Structural Patterns for System Sustainability: Experimental Study

Olga M. Zvereva, Dmitry B. Berg, and Andrey Kondratyev

Ural Federal University, 19, Mira str., Ekaterinburg, Russian Federation
{OM-Zvereva2008@yandex.ru, BergD@mail.ru, race.timo@gmail.com}

Abstract. Social and economic in our life are tightly interconnected and interrelated. Any social system cannot exist without material economic basis, and along with formal economic relations social informal relations, as the rule of thumb, are formed. One can distinguish two type networks: formed by social relations and relations of economic type. This study was conceived to compare structures of social and economic systems in order to find out their structural peculiarities. Better understanding of structural characteristics can result in better system control. The focus was made on structural characteristics providing system sustainability. It was revealed that cyclic contour set could be proposed as a sustainable structural pattern for an economic system, but it is not true for a social one. For a social system, analysis of triad census on the theoretical basis of structural balance models delivers valuable results for predicting this system sustainability, but for an economic system, this concept was not proved to be the truth. For information support of the research, program was coded that calculates main network parameters and reveals all the cyclic structures in the input network.

Keywords: Social Network Analysis, Economic System, Social System, Structural Pattern, Sustainability.

1 Introduction

Social and economic in our life are tightly interconnected and interrelated. A social system cannot exist without material economic basis, and along with formal economic relations social informal relations of friendship, fellow feeling, and etc., are usually formed. For economic relations interconnected with social ones, new term "embedded" was introduced. This idea of structurally embedded ties was discussed in details by M. Granovetter in his famous paper [1] and widely supported by other scholars. "Embedded ties make firms more economically successful because they are characterized by trust, fine-tuned information transfer and joint problem solving arrangement"- postulated B.Uzzi in [2].

On the other hand, during the last decade the issue of "social capital" becomes a really challenging concept in the social theory. This view of social sounds as a real economic term: "Social capital can be defined as resources embedded in a social structure which are accessed and/or mobilized in purposive actions" [3]. Both in economic and social theories the network approach has been successfully used. This approach denotes that economic and social relations may be considered as to form networks. Fukuyama discussed in [4] that a network could be considered as the most prospective form in comprehensive economy, as it appears to be a compromise between hierarchy and market. B.Wellman in [5] proposed basic principles which substantiated network approach relevancy for social network analysis.

Moreover, social and economic systems may be considered as communication networks. Luhmann in [6] thoroughly discussed this idea for a social system. He has stated that society is only possible where communication is possible. But there is an evident difference: in social communications meanings (non-material objects) are conveyed [7], in economic networks goods are circulated in one direction and money in the opposite one. The question is: will this difference t influence topological characteristics of these type networks?

These materials propose a piece of consideration on the topic of economic and social network topological peculiarities from the standpoint of their sustainability.

In many economic theories cycle is proposed to be a structural pattern delivering economic system sustainability. In the field of social system theory there are special theories and models of sustainability known as the "structural balance" concepts. They are detailed in [8]. We try to discuss two main issues: whether a cyclic contour as a structural pattern is inherent both for economic and social systems, and whether structural balance models are adequate both for social and balanced economic systems.

In this research social and economic networks were engineered. All techniques used for data collection and network reconstruction are discussed in the next section. Special software product was coded to calculate network parameters and to detect all the cyclic structures in a network.

2 Techniques used for data collection

A questionnaire is considered to be the most common source of social communication data [9], nevertheless, its usage has well-known disadvantages. In this research one more way of data collecting was proposed, data was collected with "KOMPAS TQM" system usage (but some networks were built based on questionnaire results). "KOMPAS TQM" system is a quality management system [10] introduced into the educational process in Ural Federal University. This system supports the process of regular communication result evaluation. System users enter positive or negative marks from the certain range. Every mark must be followed by a comment. Thus, the marks entered into the system reflect the real communications between system users and they are confirmed by comments. The mark sign ("+" or "-") characterizes the "information receiver" attitude to the communication result in a whole (positive or negative) while numerical value (from 1 to 5 points) reflects the communication strength (weight) (i.e. the usefulness degree for receiver).

It is common knowledge that it is very difficult to receive real economic data. That is why, economic communication networks were developed with the experimental economics [11] approach usage. On the basis of three different entrepreneurial communities three economic communication networks were generated through business game usage. For more representativeness, business games were organized in different regions of Russian Federation: Ufa city (Bashkortostan Republic), Ekaterinburg (one of the industrial centers), and Moscow (the capital).

