Processes of Self-Organization in the Community of Investors and Producers

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Abstract. The paper analyzes the processes of self-organization in the economic system that consists of investors and producers. There is intensive information exchange between investors and producers in the considered community. The model that describes the economic processes has been developed. The model proposes a specific mechanism of distribution of investors capital between producers. The model considers the interaction mechanism between investors and producers in a decentralized economic system. The main element of the interaction is the iterative process. In this process, each investor takes into account the contributions of other investors into producers. The model is investigated by means of the computer simulation, which demonstrates the effectiveness of the considered mechanism.

Keywords: investors, producers, decentralized system, competition, self-organization, collective behavior.

1 Introduction

Competition is an important element of the economic systems. Is cooperation possible in competitive societies? Based on game theory and computer simulation, Robert Axelrod demonstrated the advantages of cooperation for two players [1]. Forms of aggressive and constructive competition between individuals within an agent-oriented approach were also analyzed in [2]. In the current paper, we design and investigate the model of the economic system with a soft constructive competition. The prototype of our model is the works of Belgian researchers [3, 4]; their systems have used agents-messengers to optimize a production hall's operation and a routing car traffic in a city.

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In our model, the economic system is the community of producers and investors. The producers and investors compete with each others. Nevertheless, the information about capitals, profits, and intentions of community members is open within the community. In particular, investors inform producers about their intention to invest the certain values of capital into the separate producers. The information exchange ensures the possibility to create a decentralized system of interaction within the community of investors and producers. The iterative process is an important element of the model. This iterative process helps each investor to take into account the intentions of other investors. The model describes an effective interaction of investors and producers in the economic community. This effective interaction was demonstrated by means of computer simulation.

2 Description of the Model

2.1 General Scheme of the Model

We consider a community of N investors and M producers; each of them has a certain capital K_{inv} and K_{pro}. The investors and producers operate in the transparent economic system, i.e. they provide the information about their current capital and profit to the entire community. There are periods of operation of the community. For example, a period can be equal to one year. Further, T is a time period number.

At the beginning of each T period, a particular investor makes an investment into m producers. At the end of the period, every investor has to decide: how much capital should be invested into one or another producer in the next period. In order to take into account the intentions of all investors, we introduce an iterative process, which is described below.

The i-th producer has its own initial capital C_{i0} before the period T. The producer obtains some additional capital from investors. The whole capital of the producer i is:

$$C_i = C_{i0} + \sum_{j=1}^{N} C_{ij}\,, \tag{1}$$

where C_{ij} is the capital invested into the i-th producer by the j-th investor at the beginning of the period T.

We believe that the dependence of the producer profit R_i on its current capital C_i has the form:

$$R_i(C_i) = k_i F(C_i), \tag{2}$$

where the coefficient k_i characterizes the efficiency of the i-th producer. The values k_i vary randomly at the end of each period. The function $F(x)$ is the same

for all producers. In the current work, we believe that the function $F(x)$ has the form:

$$F(x) = \begin{cases} ax, & if\ ax \le Th \\ Th, & if\ ax > Th \end{cases}, \tag{3}$$

where Th is the threshold of the function $F(x)$.

At the end of the period T, the producer returns the invested capital to its investors. In addition, the producer pays off a part of its profit to the investors. The j-th investor receives the profit part that is proportional to the investment made into this producer:

$$R_{ij} = k_{repay} R_i(C_i) \frac{C_{ij}}{\sum_{l=1}^{N} C_{il}}, \tag{4}$$

where C_i is the current capital of the i-th producer, k_{repay} is the parameter determining the part of the profit that is transferred to investors, $0 < k_{repay} < 1$. The producer itself gets the remaining part of the profit:

$$R_i^* = (1 - k_{repay}) R_i(C_i). \tag{5}$$

Each investor has the following agents-messengers: the searching agents and the intention agents; these agents are used for information exchange within the community.

2.2 Description of the Iterative Process

At the first iteration, the investor sends the searching agents to all producers in order to determine the current capital of each producer. At the first iteration, the investor does not take into account the intentions of other investors to invest some capitals into producers. The investors estimate the values A_{ij}, which characterize the profit expected from the i-th producer in the next period T. These values A_{ij} are:

$$A_{ij} = k_{dist} R_{ij} = k_{dist} k_{repay} k_i F(C_{i0}^{'}) \frac{C_{ij}}{\sum_{l=1}^{N} C_{il}}, \tag{6}$$

where C_{il} is the capital invested into the i-th producer by the l-th investor, $C_{i0}^{'}$ is the expected initial capital of the i-th producer at the beginning of the next period, $k_{dist} = k_{tested}$ or $k_{untested}$ ($k_{tested} > k_{untested}$). The positive parameters k_{tested}, $k_{untested}$ indicate the level of the confidence of the investor for the considered producer; this

level of confidence is k_{tested} and $k_{untested}$ for the tested and untested producers, respectively. At computer simulation, we set: $k_{tested} = 1$, $k_{untested} = 0.5$.

