5. ANALYZING THE DYNAMICS OF RELATIVE PRICES ON A MARKET WITH SPECULATIVE AND NON-SPECULATIVE AGENTS BASED ON THE EVOLUTIONARY MODEL[1]

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Abstract

The paper deals with an evolutionary model focused on the relation between the behavior of prices and the structure of the population of economic agents. The model allows for identification of the short-term behavior of prices and the dynamics of the population of economic agents in the context of seven scenarios. These scenarios are a combination of four key factors: market regulations, the maturity of the market; the intervention of the state on the market supply side and the modifications of the incentives to speculate and not-speculate. The main findings of the simulation of the scenarios are: i) The presence of speculators leave long lasting effects which do not die out with the decrease in the number of speculators; ii) In the presence of high speculations the intervention of the state can act as an anchor to the market helping to lower the prices; iii) The market forces have a more lasting effect than the state regulation mechanisms.

Keywords: relative prices, speculative and non-speculative agents, evolutionary model
JEL Classification: C15, C73, E37

1. Introduction

The evolutionary modeling offers powerful instruments to capture the dynamics of a system with non-linear interactions between the components. These models are able to capture the short-term evolution of relative prices which exhibit high volatility. This is the case of the prices of economic agents. In this case, the volatility is intrinsic to the phenomenon, meaning it is governed by volatile endogenous factors.

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The objective of the paper is to analyze the behavior of prices and the dynamics of the population of economic agents in different market conditions defined by the combination of four key factors: market regulations, the maturity of the market; the intervention of the State on the market supply side and the modifications of the incentives to speculate and not to speculate.

The paper is based on a computer simulation. As an application, the simulation focuses on the housing market. The characteristics of this market namely the presence of speculative and non-speculative agents and the high volatility of prices make it a good subject for the simulation.

There are numerous approaches in modeling the housing market, which can be classified into two categories.

The first category analyzes the historical data and can be generically defined as econometric approach. For example, Case and Shiller (1989), Abraham and Hendershott (1993) analyzed the housing price series from the perspective of serial correlation. Abraham and Hendershott (1996), Capozza and Seguin (1996), Malpezzi (1999) analyzed the housing price series from the perspective of mean reversion. Other studies focused on more complex techniques. Kauko (2003), Kershaw and Rossini (1999), Rossini (1997) used neural networks and value tree approaches to analyze and forecast the housing price data. Carvalho (2003) used spatial analysis to identify the impact of speculation behavior on the housing market prices.

The second category is based on simulations. For example, Goldstein (2003) used a cellular automata model to analyze the housing growth pattern. Amri and Bossomaier (2003) used an agent-based model to simulate the behavior of sellers and buyers on the housing market prices. Bossomaier, Amri and Thompson (2005) defined fuzzy variables and fuzzy rules to model the interactions of demand and offer on the housing market.

The current paper is based on an evolutionary modeling framework (see Nelson and Winter, 1982; Winter, 1984; Winter, Kaniovski and Dosi, 1997, 2000) and uses an evolutionary game theory approach (see Maynard Smith and Price, 1973; Maynard Smith, 1982). The behavior of agents is regulated by a pay-off matrix similar to the one used by (Maynard Smith and Price, 1973). The transition of the agent population from one state to the other is based on dynamic multiplayer proposed by Taylor and Jonker (1978). The dynamics of the agent population is similar with the one proposed by Carpenter (2002), in which agents in each period adopt a strategy with probability equal to the strategy's relative success. Our modeling approach of the housing market is similar to Amri and Bossomaier (2003) in the sense that it uses an agent-based computer simulation. In both cases, the dynamics of prices and the evolution of the population of economic agents are analyzed using scenarios that define market conditions and the speculative and non-speculative behavior of these agents.

The novelty of the paper is represented by the analysis of the effectiveness of different combinations of four key factors in combating the speculative behaviors on the housing market. These factors are: market regulations, the maturity of the market; the intervention of the State on the market supply side and the modifications of the incentives to speculate and not to speculate. This way we want to understand which of the conditions is more effective in diminishing the effects of the speculative behaviors on the market, and how these conditions influence each other.

The next section will present the theory behind the modeling strategy. The focus is on the evolutionary models and the evolutionary game theory. The third section presents the model developed. It focuses on presenting the blocks of the model, namely the price analysis block and the economic agents block. The fourth section presents the output of the model computer simulation. The final section presents the conclusions.

