The Detailed Structure of Local Entrepreneurial Networks: Experimental Economic Study

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Abstract. Economic agents' behavior during the last 40 years had tremendously changed from perfect competition to cooperation between them, and coopetition phenomenon was revealed. This phenomenon is always based on the certain entrepreneurial network. The paper is focused on entrepreneurial networks which are geographically localized. Such networks are formed as a result of two different types of cooperation: production cluster cooperation and cooperation in a community. The main goal of the present study is to find differences between internal structures of these two types entrepreneurial networks. Data was collected using experimental economic techniques, it was represented in the form of transactions between network agents and was aggregated over the certain time period. Social Network Analysis (SNA) methods and instruments were used in this research. Detailed structure analysis was based on the set of quantitative parameters such as density, diameter, clustering coefficient, different kinds of centrality, and etc. The entrepreneurial networks of two production clusters and three cooperative communities were under investigation. These networks were compared with each other and also with random Bernoulli graphs of the corresponding size and density. It was found that cooperative community networks are more random and dense than the production cluster ones and their other parameters also differ. Discovered variations of network structures are explained by the peculiarities of agents functioning in these two type networks.

Keywords: Economic network · Entrepreneurial network · Social network analysis · Experimental economics · Communications · Coopetition · Localization · Local payment system

1 Introduction

Economic agents' behavior during the last 40 years had tremendously changed from the perfect competition to cooperation between them. One can find different forms of cooperation relationships. If they are localized in the certain territory in order to supply a special complex product with a high level of added value, one might identify this structure as a "cluster" [1]. If agents are mostly interested in meeting each other

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demands, it is a cooperative community [2]. If agents are distributed geographically, they become parts of a vertically integrated production structure with crossed shareholdings, than we call this structure an "international corporation" [3]. One more form of cooperation between agents is a barter network [4]. Even if employees are distributed geographically, more and more often they become to work in the same company. Such great variety of cooperative relationships now is considered in the ranks of the coopetition concept [5].

"Coopetition or Co-opetition (sometimes spelled "coopertition" or "co-opertition") is a neologism coined to describe a kind of cooperative competition. Coopetition is a portmanteau of cooperation and competition, emphasizing the "petition"-like nature of the joint work" [6].

Embedded ties [7] at formally competitive markets became another aspect of this phenomenon. Now it is absolutely clear that the composition of competition and cooperation determines agents' behavior in the modern markets. Competition in different forms (perfect, imperfect, monopolistic, etc.) nowadays is the well studied phenomenon. There is the opposite situation if we consider cooperation. Cooperation occurs to be on the sidelines of the mainstream and most of economists pay it less attention because of its poor mathematical base. Nowadays, cooperation requires close attention and detailed study because of its significance both for economic theory and practice.

Cooperative relationships are institutionalized in recurring communications between agents – entrepreneurs. In every communication act they can exchange information, senses, money, services, industrial goods, energy, and etc. The set of communications forms a stable cooperative network with corresponding commodity and financial flows. Communications' dual nature makes it possible to design the network communication matrix using the information about agent transactions.

This paper is focused on the entrepreneurial networks localized geographically. They are based on production cluster cooperation and cooperation in a community. The main goal of the present study is to compare internal structures of these two type entrepreneurial networks.

2 Data Description

Exact data of entrepreneurial production network structure and its functioning can be obtained from the set of agents' (actors') bank statements. A bank statement contains all information required to design a communication matrix: the sum, the recipient/payer name and the date of transaction. One can investigate communications day-by-day or aggregate them for the certain period of time. A communication matrix with information about transaction dates makes it possible to study a network structure evolution. But an agent's bank statement is a trade secret, so it seems impossible to get real statements of agents of a network.

There are two basic sources to obtain data about a cooperative community entrepreneurial network. One of them is the same as for a production network. The main difficulties, which arise, were described above. If a community is using so-called "complementary" currency, or "local" currency [8] for payments and it is an electronic currency, all transactions are recorded in a local payment system. The required communication matrix can be easily exported (under permission of the operator) and utilized for the further analysis. Unfortunately, the operator's permission is also a great problem. Besides, there are almost no local payment systems in cooperative communities in Russia.

In order to solve this problem it was decided to use the experimental economics [9] approach. Two sets of experiments were performed and five different entrepreneurial networks were obtained as the result: three cooperative community networks and two production ones.

For relevant results obtaining, the experiments for cooperative community network generation were organized in three different regions of the country: Ufa city (Bashkortostan Republic of Russian Federation), Nabereznye Chelny city (Tatarstan Republic of Russian Federation) and Moscow city. Every group of entrepreneurs was comprised randomly using Facebook but from the local entrepreneurial community. Experimental network was formed on the basis of their face-to-face communications. Each experiment lasted for two hours: during the first hour participants read the rules and regulations, the second hour was spend in communications and network building activity. The main requirement of experiments was to exchange the real goods and services produced by the participants themselves. Exchange intensification and network formation was received through the negative cash fund interest rate [10] usage.

