www.ijccr.org · ISSN: 1325-9547

Panachev, A. & Berg, D. (2021). Prospects of implementation of complementary currencies at the municipal level by dataset of economical agents banking transactions. *International Journal of Community Currency Research 25*(1), 107-115. https://doi.org/10.15133/j.ijccr.2021.008

International Journal of Community Currency Research

VOLUME 25 (ISSUE 1, 2021) 107-115

PROSPECTS OF IMPLEMENTATION OF COMPLEMENTARY CURRENCIES AT THE MUNICIPAL LEVEL BY DATASET OF ECONOMICAL AGENTS BANKING TRANSACTIONS

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ABSTRACT

The main goal of the research is to determine prospects of complementary currencies implementation at municipal level. The researching object is a small city. For reaching a goal of the research it was necessary to solve following tasks: to determine the causes of closed networks formation, to analyze networks as well as to calculate the possible economic effect of implementation. The main precondition to implementation is the presence of networks of closed transactions when the groups of economic agents are joining to clusters and exchanging goods and means of calculation inside the system. The algorithm in python was created to find such networks. The searching result consists of 17 closed networks and 102 organizations. The Social Network Analysis system of metrics was used to analyze discovered networks. In comparison process with Bernoulli random graph was found that the networks aren't random and further searching/research is needed. The analysis process of dynamics of forming networks discovered that the maxim value of metric in the first and second periods and the peak of participant's number is in the third week. The process of economic effect calculations demonstrates that the turnover 2705 million rubles can free 7,42 million through the complimentary currencies implementations.

KEYWORDS

Alternative currency, Social Network Analysis, Local payment systems, Experimental economic models, Bernoulli random graph.

ACKNOWLEDGMENTS

Present study was carried out under financial support of the Russian Fund of Fundamental Research grant № 19-010-00974 "Experimental institutional models of the autonomy of local communities' finances in context of public confidence decreasing in forms of participation in the budget process".

To cite this article: Panachev, A. and Berg, D.B (2021) 'Prospects of implementation of complementary currencies at the municipal level by dataset of economical agents banking transactions' *International Journal of Community Currency Research* Volume 25 (Issue 1) 107-115; www.ijccr.net; ISSN 1325-9547; DOI http://dx.doi.org/10.15133/j.ijccr.2021.008

1. INTRODUCTION

Since the last two decades the researchers have been paying more and more attention to network aspect of social and economic systems. According to one of the main researchers in this area, Manuel Castells, networking is at the forefront of the modern economic society (Castels 1996). The developing nature of telecommunications area enables the selection of contractors and suppliers by entrepreneurs throughout the world. They are able to exchange goods and transact with thousands of potential clients from every country – a well as adapt their products and make product diversification based on individual client's needs. One of the most important and actual steps in process of researching the network societies is researching entrepreneurial network societies which are formed by permanent or temporary basis. Entrepreneurial cooperation in economic networks is a natural economic process. The diversity of entrepreneurial relations is considered within the conception of economic cooperation (Gnyawali 2009).

Cooperation is a neologism which means a phenomenon named as cooperative competition. Cooperation is synthesis of cooperativeness and competition which illustrates a natural form of mutual activity.

Another additional aspect in cooperation is deep-rooted ties (Uzzi 1996) at the markets with market competition.

There are several reasons to cause the cooperation as economic phenomenon.

Firstly, it is specific for the beginning of business. This step assumes the gradual extensive scaling up of a new business. The business develops from the regional level to the federal. The way to accelerate new business to scale is to form clusters. The entrepreneurs can unite organizations to the chain of added value production «Money-goods-money'» (by K. Marks) or as the end user of services.