2. Evolutionary modeling approach

Evolutionary models, originated in biology, are better equipped to analyze complex systems. Economic modeling approaches have been focused, for a long time, on the idea of equilibrium and did not use the insights of biology. It was not until Winter and Nelson (Nelson and Winter, 1982; Winter, 1984) that a rigorous use of such insights came about. Later developments continued the Schumpeterian tradition of the original approach (see Jonard and Yildizoglu, 1998) but also included new technical novelties; for example, the inclusion of a stochastic system regulating the arrival of new firms or economic agents on the market (see Winter, Kaniovski and Dosi, 1997, 2000).

The modeling strategy in this paper is based on the evolutionary model framework. The characteristic of the market and the behavior of the economic agents are governed by dynamic processes. Prices are changing following the rules of evolution, such as natural selection, as in the case of Price's equation (Price 1970), or statistical rules, as in the case of our paper. The structure of the population of economic agents is changing, reflecting different rules of fitness. In the case of the paper, the fitness is reflected by the pay-off matrix (Maynard Smith and Price 1973). The dynamics of the population is based on an evolutionary game theory approach (see R.A. Fisher, 1930; Lewontin, 1961; Maynard Smith, 1972).

The model development focuses on the analysis of the transition of the economic agents' population from one state to another, and on the modifications of its key characteristics. It is based on the approach of Maynard, Smith and Price (1973). The novelty of this approach comes from the explicit definition of the transition rule of the population from a state to another state. This allows for the explicit identification of the modifications in the population following one strategy or the other.

The paper uses as a rule of transition the dynamic multiplayer proposed by Taylor and Jonker (1978). The percentage of population following a strategy at a moment t+1 is a function of the number of members following that strategy at the moment t, the benefits of adopting that strategy at moment t, and the aggregated benefits of following any of the strategies. This approach allows for the correlation between the changes in the population of speculative and non-speculative agents and the pay-off matrix.

3. Modeling the dynamics of relative prices using an evolutionary model

The model developed in this paper is based on the evolutionary approach. Consequently, it has two main theoretical components, an evolutionary model component and an evolutionary game component. The models allows for modeling the short and medium time dynamics of relative prices. This is firstly done by constructing a price block. The dynamics of relative prices is modeled on a market with speculative and non-speculative agents. Consequently, a second block is added to the model, namely the economic agents block. We want to allow for the presence of shocks in the economy; consequently, a function that models the reaction of the economic actors to different economic shocks was added.

By speculative agents we mean the agents characterized by a high variation of their prices as against the mean of the market and to the mean of the recorded prices of those agents. Non-speculative agents are the agents that register low variation of prices comparative to the mean of the market and to the mean of the recorded prices of those agents.

The economic agents block

The behavior of economic agents is modeled by using the evolutionary game theory approach. The pay-off matrix is a prisoner's dilemma type. The model is largely used in analyzing social decisions due to its characteristics, one important characteristic from this point of view being that it can generate a suboptimal Nash equilibrium (see Nash, 1950). In this kind of game the value of pay-offs and the type of strategies adopted are fundamental for the evolution of the game.

Figure 1

The pay-off matrix used in the economic agent block

	NS	*S*
NS	B_{NS} B_{NS}	B_{NS} B_S
S	B_{NS} B_S	B_S B_S

where: NS is the non-speculative strategy and *S* is the speculative strategy, B_{NS} is the benefit from following strategy *NS* and B_S is the benefit from following strategy *S*.

We are going to model the changes in the population of agents using the following relations.

$$F(NS) = P_{NS}\Delta F(NS,NS)+P_S\,\Delta F(NS,S) \quad (1)$$

$$F(S) = P_{NS}\Delta F(S,NS)+P_S\Delta F(S,S) \quad (2)$$

$$F = P_{NS}F(NS)+P_S\,F(S) \quad (3)$$

where: $\Delta F(\mu,\sigma)$ represents the benefits of a member of the population adopting strategy μ when another member is adopting strategy σ, $F(\sigma)$ represents the total benefit of a member adopting strategy σ, F_0 represents the initial benefit, μ represents the mutant strategy, P_s is the percent of population adopting strategy *S* and P_{NS} the percent of population adopting strategy *NS*.

