Model of Collective Behavior of Investors and Producers in Decentralized Economic System

Vladimir G. Red'ko[1,2*], Zarema B. Sokhova[1]
[1]*Scientific Research Institute for System Analysis, Russian Academy of Sciences, Moscow, Russia*
[2]*National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Moscow, Russia*
vgredko@gmail.com, zarema_s@mail.ru

Abstract
The paper presents 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, agents-messengers, collective behavior.

1 Introduction

Competition is an important element of the economic systems. Is cooperation possible in competitive societies? Basing 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 work of Belgian researchers [3, 4]; their systems have used agents-messengers to optimize a production hall's work and routing car traffic in a city.

In our model, the economic system is the community of producers and investors. The producers and investors compete each with 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

* Corresponding author: Tel.: +7 915 1673584.
E-mail address: vgredko@gmail.com

of investors and producers. The iterative process is an important element of the model, which 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 intentions of all investors, there is an iterative process, which is described in details 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 C_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 is nonlinear: $R_i(C_i) = k_i F(C_i)$, the coefficient k_i characterizes the efficiency of the i-th producer, the function F is the same for all producers. In computer simulations, it was supposed that the function $F(x)$ has the form $F(x) = x^2/(x^2+a^2)$, where a is a positive parameter. The values k_i vary randomly at the end of each period.

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:

$$R_{ij} = k_{repay} R_i(C_i) \frac{C_{ij}}{\sum_{l=1}^{N} C_{il}} , \tag{2}$$

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:

$$R_i^* = (1 - k_{repay}) R_i(C_i) . \tag{3}$$

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:

$$A_{ij} = k_{dist} R_{ij} = k_{dist} k_{repay} k_i F(C'_{i0}) \frac{C_{ij}}{\sum_{l=1}^{N} C_{il}}, \tag{4}$$

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 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:

$$C_{ij} = K_{inv\,j} \frac{A_{ij}}{\sum_{i=1}^{M} A_{ij}}. \tag{5}$$

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 (4), which already takes into account the intentions of all investors. Any investor ranks the producers and chooses m most profitable producers again. After this, the investors estimate new planned values C_{ij} according to the expressions (4), (5). 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 ($0 < k_{amr} \leq 1$). 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 ($0 < k_{inf} \leq 1$).

3 Results of Computer Simulation

The described model was implemented into a computer program. The simulation parameters were as follows:

– the total number of periods of considered processes: $N_T = 100$,
– the number of iterations in each period: $k_{iter} = 30$,
– 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: $N_{pro\_initial} = 50$, $N_{inv\_initial} = 50$,
– the maximal number of producers m, in which the investor can invest its capital, usually $m = 100$,
– the part of the profit that is transferred to investors: $k_{repay} = 0.3$,
– the characteristic variation of the coefficients k_i: $\Delta k = 0.01$,
– the parameter of function $F(x)$: $a = 5$.

The initial capitals of investors and producers were uniformly distributed in the interval [0,1]. Since the calculation used random processes, averaging over 100 different calculations was performed in order to obtain reliable data.

The verification of the convergence of the iterative process. We obtained the dependence of the final total capital of all producers and investors on the number of iterations (at $T = 100$). The results are given in Figure 1.