Participants were collected among representatives of the local entrepreneurial community. Each experiment lasted for two hours: during the first hour participants were acquainted with the rules and regulations, the second hour was spent for communications of participants and network formation activity. One of the main requirements of the experiment was exchange of goods and services produced by participants in the real life conditions. Intensification of exchange and network formation was reached by the negative interest rate [12] of the cash fund available in the experiment.

The main network parameters are collected in Table 1. Economic networks, as was discussed above, are the results of the business games in Ufa (column Ufa), Ekaterinburg (column Ekaterinburg), and Moscow (column Moscow). Two of social networks were built based on data stored in “KOMPAS TQM” system and reflect communications between students from two different groups (Gr.34 and Gr.35) from the fourth year of education. The third social network is the result of special survey where students were asked to choose their friends from the list, and the friendship network was engineered based on the received data (Fr.201 network).

Table 1. Main parameters of investigated networks

Parameter	Economic Networks			Social networks		
	Ufa	Ekaterinburg	Moscow	Gr.34	Gr.35	Fr.201
Size	11	13	17	13	17	10
Number of Arcs	29	30	50	103	220	26
Density	0.264	0.192	0.184	0.66	0.809	0.289
Diameter	4	4	5	2	2	4
Clustering Coefficient	0.282	0.141	0.227	0.715	0.822	0.542

Networks of both types are of similar sizes, but social networks are more cohesive: have bigger density and clustering coefficient values than economic ones (more details of similar comparison one can find in [13]).

3 Cyclic structure detection

The first task was to find cyclic structures of different dimensions in economic and social networks. In order to understand how these structures are common for these type networks, this procedure was fulfilled also for the corresponding random networks (of the same size and density). Several random networks were built and investigated for every real network, and mean numbers of revealed cyclic structures were calculated.

In general, the task to detect cyclic structures in a network in the graph theory sounds as to find simple cyclic subgraphaphs in a graph. In our research we had to analyze oriented graphs (orgraphs) and, consequently, had to take arc direction into consideration.

The program was coded for network analysis. This program visualizes network as a graph, calculates network main parameters, and finds all cyclic structures in it.

In Fig. 1 program window is shown. In the center of the window network graph is visualized. In the right side panels, network parameters (the upper panel) and the chosen node parameters (the lower panel) are listed.

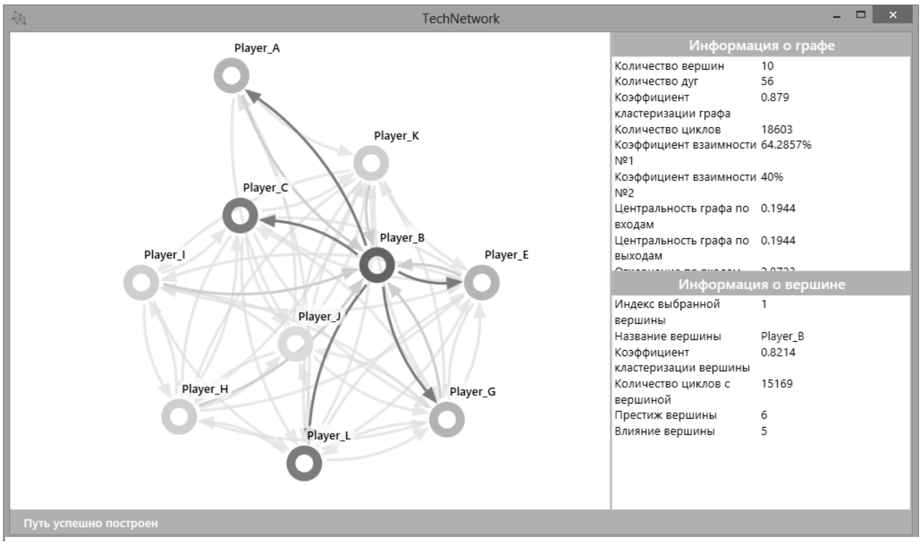

Fig. 1. Program window with an economic network in it

In order to reveal all cyclic structures, DFS-algorithm (DFS – depth-first search) with some improvements was implemented. This recurrent algorithm supposes a graph vertices bypass with “deeper“ motion into the graph while it is possible.