The transition from a state to another state is modeled using a dynamic multiplier.

$$P'_{NS}-P_{NS} = (P_{NS}(F(NS)-F))\,/\,F \quad (4)$$

$$P'_S-P_S = (P_S(F(S)-F))\,/\,F \quad (5)$$

where: *P* represents the population at moment t and *P*' the population at moment t +1.

Equations (4) and (5) allow for the identification of the modifications in the percent of the population adopting one or another strategy. In other words, the relations model the number of agents who are cooperative or non-cooperative in each period.

The model allows for the presence of shocks in the economy. The value of the shock is a percent of the aggregate benefits of the economic agents. The shocks are introduced using a step function. The algorithm is:

If $P_{NC} / P > m$ then

$$P'_{NS} - P_{NS} = (P_{NS}(F(NS)-F)) / F + F/n \quad (6)$$

$$P'_{S} - P_{S} = (P_{S}(F(S)-F)) / F - F/n \quad (7)$$

else

$$P'_{NS} - P_{NS} = (P_{NS}(F(NS)-F)) / F$$

$$P'_{S} - P_{S} = (P_{S}(F(S)-F)) / F$$

where: the value for m is decided by experts given the economic environment and n is a random generated number between 0 and 1.

The value of m allows for the modeling of the critical point at which the number of speculative agents becomes to grate and supplementary regulations of the market become necessary.

The price block

We define an initial state of the market in which we have a number of price clusters and the economic agents are speculative and non-speculative.

In the case of the non-speculative agents, the price in period *t*+1 will be a function of their prices in the period *t* and the average price on the market at the same period *t*. The prices of the non-speculative agents will converge to the average price on the market. The price is modeled by using the following relation:

$$P_{ai} = P_{ai} + \alpha * P_{mean} \quad (8)$$

where: P_{ai} is the price of the ai non-speculative agent, P_{mean} is the average price on the market, and α is a number between (0, 1) which models the tendency of the price of the non-speculative agent to converge to an average price on the market.

In the case of the speculative agents, the price in period *t*+1 will be a function of their prices in period *t* and the difference between the mean price on the market and the maximum price, both at moment *t*. The prices of the speculative agents will converge to the maximal value. The price is modeled using the following relation:

$$P_{aj} = P_{aj} + \alpha * P_{max} \quad (9)$$

where: P_{aj} is the price of the aj speculative agent, P_{max} is the maximum price on the market, and α is a number between (0 1) which models the tendency of the price of the speculative agent converge to a maximum price on the market.

The selection of the type of agent is done by using a random function. If the number of one type of agents is growing then the probability to select this type of agents is higher. As a consequence, the dynamics of prices on the market will be influenced by the dynamics of the populations of agents. In the simulation, we worked with 50 speculative and non-speculative agents. The procedure is as following: i) we generate a random number y between 1 and 50 and we define x=int(*y*), thus x is the integer part of y; ii) we have a set S composed of 50 speculative and non-speculative agents; iii) we define a bijective function:

$$\begin{aligned} &N = \{1, 2, 3 .. 50\} \\ &f : N \rightarrow S \\ &f(x_i) = a_i \end{aligned} \quad (10)$$

where: $x_1 = 1.....x_{50} = 50$, $a_1 = 1.....a_{50} = 50$

Initially, on the market we have a population of agents and one of prices. Using the first block, we make the transition of the population of agents from moment t to moment t+1. Using the second block, we link the population of agents to the population of prices and make the transition of the prices on the market from moment t to moment t+1. In Table 1, we present synthetically the two blocks of the model and their roles.

Table 1

Synthesis of the model's blocks

Blocks	Objective	Instruments
B1	1) Models the characteristics of the population of agents at moment t 2) Models the transition of the population from moment t to t+1	1) Uses a prisoner's dilemma type pay-off matrix 2) Uses a dynamic multiplier to model the transition of the population from a state to another state, see relations (4) and (5) 3) Uses function that allows for modeling the effects of economic shocks on the pay-off matrix, consequently on the strategy adopted by the economic agents, see relations (6) and (7).
B2	1) Models the non-linear evolution of prices on short and medium term 2) Connects the dynamics of prices with the dynamics of economic agents.	1) Uses a function to analyze the dynamics of prices see relations (8) and (9) 2) Uses a function to select the type of economic agents and to connect the dynamics of prices with the dynamics of the population of agents, see relation (10)

4. The results of the model computer simulation

The role of the application is to underline the characteristics of the models and to illustrate the behavior of prices on short and medium term and the behavior of the population of agents. Hypothetical data will be used. This does not have a negative impact on the results taking into account that our objective is not to forecast the evolution of some prices on the market, but to illustrate the mechanism that explains the non-linear behavior of prices on the market. We assume three clusters of prices which follow a normal distribution and we model the mean of that distribution. Let us take the price of an apartment with two bathrooms in Bucharest, in 2009 and consider three clusters of prices with the mean price of 45, 60 and 78 thousand euro.