Production cooperative networks were designed in two different ways. The first production network was obtained from the municipal economy's model discussed in [11, 12]. It is based on the set of the 12 real business entities which have the partner relations in manufacturing and consuming their goods and services for 10000 residents. The set of municipal business entities includes farms (agricultural, poultry, meat and dairy), plants (dairy, meat processing), mills (flour, feed), bakery, factory, workshop, and etc.

The second network was generated by the group of students in economics (School of Economics and Management of Ural Federal University, Ekaterinburg) while developing the project task: to design a network of small business companies which will be able to supply the whole life cycle (for two weeks) of a summer tourist camp with educational and entertainment programs, with building, rent, logistics, catering, security, garbage collection, and other required services. The total number of virtual camp inhabitants was set to 120 including children and staffs. First two and two last days were spent for assembling/disassembling building constructions. The balanced matrix of payments between agents aggregated for 14 days is the base for the second production network under investigation.

Both production networks include population as the special agent which consumes the other agents' products and provides them with the necessary labor resource.

Networks are determined by the following parameters:

- Nn - number of nodes (agents, actors);
- Ne - number of edges (relations, communications, ties, links);
- D - density (the proportion of all possible ties which are actually present), $D = Ne/Nn(Nn - 1)$;
- Sum – total amount of transactions/payments (in rubles);
- $AvrCost$ - average transaction cost (in rubles), $AvrCost = Sum/Ne$

– *Ng* - number of different types of goods and services produced and consumed in the network;
– *Var* - variety of products in the network, *Var* = *Ng/Nn*.

Values of network parameters are listed in Table 1. The network graphs are shown in Fig. 1.

Table 1. Network parameters

Parameter	Community networks			Production networks	
	1	*2*	*3*	*1*	*2*
Nn	10	11	17	12	8
Ne	56	29	50	28	19
D	0.622	0.264	0.184	0.212	0.339
Sum	438000	80000	576000	306200000	2484599
AvrCost	7821.43	2758.62	11520	10935714	130768
Ng	42	29	44	14	8
Var	4.2	2.64	2.59	1.17	1

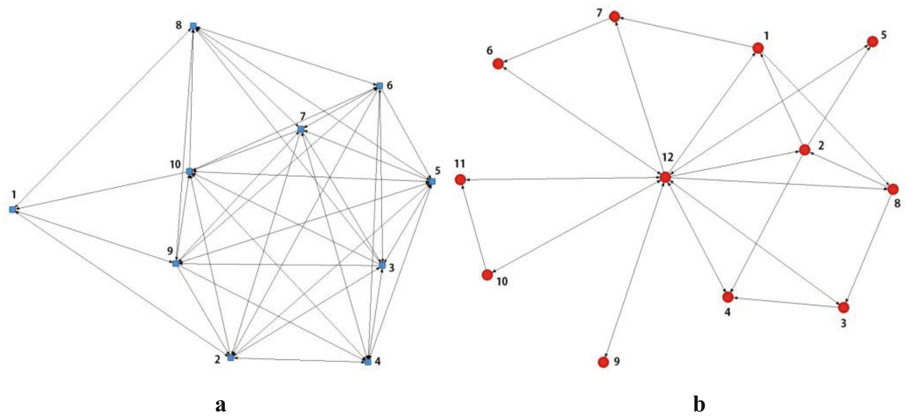

Fig. 1. Network Graphs of: (a) community 1 network; (b) production 1 network. Designed in UCINET 6 for Windows

All investigated networks are of the comparable size (*Nn* and *Ne*) and density (may be, except community 1 network, which density reflects the extremely high intensity of agent communications). The main differences of the community and production network sets are:

– in the total amounts of transactions (production networks demonstrates the higher values);
– number of goods and services consumed in the community networks exceeds two times or more the corresponding number in the production networks;

– variety of products in the community networks is also two of more times higher than in the production ones;
– average transaction cost in the community networks is at least 10 times lower than one was obtained in the production networks.

Such significant differences are the results of the network nature: the most number of production network transactions are localized in B2B segment, while a community network is focused on B2C communications. So, every production network agent tries to supply large volumes from the limited range of products in order to reduce product costs. Conversely, every community network agent is interested in production of a wide variety of products, even whether only one sample is demanded. Moreover, a community network agent can be both a product manufacturer and its final consumer.