Then the j-th investor ranks all producers in accordance with the values A_{ij} and chooses the m most profitable producers with the large values A_{ij}. After this, the j-th investor forms the intention to distribute its total capital $K_{inv\,j}$ among the chosen producers proportionally to the values A_{ij}. Namely, the j-th investor intends to invest the capital C_{ij} into the i-th producer:

$$C_{ij} = K_{inv\,j} \frac{A_{ij}}{\sum_{i=1}^{M} A_{ij}}. \tag{7}$$

At the second iteration, each investor uses the intention agents to inform the selected producers about these values C_{ij}. Using this data, the producers evaluate their new expected capitals C'_{i0} in accordance with the expression (1).

Then the investors again send searching agents to all producers and estimate the new capitals of producers and the sums $\sum_{l=1}^{N} C_{il}$, taking into account the intentions of other investors. Profits of investors are evaluated by the expression (6), which already takes into account the intentions of all investors. Any investor ranks the producers and chooses the m most profitable producers again. After this, the investors estimate new planned values C_{ij} according to the expressions (6), (7). Once again, investors send intention agents to inform the producers about the planned capital investment values.

After a sufficiently large number of such iterations, the investors do the final decision about the investments for the next period T. Final capital investments are equal to the values C_{ij} obtained by the investors at the last iteration.

At the end of each period T, the capitals of producers are reduced to take into account the amortization processes: $K_{pro}(T+1) = k_{amr}\, K_{pro}(T)$, where k_{amr} is the amortization factor ($0 < k_{amr} \le 1$). The capitals of investors are reduced similarly (further, corresponding indicators are called inflation factors for convenience): $K_{inv}(T+1) = k_{inf}\, K_{inv}(T)$, where k_{inf} is the inflation factor ($0 < k_{inf} \le 1$).

3 Results of Computer Simulation

The described model was investigated by means of computer simulation. The simulation parameters were as follows:

- the total number of periods of considered processes: $N_T = 100$ or 500,
- the number of iterations in each period: $k_{iter} = 1,\ldots,50$,
- the maximal thresholds of capitals of investors or producers (exceeding these thresholds leads to the reduplication of the investor or producer): $Th_{max\_inv} = 1$, $Th_{max\_pro} = 1$,

- the minimal thresholds of capitals of investors or producers (if the capital falls below these thresholds, then the corresponding investor or producer dies): $Th_{min\_inv} = 0.01$, $Th_{min\_pro} = 0.01$,
- the maximal number of producers and investors: $N_{pro\_max} = 100$, $N_{inv\_max} = 100$,
- the initial number of producers and investors: $N_{pro\_initial} = 2$ or 100, $N_{inv\_initial} = 50$ or 100,
- the maximal number of producers m, in which the investor can invest its capital, usually $m = 2$ or 100,
- the part of the profit that is transferred to investors: $k_{repay} = 0.6$,
- the characteristic variation of the coefficients k_i: $\Delta k = 0.01$,
- the parameters of function $F(x)$: $a = 0.1$, $Th = 100$.

The initial values k_i were uniformly distributed in the interval [0,1].

The specifics of the iterative process. In order to demonstrate the specifics of the iterative process clearly, we consider the results for the case of 2 producers and 50 investors. We assume that initial capitals of both producers are equal to 0.25 units. The production efficiencies k_i of the first and the second producers are equal to 0.5 and 0.9, respectively. The first producer is tested ($k_{dist} = 1$), and the second producer is untested ($k_{dist} = 0.5$). Fig. 1 presents the simulation results for the investor with the number one.