We want to analyze the following: i) the impact of market regulations on prices; ii) the impact of the maturity of the market on prices; iii) the impact of the intervention of the State on the market supply side on prices; iv) the impact of the modifications of the incentives to speculate and not-speculate on prices.

To understand the interplay between various characteristics of the market we are going to present a synthetic table underling the characteristics and how they appear in the scenarios.

Table 2

Synthetic presentation of the scenarios

	S1	S2	S3	S4	S5	S6	S7
Efficient market mechanism	no	yes	no	yes	no	no	no
Efficient regulations	no	no	yes	yes	yes	no	yes
The intervention of the State in the market supply side	no	no	no	no	no	yes	yes
Incentives not to speculate on the market	no	no	no	no	yes	no	yes

All the characteristics presented above were modeled in a simulation using Visual Basic. By efficient market mechanism, we refer to a market where the interplay of demand and supply does not allow for consistent increases in prices, there are market forces in play that tend to generate equilibrium on the market. We modeled this by putting a smaller weight on the maximum prices and, at the same time, by the action of the non-speculative agents who put a significant pressure on prices on the market (see relations 8 and 9, the value of α is higher in 8 and lower in 9 in comparison with the case of the lack of efficient market mechanisms)

By efficient regulation, we mean that the institutions monitor the evolution of the market and take measures when the percentage of speculative agents becomes too high. We model this by using a random function for selecting the moment when the regulations are active and by selecting the percentage of speculative actors allowed (see relations 6 and 7).

By intervention of the state in the market supply side we mean, for example, the case of ANL (Housing National Agency) constructions. We model this by choosing one of the clusters to represent the prices of the State buildings, and we consider those prices unchanged so as to act as an anchor.

By incentive not to speculate we refer to all the characteristics of the market and of the regulations that make the non-speculative behavior less attractive. We model this by using a prisoner dilemma type of pay-off matrix, and by changing the incentives for choosing a strategy that indicates speculation (in our case, speculate-speculate and speculate-not speculate).

We simulated the evolution of prices on the market for 45 periods. The population of economic agents transits from one state to another once three periods. The periods can be seen as days, weeks, months, years. We choose the transit state of three periods having in mind the length of a month. The idea is that reliable economic information for all important economic indicators can be obtained on a quarterly basis. This information influences the behavior of economic agents.

Scenario 1 illustrates the condition of a not well-tuned market. From the perspective of prices, there are two main conclusions: a) the prices rise from a mean of 61 to a mean of 137; b) the spread of prices is less in the final periods, which indicates that *even the agents that do not speculate practice very high prices* (see Appendix 1, Figure 1). From the perspective of the population of economic agents, the percentage of non-speculative agents varies following a multiple v shape for some periods, due to the type of regulations on the market (which becomes active randomly). The lack of consistent regulation and the high incentives to speculate affects the non-speculative agents, their percentage drops to almost zero (see Appendix 1, Figure 2).

Scenario 2 illustrates the case where we have an efficient market mechanism. The prices stabilize in 16 periods to a mean value of 61.6 (see Appendix 1, Figure 3). Even if we do not have regulations in place, the effect of market mechanism stabilizes the price. There is a Marshall type of lag (the supply side reacts to changes in the economy slower than the demand) between demand and supply, and the market does not adjust instantaneously to different shocks, but the key idea is that the market forces counteract the tendency to speculate and we end up having equilibrium.

