] Andrášik, L., (2010), Qualitative Economics: Computational Intelligence Assisted Building Writing and Running Virtual Economic Theories, In: A Studies in Computational Intelligence, 313, pp. 247-262. Springer-Verlag, Berlin, 2010.
- [2] Albert, R., Barabási A.-L., (2002) Statistical mechanics of complex networks, Reviews of Modern Physics, Vol. 74, Nr. 1, pp. 47–97.
- [3] Barabási, A.-L., (2003). Linked: The New Science of Networks, Perseus Books, New York.
- [4] Barrat, A., Weigt, M., (2000). On the properties of small-world networks. The European Physical Journal B 13, pp. 547–560

- [5] Cohen, R., Havlin, S., (2010) *Complex Networks: Structure, Robustness and Function*, Cambridge University Press, Cambridge.
- [6] Cohendet, P., Llerena, P., Stahn, H., Umbhauer, G., (1998). *The Economics of Networks, Interaction and Behaviours*, Springer-Verlag, Berlin, 1998.
- [7] Charness, G., Corominas-Bosch, M., Frechette, G., R., (2005). *Bargaining and Network Structure: An Experiment*, Available at SSRN: <https://ssrn.com/abstract=248669> or <http://dx.doi.org/10.2139/ssrn.248669>
- [8] Erdős, P., Rényi, A., (1959). *On Random Graphs I*. *Publicationes Mathematicae*, vol. 6: pp. 290–297.
- [9] Erdős, P., Rényi, A., (1960). *On the evolution of random graphs*, *Publ. Math., Inst. Hung. Acad. Sci.*, vol. 5, pp. 17–61.
- [10] Gomes, O., (2014), *Complex Networks in Macroeconomics: A New Research Frontier*, *Applied & Computational Mathematics*, Volume 3, Issue 3, pp. 1-2. Available from: https://www.researchgate.net/publication/314799413_Complex_Networks_in_Macroeconomics_A_New_Research_Frontier
- [11] Ioannides, Y., M., Datcher Loury, L., (2004). *Job Information Networks, Neighbourhood Effects, and Inequality*, *Journal of Economic Literature*, Vol. XLII (December 2004) pp. 1056–1093
- [12] Ioannides, Y., M., (1997). *Evolution of Trading Structures*, in: *The Economy as an Evolving Complex System II*. W. Brian Arthur, Steven Durlauf and David Lane, eds. Menlo Park, CA: AddisonWesley, pp. 129–67.
- [13] Ioannides, Y., M., (2001). *Topologies of Social Interactions*, in: Tufts U., econ. dept. work. pap., revised June 2004.
- [14] Kirman, A., P., (1998). *Economies with Interacting Agents*, In: Cohendet P., Llerena P., Stahn H., Umbhauer G. (eds) *The Economics of Networks*. Springer, Berlin, Heidelberg, pp. 17 – 51.
- [15] Kirman, A. P., Oddou, C., Weber, Sh., (1986). *Stochastic Communication and Coalition Formation*, *Econometrica*, *Econometric Society*, vol. 54(1).
- [16] Namatame, A., Kaizouji, T., Aruka, Yu., (Eds.), (2017), *The Complex Networks of Economic Interactions*, *Essays in Agent-Based Economics and Econophysics*, vol. 567.
- [17] Newman, M. E. J., Watts, D. J. and Strogatz, S. H., (2002), *Random graph models of social networks*, *PNAS* February 19, 2002, 99 (suppl. 1), 2566-2572; <https://doi.org/10.1073/pnas.012582999>
- [18] Newman, M., E., J., (2003). *The structure and function of complex networks*, *SIAM Review*, 45(2), pp. 167–256.
- [19] Strogatz, S., H., (2001). *Exploring complex networks*. *Nature* 410, pp. 268–276.
- [20] Tesfatsion, L., (2006). *Agent-based Computational Economics: A Constructive Approach to Economic Theory*, No. 527. In: *Computing in Economics and Finance Society for Computational Economics CA*.
- [21] Travers, J., Milgram, S., (1969). *An experimental study of the small world problem*. *Sociometry* 32, pp. 425–443.
- [22] Wang, P., Watts, A., (2002). *Formation of Buyer-Seller Trade Networks in a Quality-Differentiated Product Market*, see its version in book: Jackson, M., O., (2008) *Social and economic networks*, Princeton University Press, Princeton.
- [23] Wasserman, S., Faust, K., (1994). *Social Network Analysis: Methods and Applications*. Cambridge University Press.
- [24] Watts, D., J., Strogatz, S., H., (1998). *Collective dynamics of small-world networks*. *Nature* 393(1), pp. 440–442.

▲ Authors



Prof. Ladislav Andrášik, DrSc. (DSc.), PhD., MSc.

Professor emeritus of Slovak University of Technology
ladislav.andrasik@gmail.com

The author is specialist in application of Information Technologies into anti-aircraft missiles/guidance systems and scholar in introducing ICT/CI into theory and methodology of socio-economic sciences. He is graduated of different military schools and alumni of Economic University. His brown jobs in Army persist 35 years (ten years he occupied roles in anti-aircraft brigade and 25 years in Military Academies and in General Staffs of Army). After he reached statutory retirement age in army he works in Academy of Science as chief scientific worker and as a department chief in Faculty of Electrical Engineering and Information Technology of Slovak University of Technology. He is author, editor and contributor of several monographs, textbooks for Military Academy and for Slovak University of Technology and for Economic University. He published more than 100 scientific essays, articles and papers for scientific conferences organized in several European countries.