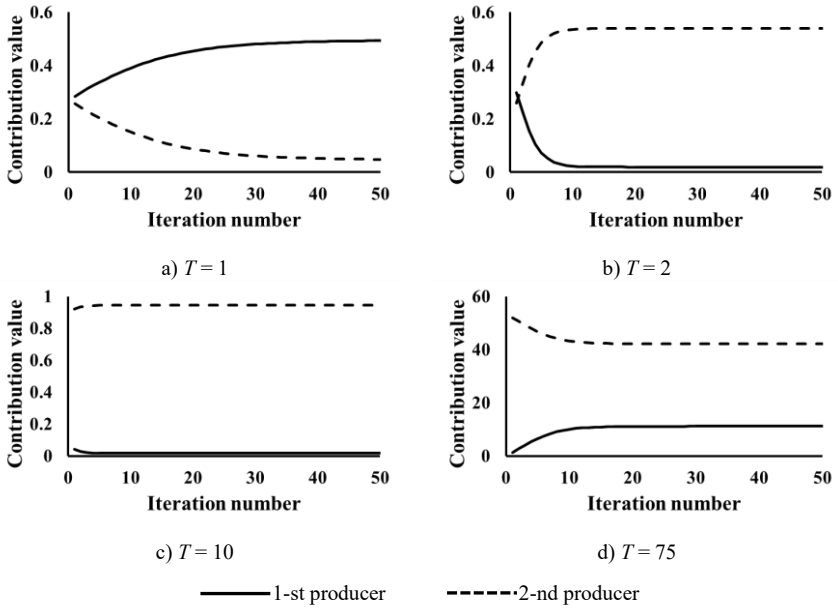
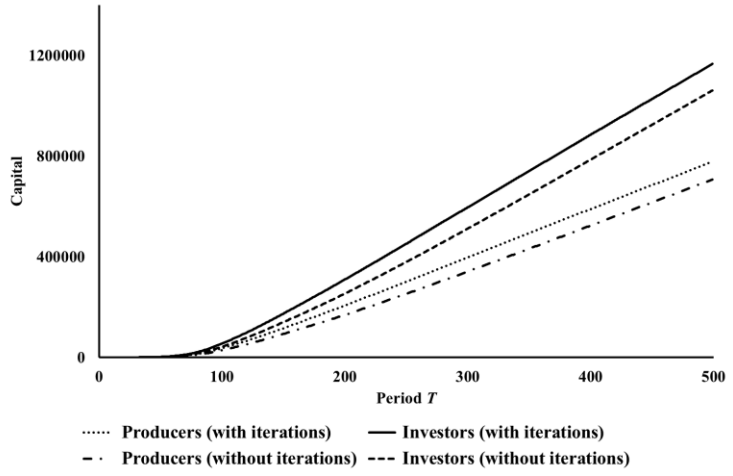


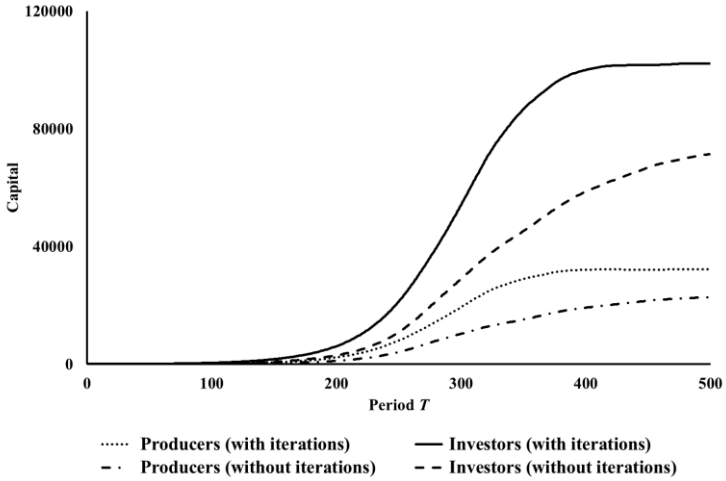
Fig. 1. The dependence of first investor contributions on the number of iteration at different periods T

The results characterize the following. At $T = 1$, when the more efficient second producer has not been tested, the investor from iteration to iteration increases the contribution to the first producer, despite its smaller efficiency (Fig. 1a). In the next period $T = 2$, the investor prefers the second more efficient producer (already tested), and the contribution to the first producer is gradually reduced (Fig. 1b). During the next periods, the investor contributes almost the entire capital into the second efficient producer (Fig. 1c). The investor makes such choice as long as the function $F(x)$ for the second producer does not reach the limit Th (see the expression (3)). After that, the investor begins to make a contribution to the first producer (Fig. 1d). Thus, it is beneficial to investors to make contributions into *perspective producers*, namely, into such producers, whose profits will grow with increase of their capital. The iterations play the important role in these processes of adjustment of contributions.

The effectiveness of iterative evaluations for the case N = M = 100. In order to show that investors are more successful, if they take into account the intentions of other investors, we simulate the processes without the iterative estimates ($k_{iter} = 1$) and with iterations ($k_{iter} = 50$). We consider two cases: 1) without amortization and inflation and 2) with amortization and inflation. Fig. 2 demonstrates that the iterations increase the capital of both investors and producers. Without amortization and inflation, the iterations increase the capital of the community by 10% (Fig. 2a). In the case of amortization and inflation, the effect is more significant, the iterations increase the capital of producers and investors by 41-43% (Fig. 2b).



a) without amortization and inflation ($k_{amr} = 1$, $k_{inf} = 1$)



b) with amortization and inflation (k_{amr} = 0.9; k_{inf} = 0.95)

Fig. 2. Influence of iterative evaluations. The dependence of the total capital of the producers and investors on period *T*

4 Conclusion

Thus, the processes of self-organization in the community of producers and investors have been analyzed. Original features of the current model are the following: 1) the cooperation between investors and producers, 2) the openness of information about the current capitals and effectiveness of the producers and about the intentions of investors to invest capitals into different producers, 3) the iterative process of the formation of capital investments. The most important result of the model is the development of the new method for profitable capital investments. It is beneficial to investors to make contributions into *perspective producers*, namely, into such producers, whose profits will grow with increase of their capital.

Acknowledgments
This work was partially supported by the Russian Foundation for Basic Research, Grant No 16-01-00223.

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