Scenario 3 illustrates the case where we do not have an efficient market mechanism, but we have efficient regulations in place. From the perspective of the population of economic agents, this regulation generates more pronounced multiple v shapes in the evolution of the cooperative agents than in the case of scenario 1 (see Appendix, 1 Figure 5). The explanation is that we have a higher number of times when the institutions intervene and regulate the market. The lack of specific market incentives not to speculate generates the return to a high number of speculative agents, until the moment of another intervention. From the perspective of prices, the key comparison is with the first scenario. What are the effects of efficient regulations? The mean of the prices drops to 117, as compared to 137, and the spread is similar to the first scenario (see Appendix 1, Figure 4). The drop is not significant if we think that the mean price in Scenario 2 is 61.6. The key idea behind the results is the impact of the high level of prices. When the speculative actors generate high prices on the market, even if a drop in the number of non-speculative actors occurs, for some period, a drop in prices is not recorded, due to the fact that the non-speculative actors look at the average price on the market, which was affected by speculation. *Thus, the effects of speculation on prices do not die out with the decrease in the number of speculators.*

Scenario 4 illustrates the case where we have efficient regulations and efficient market mechanisms in place. The main difference in comparison with Scenario 2 is the higher number of cooperative agents as in the case of Scenario 4. The key point is to see if this high number of non-speculative agents makes a key difference. The mean of prices is 63.3, in the vicinity of the one obtained in Scenario 2 (see Appendix 1, Figure 6). The type of speculative or non-speculative agent is chosen using a random function to select the position from the population of economic actors. Even if the probability to select a cooperative agent is higher in Scenario 2 as compared to Scenario 4, for the first 10-15 periods the distribution is comparable. Moreover, we have a *sensibility to initial conditions*. It is possible to select a speculative agent in the first periods in Scenario 4 and a non-speculative agent in Scenario 2. This leads to an increase in the mean of prices, in the first 10 periods, in Scenario 4, a mean that is higher than in Scenario 2. This affects the cooperative agents, which face a higher mean on the market. *The main idea is that a shock that affects the mean of prices has irreversible effects on the market, which will converge to a higher equilibrium*.

Scenario 5 illustrates the case where we have efficient regulation and incentives not to speculate, but we do not have an efficient market. From the perspective of the population of economic agents (see Appendix 1, Figure 8), one may see the impact that the changes in incentives has on the volatility of the population of economic agents. The incentives keep the number of cooperative agents high. Approaching the end of the periods, the state intervenes with a higher frequency, making the number of speculative agent lower, but *once the intervention stops the number of speculative agents rise to their natural level, defined by the incentives to speculate or not to speculate* (see Appendix 1, Figure 9). The mean of prices rise to 96.6 at the end of the simulation. The benchmark scenario is Scenario 3, where we have only efficient regulations and the mean of prices is 117. It is visible that the decentralized conditions, namely incentives on the market not to speculate, tend to have a higher impact on the level of prices. In this case, the incentive not to speculate that are characteristic to the market have a higher impact than the regulations of the market.

Scenario 6 illustrates the case of an inefficient market: lack of efficient regulations and dominance of speculators. The only difference from Scenario 1 is the intervention of the state in the market supply side. The state has a price in the vicinity of the lowest price on the market. This leads to a mean of 48, lower than in the case of efficient market regulations with a mean of 63.3 (see Appendix 1, Figure 10). *This shows that the intervention of the state produces a lower mean price and that there is the possibility for this state intervention on the market to lead to a price that does not reflect the interplay of demand and supply on a free market.*

Scenario 7 illustrates the case when we have efficient regulations on the market and incentives not to speculate. The main difference from Scenario 5 is that the market mechanism is replaced by the intervention of the state in the market supply side. We obtain in this case a mean of 47, just bellow the value obtained in Scenario 5 (see Appendix 1, Figure 11). In respect to the results, the main difference in comparison with Scenario 5 is the much higher number of non-speculative actors on the market. We want to see if the presence of a high number of non-speculators will push the price even lower and by how much. The results indicate that the mean price is almost unchanged. The main factor remains the intervention of the state on the supply side which acts as an anchor.

Conclusions

In the simulation we analyzed: i) the impact of market regulations on prices; ii) the impact of the maturity of the market on prices; iii) the impact of the intervention of the state on the market supply side on prices; iv) the impact of the modifications of the incentives to speculate and not to speculate on prices. The synthesis of the simulations results is presented in Table 3.