The algorithm for cyclic structures search consists of the following steps:

1. Choose a vertex in the graph in a random way;
2. This vertex is marked as a “visited” one;
3. Look for neighbours of this vertex (the vertex’s neighbour is a vertex in the opposite end of an arc starting with this vertex);
4. For every revealed neighbour, the same actions for their neighbour revealing are done. All found neighbours are stored in the special stack;
5. This search is interrupted when the current vertex has been already marked as a “visited” one or when all vertices have been bypassed;
6. If the current vertex has been already visited (is marked as a “visited” one), the stack is analyzed to determine this vertex first position in it (thus, a cycle is detected):

- for the detected cycle hash function is calculated;
- if this cycle is a new one (with a new hash function value), then this cycle is inserted in the special program collection, and this vertex is deleted from the stack;
- a new search starts for the preceding vertex from the stack.

Cyclic structures were revealed in economic networks and in corresponding random networks. Random networks were built with the help of Pajek [14] as Erdos-Renyi random graphs of the same size and with the same number of arcs (the same density).

Cyclic structure distributions are demonstrated for two economic networks in Fig.2. It is evident, that for economic networks these structures are really intrinsic, as if they are more frequent for every dimension in distribution than for random networks.

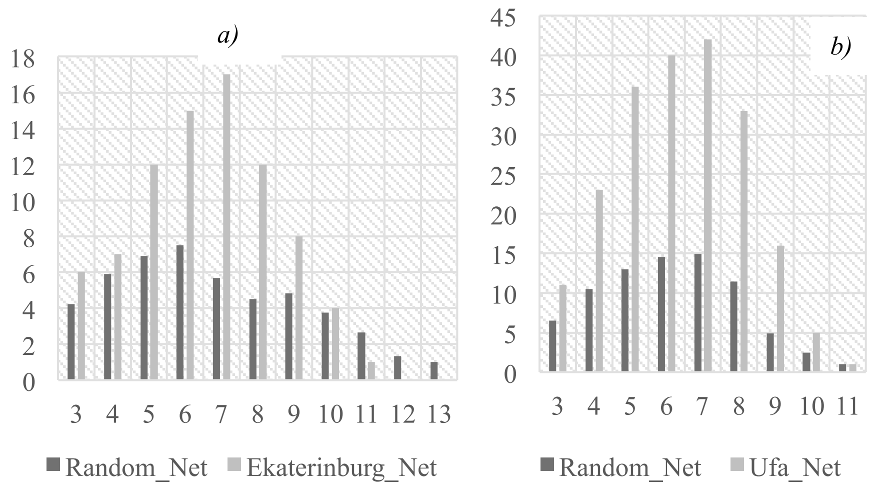

Fig. 2. Cyclic structure distribution in economic and corresponding random networks (a) business game in Ekaterinburg network; b) business game in Ufa network)

Quite opposite results were received for social networks. This is quite clear from the diagrams demonstrated in Fig. 3. One can infer that a cyclic contour of any size in a social network is not its inherent structure.

4 Structural balance models

There are several structural balance theories. They are described in details in [8, 15]. The cognitive theory of Heider can be considered as an origin for most of them. Heider's theory posits that there are a number of psychical forces in the individual cognitive field which are oriented towards the balance preservation.

According to the first (Basic, in Pajek - Balance) model a group presented by a balanced directed graph can be partitioned into two antagonistic subgroups (one of these subgroups can be empty), every subgroup has only mutual ties within its subgraph, and there are only null ties between the two subgraphs.