The second cause is economic instability and other external changes which can destabilize the system (i.e. changes of laws, changes in consumers condition and etc.). These changes are catalyst when the system is trying to find new point of optimum. The cooperation of entrepreneurs (economic agents) takes place in the market if each of them produce the unique goods or services. The problems of regulation instability of the economy for each level was researched by American researcher W. Leontief who was dedicated to solve the problem in his main work «Economics «Input-Output» (Leontief, 1990) in year 1996. The inter-industry linkages were investigated in that work. Leontief thought that all the economy represents the systems of horizontal and vertical connections and the logic of this process can help to regulate economic balance. The linear differential equations and mathematical methods were created in researching process. The instruments allow to analyze the current condition of economic and to model the different scenarios of improvement (Cicishvili 1995). The «Input-Output» methodology and their practical application brought a Nobel Prize for the progress in economics in 1973.

The entrepreneurs can cooperate in networks for personal satisfaction (Mc Millan 1986) and not only for value-added production. It creates the local market in the certain territory. The example is small villages with one thousand citizens. The cooperation there is the regulator of goods flow.

There are three main forms of local industrial cooperation: clustering (Porter 1990), entrepreneurial networks (Mc Millan 1986) and barter network (Birch 1998).

The main form of cooperation is entrepreneurial networks when each participant becomes the contractor to others. A certain group of agents which don't link, participate in the chain of additional value «money-goods-money». All kinds of joint entrepreneurial activities assume goods or facilities exchange in process of relationship.

The situation of economic instability leads to decentralization of enterprise actives that creates a competitive advantage. The part of industrial capacity follows to outsourcing organizations which can maintain the production capacity and reduce costs by the scale effect. The decentralization of enterprise activities can help in the initial stages of a new business.

Goods and facilities can be different: energy, material, human, information, financial and other resources. The financial flows are arising between organizations which circulate between agents on regular basis. The part of financial flows doesn't go beyond the closed circuit. Only the value in amount is changed.

Financial networks as social-economic complex was researched on by the American scientist, mathematician and founder of cybernetics N. Winner at the 60th years of last century. Winner considers that complexity as a «black box» and the control system was considered as an outside observer (Ulianova 2011). The managing of such systems is an important part of region economic welfares by Winner.

The systems of closed circuits are great opportunity to free the money for additional investments by the regional turnover in region. The same idea in scientific works was expressed by F. A. Khayek in (Khayek, 1996). The two main ways to do it: the creation of clearing center which will do the offset of transactions or complementary currency implementation which can become tickets, coupons or electronic forms of non-cash payment.

The main goal of the research is to identify complementary currencies implementation potential at the municipality level.

2. DATA DESCRIPTION AND NETWORKS SEARCHING

The dataset to process closed transactions was collected from real banking transactions for the period of one month. It consists of data from three bank branches in a small town of the largest bank in Russia. The sample includes 15 thousand transactions between 2394 companies.

The closed transactions query algorithm was written in Python language. It constructs the matrix of economical communications between agents and excluding agents which are not involved in networks.

For the graph construction and further analysis, the matrix of properties and directions is created (Berg 2015).

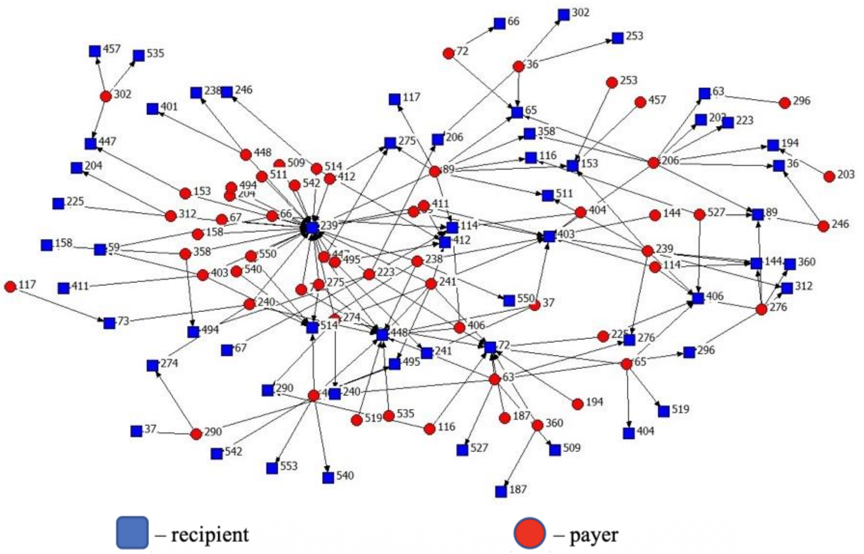
The process of projecting and building of result model, it was discovered that the transactions contained 17 closed networks which consist of 102 companies in closed outline and 1205 companies with outside directed transactions. The economical industries are widespread, and they cover the following industries:

1. wholesale;
2. production of dry mixes;
3. residential property leasing;
4. publication of books;
5. trucking industry;
6. telecommunications, etc.