Table 3

Synthetic presentation of the results of the scenarios

	S1	S2	S3	S4	S5	S6	S7
Mean level of prices at the end of simulation	137	61.6	117	63.3	96.6	48	47
Existence of market equilibrium	no	yes	No	yes	no	yes	yes
Percent of cooperative agents	low	low	high	high	high	low	high
Degree of volatility in the population of economic agents	medium	medium	high	high	low	medium	low

The main findings of the simulation are:

i) The presence of speculators leaves long lasting effects, which do not die out with the decrease in the number of speculators. The non-speculative behavior does not generate high prices on the market, but once these prices are formed it sustains the high level of prices.

ii) In the presence of high speculations, the intervention of the state can act as an anchor to the market helping to lower the prices. There are situations when the adjusting mechanisms of the market work with a considerable lag, due not only to the imperfection of the market, but also to another mechanism. The non-speculative behavior of the market does not generate a higher level of prices, but by itself helps maintain it and acts as a brake to a market that tries to move to lower prices. In this case, it is the market who maintains a sub-optimal situation and the intervention of the state ensures a speedy adjustment. This intervention also leads to a price that doesn't reflect the interplay of demand and supply on a free market. This suggests that once the adjustment has been made the state should retry from the market.

iii) The market forces have a more lasting effect than the state regulations mechanisms. The market regulations act via a feed-back loop mechanisms at best, thus with a lag. Self-regulation of the market via the modification of the benefits of the non-speculators in comparison with the speculators is much more efficient, once we have an efficient market and an efficient level of prices (by efficient we mean a level that allows the economic system to be in a stable state). The model indicates that a lack of incentives generates volatility to the market, because when not observed the economic agents will always try to maximize what they perceive as their best interest.

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Appendix 1

Figure 1

Evolution of prices on the market - characteristic to Scenario 1

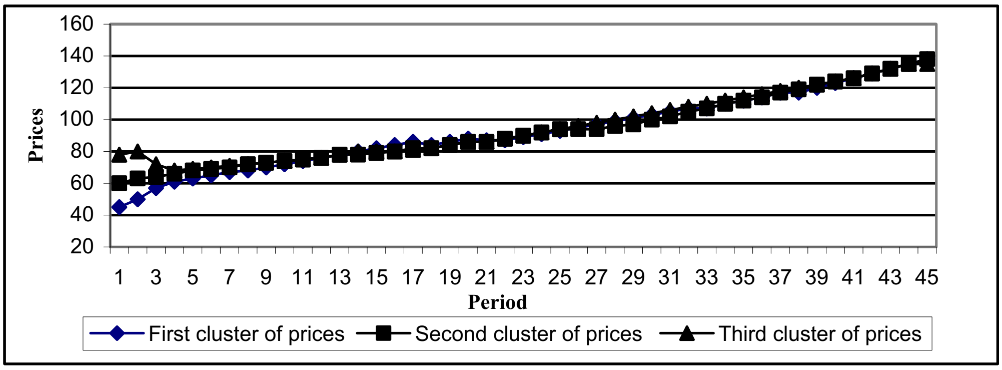

Figure 2

Evolution of the number of cooperative agents in the population - characteristic to Scenarios 1, 2 and 6