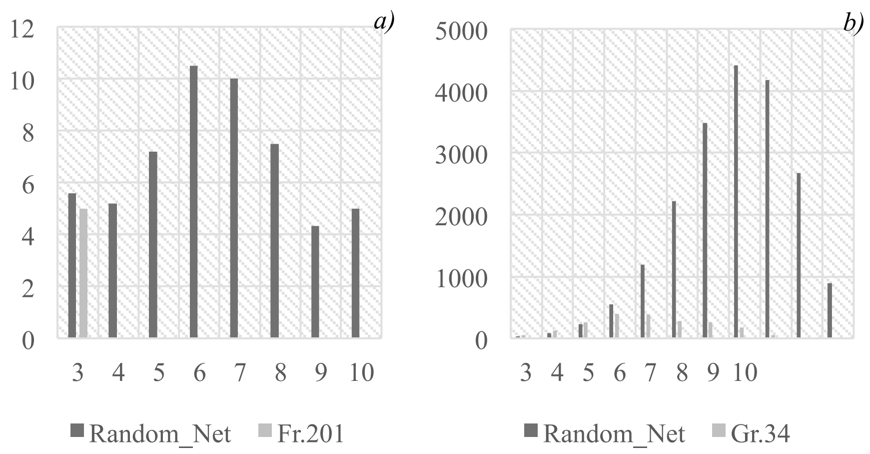

Fig. 3. Cyclic structure distribution in economic and corresponding random networks (a) network of friendship relations in the student group b) network of social communications in the student group)

The second (Clusterability) model extends Balance model to more sociologically reasonable notion of clusterability, which allows existence of more than two subgroups (subgraphs). But the rules are the same: mutual links in a subgroup (subgraph), and null links between the subgroups (subgraphs).

The third (Ranked Clusters) model assumes that any group is a subgroup hierarchy where every hierarchical level has at least one subgroup. This model extends clustering introducing directed (asymmetric) ties between subgroups, with orientation of this ties consistent with hierarchical ordering in which ties are directed from ”lower” to “higher” levels (any lower level subgroup member prefers those who are members of the higher level subgroups).

The fourth (Transitivity) model is the most general model of all discussed and subsumes the other models as special cases. The main rule in this model is as follows: if there are 3 members named A, B, C in a group, and A has a tie with B, B has a tie with C, then A must have a tie with C.

To reveal whether a network graph corresponds to the discussed models, SNA-methodology proposes to analyze the triad census characteristic of a network graph. This procedure is realized by Pajek framework [14], and its results for one of investigated social networks (Gr.34) and for the economic network (result of business game in Moscow) are presented as Table 2. The “Revealed” column demonstrates the numbers of different type triads revealed in networks under investigation, and the column “Expected” contains triad numbers in corresponding random networks.

Table 2. Triad census analysis for economic and social networks

Triad type	Social Network (Gr.34)		Economic Network (Moscow)		Structural Balance Models
	Revealed	Expected	Revealed	Expected	
102	21	18.04	37	30.59	*Basic Model*
300	16	1.02	0	0.03	
003	41	14.59	232	201.01	*Clusterability Model*
021D	50	18.04	18	30.59	*Ranked Clusters Model*
021U	3	18.04	26	30.59	
030T	8	23.07	5	13.78	
120D	0	7.44	3	1.55	
120U	31	7.44	1	1.55	
012	45	56.20	239	271.63	*Transitivity Model*
021C	10	36.08	52	61.18	*Forbidden Triads*
111D	5	23.17	23	13.78	
111U	36	23.17	24	13.78	
030C	0	7.72	8	4.59	
201	4	7.44	4	1.55	
	55	97.58	111	94.78	*Total for Forbidden Triads*

It was proved with χ^2 criteria usage that:

- there is a statistically significant difference between a social network triad census (column "Revealed") and the census of corresponding random networks (column Expected);
- difference existence/absence for an economic network and corresponding random networks cannot be proved because the portion of expected values less than 5% is more than 20%, and χ^2 criteria cannot approve or disapprove the hypothesis of difference existence/absence in this case.

On the base of results in Table 2 (this table in the research report contains censuses for all discussed networks and some more networks which were not mentioned in this paper), one can conclude that social networks meet the balance model requirements, and there are no reasons to make the same decision for economic networks. For example, Gr.34 network is well conformed with Basic model, Clusterability model, and Ranked Clusters model, and do not corresponds to Transitivity model, but it includes the less number of forbidden triads that the corresponding random networks (55 against 97.58). For the Moscow game economic network, numbers of forbidden triads in this network and in corresponding random networks are almost equal.

5 Conclusions

Although social and economic networks are tightly intertwined and make influence on each other, they have their own structural peculiarities that might be taken into consideration to propose effective system control. Cyclic contours can be considered to be inherent for an economic system and form structural basis of its sustainability, but this structural pattern is rather seldom in a social network. As for social systems, for the theoretical basis of their sustainability structural balance concepts can be adopted, but this idea was not proved for economic systems.

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