The networks covered 67 economic industries in general. This means that the majority of citizens' needs can be covered beginning from FMCG to residential property leasing.

The largest network, which was found consists of 59 companies. The graph of this network is shown in Figure 1.

Figure 1 The largest graph based on banking transactions



The unique organizations were identified by the numbers on graph. For example, the 63 number represents organizations of wholesale trade of construction materials, 72 – salesman of paints and varnishes, 144 – car dealer, etc.

The blue colored nodes do not transfer transactions to the next agents, they only get or send it back. The red colored nodes are transitive. They get and send transactions through themselves.

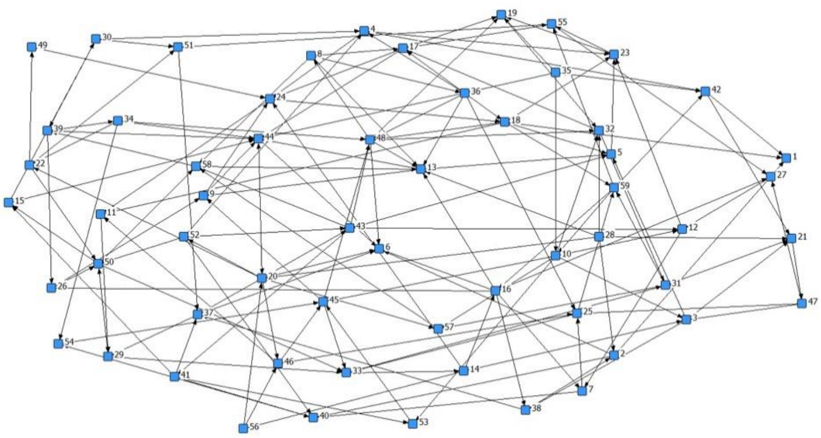
The graph shows the «celebrity» nodes which are actively participating in flows, e.g.:
72 – wholesale trade of paints and varnishes company;
239 – Water collection, treatment and distribution company;
403 – production of electrical works company, etc.

3. BERNOULLI GRAPH COMPARISON

The tasks of this research include comparison analysis between real transactions graph and the other one which is random constructed. The main question of this task is «Does the real transactions graph looks like the random one? ». For the solution of this task random Bernoulli graph was used.

The Bernoulli graph was constructed with the same parameters as one of the networks with 59 agents (i.e. the same count of agents and the same average count of connections). The result of modelling is in figure 2.

Figure 2 The Bernoulli random graph



The main difference between graphs is in transitive nodes. In Bernoulli graph all kind of nodes acts as intermediary and send transactions to the next actor. For deep structure analysis the following parameters based on Social Network Analysis (Wassermann 1994; Gradoselskaya 2004) were used. The parameters are listed in Table 1.

Table 1 Social Network Analysis Integral Parameters

Parameter	Formula	Explanation
D	$D = \max_{i,j=1,..,n}(d(n_i, n_j)),$	$d(n_i, n_j)$ – the shortest (geodesic) path n_i – agent i; n_j – agent j
Re	$Re = \frac{\sum L_p}{\sum L},$	L – dyadic tie L_p – reciprocated dyadic tie
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 agent n_i to agent n_j and from agent n_j to agent n_k
CC	$CC = \frac{1}{N}\sum_{i=1}^{N} C_i,$	C_i – density of the i-th agent's neighborhood