3 The Calculation Technique and Quantitative Parameters

Network quantitative characteristic study is focused on four types of parameters: for a whole network, for an ego network (neighborhood), dyadic, and single actor parameters. Calculations were performed according to the formulas from Table 2 [13, 14].

Table 2. Network parameters and their calculations

№	Parameter	Formula	Explanation
1	*D*	$D = \max_{i,j=1,\ldots,n} \left(d\left(n_i, n_j\right)\right)$	$d(n_i,n_j)$ – the shortest (geodesic) path n_i – actor *i*; n_j – actor *j*
2	*CC*	$CC = \frac{1}{N}\sum_{i=1}^{N} C_i,$	C_i – density of the *i*-th actor's neighborhood
3	*Tr*	$Tr = \frac{N_t}{N_d},$	N_t – number of non-vacuous transitive ordered triples N_d – number of triples in which ties go from actor n_i to actor n_j and from actor n_j to actor n_k
4	*Re*	$Re = \frac{\sum L_p}{\sum L},$	*L* – dyadic tie *Lp* - reciprocated dyadic tie
5	*IDCenz*	$\frac{\sum_{i=1}^{n}(IDC^{*} - IDC_i)}{\max_{i=1,\ldots,n}\sum_{i=1}^{n}(IDC^{*} - IDC_i)}$	IDC^{*} – in-degree centrality of the most central actor IDC_i – in-degree centrality of the *i*-th actor
6	*ODCenz*	$\frac{\sum_{i=1}^{n}(ODC^{*} - ODC_i)}{\max_{i=1,\ldots,n}\sum_{i=1}^{n}(ODC^{*} - ODC_i)}$	ODC^{*} – outdegree centrality of the most central actor ODC_i – outdegree centrality of the *i*-th actor
7	*BCenz*	$\frac{\sum_{i=1}^{n}(BC^{*} - BC_i)}{\max_{i=1,\ldots,n}\sum_{i=1}^{n}(BC^{*} - BC_i)}$	BC^{*} – berweenness centrality of the most central actor BC_i – betweenness centrality of the *i*-th actor

General network parameters are: nodes (actors) and edges numbers, density, diameter and clustering coefficient. Three of them have been already discussed and listed above in Table 1.

Diameter (D) is the largest geodesic path from one actor (node n_i) to another (node n_j). A geodesic path (or the shortest path) between nodes i and j is the path connecting these vertices with minimum length [43]. A diameter tells us how "compact" the network is (that is, how many steps at least are necessary to get from one node to another).

Clustering coefficient (CC) is the mean of neighborhood densities for all network actors [15]. Clustering coefficient *CC* indicates how "cohesive" a network is [16] proposes formulas for weighted networks.

For a directed network the *transitivity coefficient (Tr)* is often measured as the ratio of really transitive triad number in a network to the number of cases where a single link could complete the transitive triad. Transitive relationship in a triad means that if A directs a tie to B, and B directs a tie to C, then A also directs a tie to C. Transitive triads are argued by some scholars [17] to be the balanced, or natural, network patterns. So, transitivity indicates the potential ability of a network to become a "stable", or "natural", one.

One of the dyadic main characteristics is *reciprocity (Re)*. It indicates the proportion of connected actor pairs (dyads) having a reciprocated tie between them. Disconnected pairs (null relationship between actors) are usually ignored.

Different kinds of centrality are used to characterize a single actor. The chosen characteristics of centrality take into account only direct links between nodes because of the network specificity. *Centralization* indicates how unequal the distribution of actor connections (degree centrality) is in a network. There are several centrality measures, only some of them are under discussion.

If we consider a directed network, the total number of ties sent by an actor is called *out-degree centrality of the actor,* and the total number of ties received is called *in-degree actor centrality*. Actor in-degree centrality is considered to be the measure of its prestige, and its out-degree centrality characterizes the level of its expansivity.

Betweenness centrality is the extent to which an actor falls on the paths between other pairs of actors in the network. It stresses the control level or the capacity to interrupt relations [18].

Three different types of network centralization are calculated in the present study: *Indegree Centralization (IDCenz)*, *Outdegree Centralization (ODCenz)* and *Betweenness Centralization (BCenz)*. To estimate the network centralization one must find the most central actor C^*, take its centrality score and subtract the centrality score of each other actor from it, add up the differences: $\Sigma(C^* - C_i)$, then divide this by what this sum would be under the largest possible centralization ($Max\ \Sigma(C^* - C_i)$).

The main idea of the study is to compare two types of networks with the corresponding random Bernoulli graphs and with each other in order to find differences between them for deep understanding of entrepreneurial network formation.