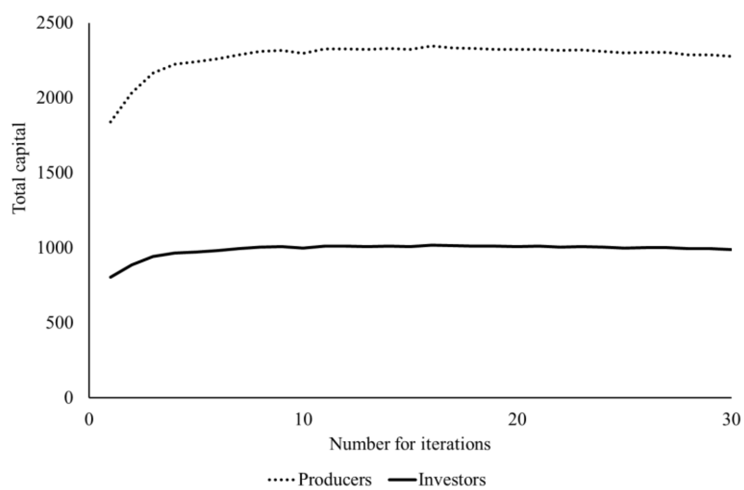
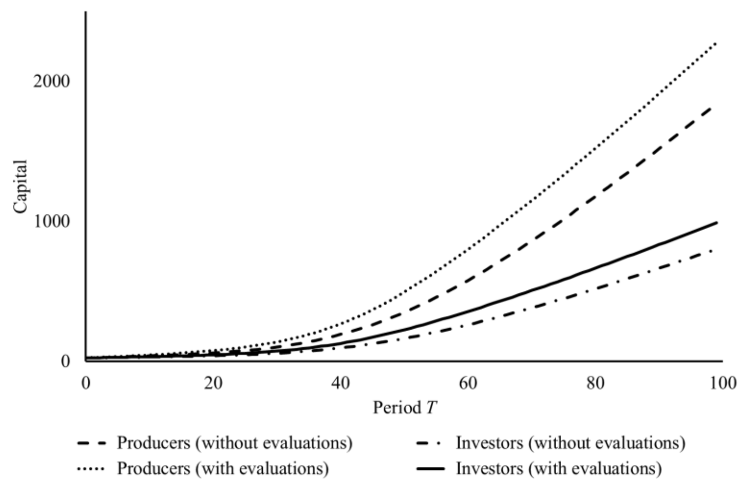


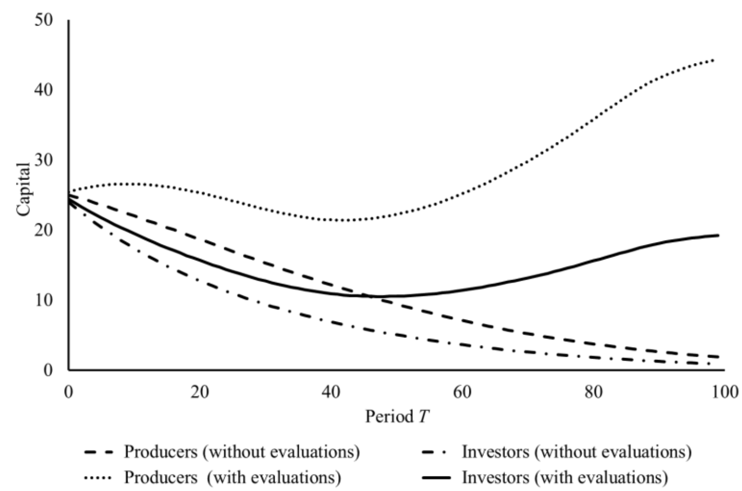
Figure 1: Convergence of iterative process ($a = 5$; $k_{amr} = 1$; $k_{inf} = 1$; $m = 100$; $T = 100$; $Th_{max\_inv} = Th_{max\_pro} = 1$; $Th_{min\_inv} = Th_{min\_pro} = 0.01$; $k_{repay} = 0.3$)

It is evident that the iterative process converges within 20-30 iterations. Taking this into account, the number of iterations was equal to 30 at our simulation.

The effectiveness of iterative evaluations. In order to show that investors are much more successful, when they make iterative evaluations of potential profits before making a decision, simulations were done for typical parameters in two cases: with the iterative process ($k_{iter} = 30$) and without the iterative process ($k_{iter} = 1$). The simulation results demonstrate that the total capital of producers and investors is much higher in the model with the iterative process. The results are given in Figure 2. If the inflation and amortization are absent, then the iterations are efficient (Figure 2a). When the inflation and amortization are present, the role of the iterations is very significant (Figure 2b). In the absence of the iterations, the capital of producers and investors decreases and the community dies. In the presence of the iterations, the capital of producers and investors increases and the community survives.



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



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

Figure 2: Influence of iterative evaluations. The dependence of the total capital of the producers and investors on period *T*. ($a = 5$; $T = 100$; $m = 100$; $Th_{max\_inv} = Th_{max\_pro} = 1$; $Th_{min\_inv} = Th_{min\_pro} = 0.01$; $k_{repay} = 0.3$)

4 Conclusion

Thus, the model of the transparent market economy has been designed and investigated. The model describes the effective interaction of investors and producers in the economic community. Original features of the model are the following: 1) cooperation between investors and producers, 2) the openness of information about the current capitals and the intentions of investors to invest into different producers,

3) the iterative process of the formation of capital investments. The model can serve as a reference model for a wide variety of similar economic systems. Moreover, the presented model can be a reference standard for honest market economics.

Acknowledgements

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