IDCenz	$\frac{\sum_{i=1}^{n}(IDC^* - IDC_i)}{\max_{i,j=1,..,n}\sum_{i=1}^{n}(IDC^* - IDC_i)}$,	IDC^* – in-degree centrality of the most central agent IDC_i – in-degree centrality of the i-th agent
ODCenz	$\frac{\sum_{i=1}^{n}(ODC^* - ODC_i)}{\max_{i,j=1,..,n}\sum_{i=1}^{n}(ODC^* - ODC_i)}$,	ODC^* – out-degree centrality of the most central agent ODC_i – out-degree centrality of the i-th agent
BCenz	$\frac{\sum_{i=1}^{n}(BC^* - BC_i)}{\max_{i,j=1,..,n}\sum_{i=1}^{n}(BC^* - BC_i)}$,	BC^* – betweenness centrality of the most central agent BC_i – betweenness centrality of the i-th agent

The method of characterization of the network integral parameters is based on four group types: ego network (neighborhood) properties, dyadic parameters, single actor parameters and the whole network parameters. Calculations were performed according to common formulas (Newman 2003; Costa 2007), see Table 1.

The main parameters of network by SNA methodology include diameter, the coefficient of transitivity, the number of nodes and ties, density, clustering coefficient and Freemans indexes of centralization (In-degree centralization, out-degree centralization). The formulas of index calculation are available in Table 1.

Diameter (D) is the largest geodesic path between agents in the network. Geodesic path (or the shortest path) is the number of nodes which is placed between the farthest agents in the network (Costa 2007). The diameter shows the scale of network.

The network clustering coefficient (CC) demonstrates the average value of ego-networks density to each agent (Hanneman 2005). The coefficient reflects the degree of network connectivity (Phan 2017).

The coefficient of transitivity (Tr) is usually used to analyze the ability of agent's bandwidth. The triad becomes transitive when the condition holds true: there are directs from A to B and from B to C it means that B is a transitive triad between A and C ("friend of mine friend is my friend"). There are two ways to calculate the transitivity coefficient:

- To count transitive triads / count triads, which are not including the third connection (from A to C);
- To count transitive triads / count all triads in network.

A lot of researchers reason that transitivity is the basis of network equilibrium existence (Faust 2006). It is «natural» for all kind of networks. The transitivity reflects the potential to bandwidth growth.

Coefficient of reciprocity (Re) is another important coefficient in SNA systems. It is calculated as a stake of connected pairs of agents (dyads) which have connection between each other. The nodes without connections are not included in the calculation.

The centrality coefficient is used to determine the direction of network. Centrality is determining the uneven distribution of connections between agents. There are a lot of centrality coefficients. Three of each will be used in that research.

The number of connections which go out from network is named Out-degree centrality. On the other hand, the number that goes in is named In-degree Centrality by degree.

Betweenness centrality, which is sometimes named as intermediary, determines the shortest path between network agents. It shows that a system could be controlled from the outstide and connections could be ended too (Marsden 1990).

In the researching process three types of centrality: in-degree (ODCenz), out-degree (ODCenz) and betweenness (BCenz) were used. The values of these parameters are estimated by Freeman's indexes. Each of the indexes illustrates the variety of individual type of centrality index. 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 integral parameters of SNA don't consider the quantitative network characteristics. It gives the opportunity to make a comparison between real and random graphs without distortion of general picture.

The comparison of parameters between real transactions and random Bernoulli graph is shown in Table 2.

Table 2 Social Network Analysis Integral Parameters

Parameter	Transactions network (59)	Bernoulli random graph
D	18	10
Re	0,025	0,013
Tr	0,126	0,048
CC	0,454	0,182
IDCenz	0,414	0,077
ODCenz	0,108	0,075
BCenz	0,23	0,106

A range of conclusions can be made after analyzing of the graphs' integral parameters.

Firstly, the levels of parameters such as diameter (D), coefficient of reciprocity (Re) and Transitivity coefficient (Tr) should be noted. The value in real transactions graph is more than 2 times larger than in random graph. The fact shows that the real network is more compact, the nodes have more transitive properties (more transactions for each network agents) and also transactions go back more often (reciprocity).