Each experimental entrepreneurial network has its own unique structure. For the aim of valid comparison random Bernoulli graphs of the same sizes and densities as the experimental network graphs were generated. Investigation of a network structure was performed according the following technique:

- calculations of the experimental network parameters;
- generation of the random Bernoulli graphs of the same size and density;
- calculations of the random Bernoulli graph parameters;
- comparison of the experimental network and the corresponding random Bernoulli graph parameters, estimation of their relative deviations;
- comparison of the relative deviations from Bernoulli graph among the community networks and the production networks separately and calculation of the relative deviation average values for each set;

– comparison of these relative deviation averaged values.

Relative deviation (RD) from a Bernoulli graph is calculated as follows:

$$RD = \frac{\Delta}{BV} \quad (1)$$

where $\Delta = |V - BV|$, V– the experimental network parameter value, BV – the corresponding Bernoulli graph parameter value.

All calculations of the network parameters listed in Table 2 were carried out utilizing framework UCINET 6 for Windows [19] which supports SNA (Social Network Analysis) methodology.

4 Results and Discussion

Calculated community network parameters (their real values (*V)* and relative deviations from Bernoulli graphs (*RD*)) are shown in Table 3. One can find that differences between "community 1" network and the two others are greater than between the "community 2" and the "community 3" networks. The main reasons of this fact were discussed above (see comments to Table 1). The most similar to the random Bernoulli graph is the "community 3" network – relative deviation values do not exceed 17% for all calculated parameters and for most of them they are in the range of 2%–13%. Centralization in general seems to be the most distinctive parameter of the community networks 1 and 2 and the corresponding random graphs: in the substantial number of cases the relative deviation reaches the values of 44% and greater. Summarizing results of comparison, it should be noted that community network graphs and the random ones differ significantly.

Table 3. Values of community networks parameters

	Community 1		Community 2		Community 3	
	V	*RD*	*V*	*RD*	*V*	*RD*
D	2	0.33	4	0.2	5	0.17
Re	0.47	0.23	0.07	0.46	0.16	0.02
Tr	0.61	0.06	0.23	0	0.14	0.12
CC	0.64	0.07	0.28	0.52	0.23	0.07
IDCenz	0.71	0.46	0.26	0.13	0.20	0.13
ODCenz	0.17	0.46	0.15	0.21	0.20	0.13
BCenz	0.03	0.70	0.15	0.44	0.17	0.15

The same comparison for production networks is shown in Table 4. Networks of this set seem more similar to each other than in the previous case. At the same time, they are tremendously differ from random Bernoulli graphs – the relative deviation exceeds 50% overwhelmingly and for the most centralization and reciprocity values is 100% and greater.

The real values of the calculated networks parameters and their relative deviations from the random Bernoulli graphs (Tables 3 and 4) were averaged for the qualitative comparison of the two investigated sets (Table 5). The networks and random graph parameters differ by more than 22% (with rare exceptions). It is the first significant result of the present study.

Table 4. Values of production networks parameters

	Production 1		Production 2	
	V	*RD*	*V*	*RD*
D	4	0.33	3	0
Re	0.33	0.99	0.46	2.92
Tr	0.15	0.52	0.30	0.38
CC	0.52	0.53	0.60	0.40
IDCenz	0.46	0.27	0.59	0.38
ODCenz	0.86	4.2	0.76	1.85
BCenz	0.77	2.2	0.83	6.4

Table 5. Averaged values of community and production networks parameters

	Average values of parameters			
	Community		Production	
D	<*V*>	<*RD*>	<*V*>	<*RD*>
	3.7	0.23	3.5	0.17
Re	0.24	0.24	0.40	1.9
Tr	0.33	0.06	0.22	0.45
CC	0.38	0.22	0.56	0.47
IDCenz	0.21	0.24	0.53	0.33
ODCenz	0.18	0.27	0.81	3.1
BCenz	0.12	0.43	0.79	4.3

The second important result is the detection of the fundamental difference between two investigated networks: a community network graph is more similar to a random Bernoulli graph than a production one. It becomes absolutely evident after comparison of averaged *RD*-values. The reason is based on the different nature of two network sets: a production network is more determined by resource supply chains, and its ability to change suppliers and buyers is very restricted, while a community network is more flexible.

It means that coopetition phenomenon is accompanied by formation of agent networks. It is important that such networks are far from random ones. The network ("production" or "community" in the present study) specificity is reflected in its structure. One might suppose that different types of entrepreneurial networks will be discovered in the nearest future. It will influence investigation of modern markets and make it more complicated.

These important findings in the structure of local entrepreneurial networks determine the direction of the further detailed study including analysis of the larger volumes of experimental data and also usage of real economic data. In combination with research of networks functioning [20], it will impact our understanding of the coopetition phenomenon.

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