The In-degree Centrality indicator (IDCenz) takes the value bigger for 4 times than the same indicator in random graph. The fact illustrates that the real transactions network direct transaction toward «celebrity » nodes more often.

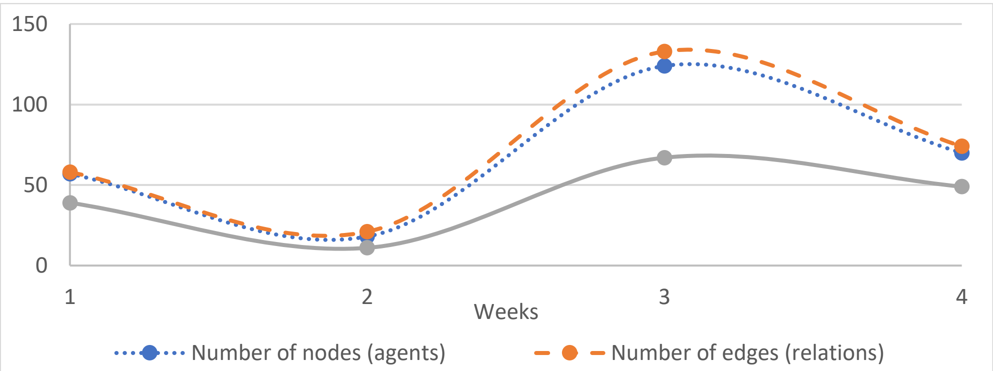
The result of index analysis shows that the real transaction network doesn't have the same or similar parameters with Bernoulli graph which was constructed with the same parameters. The real graph doesn't random. It includes agents which are connected by economic relations and the network needs further researching.

4. THE ANALYSIS OF TRANSACTIONS STRUCTURE DYNAMICS

The second task of the article is to analyze the dynamics of closed contours networks structure. The dataset covers the period of 1 month. The data was divided into 4 equal intervals, 1-week each. The analysis of shorter intervals will allow the most perspective parts of the period from the point of SNA network characteristics.

At the result of algorithm process, the 22 networks were received which include 250 unique economic agents in 134 economic industries. The dynamics of quantitate parameters is demonstrated in figure 3.

Figure 3 The dynamics of changing quantitative parameters in weekly cut



The result of analysis shows that the largest volume of connections and agents falls in the second part of month, for the third week.

Social Network Analysis also includes the quantitative systems of metrics. The 4 periods of month allow to do that research in contrast to random Bernoulli graph which does not have quantitative parameters such as network turnover and the volume of average transaction.

The SNA quantitative metrics represented by parameters:

- Nn - number of nodes (agents, actors);
- Ne - number of edges (relations, communications, ties);
- D - density is simply the proportion of all possible ties that are actually present,
  $D = \frac{Ne}{Nn*(Nn-1)}$;
- Sum - total amount of transactions/payments (in rubles);
- AvrCost - average cost of transaction in rubles,
  $\text{AvrCost} = \frac{Sum}{Ne}$;
- Ng - number of different types of goods and services produced and consumed in the network;
- Var - variety of products of network,
  $\text{Var} = \frac{Ng}{Nn}$.

The result of parameters calculation shows at the 3d table.

Table 3 Social Network Analysis Quantitative Parameters

Parameter	1st week	2nd week	3d week	4th week
Nn	57	18	124	70
Ne	58	21	133	74
D	0,0182	0,0686	0,0087	0,0153
Sum	42194,49	4401,44	14619,44	29029,41
AvrCost	727,49	209,59	109,92	392,29
Ng	39	11	67	49
Var	0,68	0,61	0,54	0,7

Quantitative parameters demonstrate significant superiority of the 3rd period in number of agents and connections. Despite this, the total turnover doesn't depend on number of agents. The maximum value of the sum is in the 1st week. The sum of turnover and average cost suggest that the main payments are falling on 1st week. The other periods are covered by standard operation activity. The thesis confirms by the 3rd and 4th weeks when the number of agents and connections takes the maximum value, but the sum of turnover and average costs reduce.

The density (D) coefficient at the 3rd week demonstrates the least result it can mean that the direction of transactions only to one side. There is no active exchange of goods and facilities between agents as in the 2nd week.

Quantitative analysis allows to make the conclusion that the maximal turnover of network provides number of relations between agents (Ne) and Density (D) but not the number of agents (Nn). That conclusion is demonstrated in the 1st period.

The conclusions based on quantitative parameters are not enough. The further steps are necessary in analysis of integral parameters SNA. The indexes were calculated and it is shown in the 4th table.

Table 4 Social Network Analysis Integral Parameters

Parameter	1st week	2nd week	3d week	4th week
D	4	3	4	3
Re	0,76	0,446	0,144	0

Tr	0,054	0,04	0,014	0
CC	0,018	0	0	0,014
IDCenz	0,036	0,0588	0,0159	0,0141
ODCenz	0,3087	0,5571	0,4667	0,4552
BCenz	0,013	0,078	0,0045	0,0054

The diameter of networks takes the low value. The fact demonstrates that the perimeter of network is small and distance between the farthest agents between 3 and 4 agents.

The low level of Transitivity coefficient demonstrates that there are few agents which make transactions to the other agents. The coefficient takes the value of zero at the 4th week that demonstrates the full absence of transitive nodes.

The biggest level of reciprocity coefficient (Re) is at the 1st week. The conclusion can be made that this time contains the largest number of mutual exchange when the transaction goes from agent A to agent B and returns. The 4th week demonstrates a one-sided direction of transactions, there are not transitive nodes and eventually the reciprocity coefficient becomes zero because all transactions are going toward one side.

The result of decomposed period analysis when one month was divided into 4 periods demonstrates that the reduction of period raises the out-degree centrality coefficient. Reduction of the period reduces the number of transitive nodes, the other transactions with the same agents can get into the late period of time.

The result of comparison analysis between 4 weeks allows to make a conclusion that the 1st week is the most effective in terms of quantitative parameters. The week reaches the most effectiveness and the sum of turnover and average cost become maximum. Certainly, the maximum number of agents is at the 3rd week but there are only one-side transactions which don't allow to raise the turnover.

The 1st week of the month is the most prospective to complementary currencies implementation. The conclusion is confirmed by integral indexes of SNA. The week demonstrates the lowest level of out-degree centrality, this fact provides the largest turnover inside the network. The coefficient of reciprocity also demonstrates the most active return of transactions.

In the process of 4 weeks analysis there is reduction of nodes in networks. The larger period analysis (e.g. 1 month) shows that the mutual turnover between agents can be not only in one-week period. Agents can perform two transactions per month but in the different weeks.

The economic agents can have transactions in different periods of time and the number of payments can be different too, but short period analysis won't detect it. The large period analysis shows that the organizations in municipal unity is closer than it can seem.

5. ECONOMIC EFFECT

For this research, the network of 12000 transactions for 1-month interval was analyzed. The general turnover of the network amounted to 2705 million rubles.

The 17 networks which were constructed from economical transactions cover the turnover equal to 260 million rubles. The sum is 9,6% from the general turnover between organizations. It is worth noting that the sample doesn't cover a lot of transactions. There are only few transactions from 4 bank branches in the same bank. There are different commercial banks in the city and the citizens participate in turnover too.

260 million rubles can be free from complementary currencies implementation. But we need to calculate the volume of money supply for regional economic maintenance. Calculating the value can be done through the formula 1:

$$M = \frac{\sum Tr * 12}{V}, \qquad (1)$$

where $\sum Tr$ – all network transactions sum,

12 – number of months per year,

V – turnover ratio.

The average coefficient of turnover ratio in Russia economy is 5. The money supply calculation result is 624 million rubles. We assume that the municipal money is borrowed for banking percent/interest (процент банка?). The average rate of banking percent/interest, by the information by Central Bank, is 14.27% per year. The monthly percent/interest for 624 million rubles debt for 10 years will be 7,42 million rubles per month.

The complementary currencies implementation in closed transactions networks can free this sum for further investment.

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