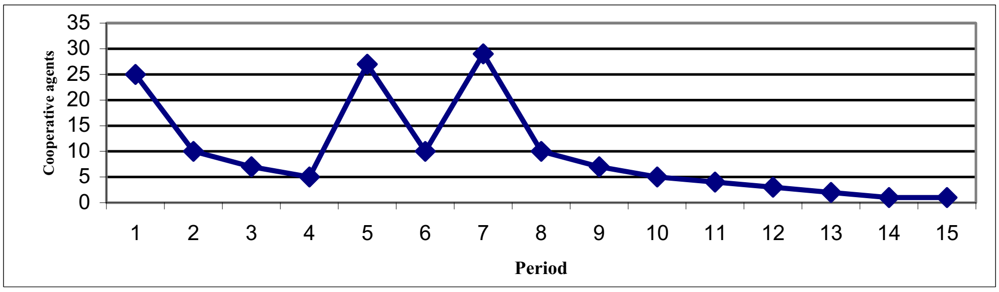

Figure 3

Evolution of prices on the market - characteristic to Scenario 2

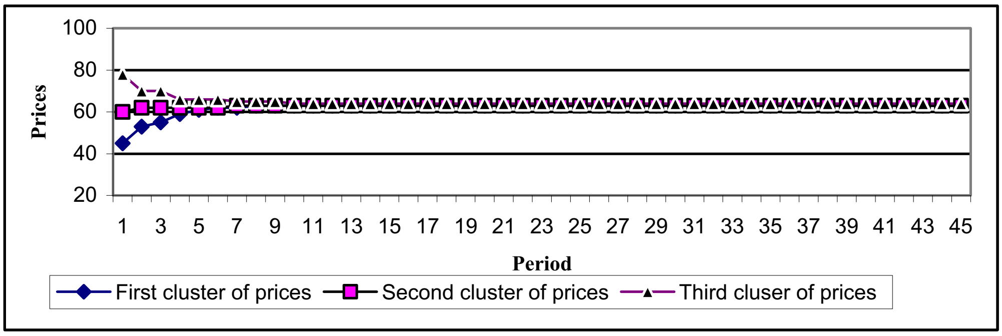

Figure 4

Evolution of prices on the market - characteristic to Scenario 3

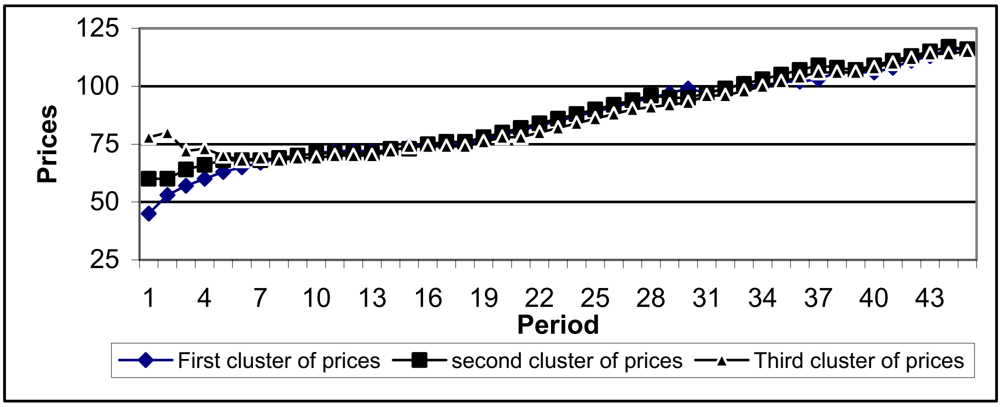

Figure 5

Evolution of the number of cooperative agents in the population - characteristic to Scenario 3

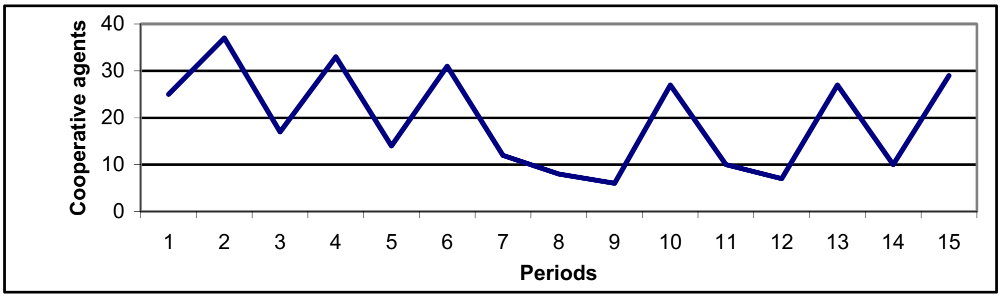

Figure 6

Evolution of prices on the market - characteristic to Scenario 4

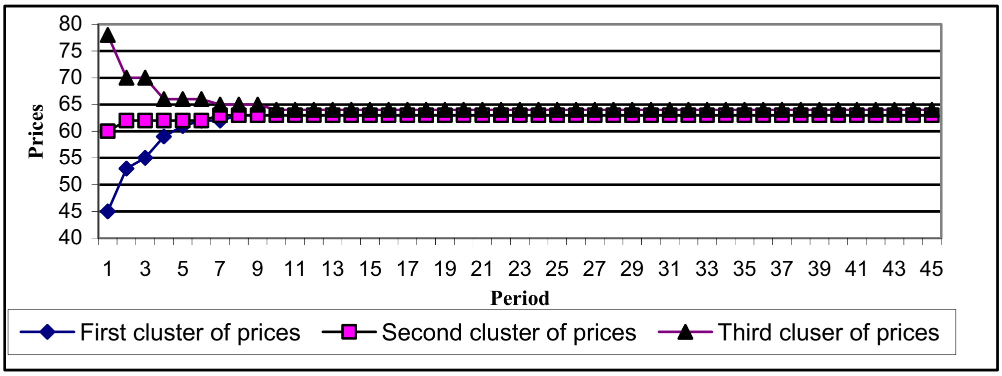

Figure 7

Evolution of the number of cooperative agents in the population - characteristic to Scenario 4

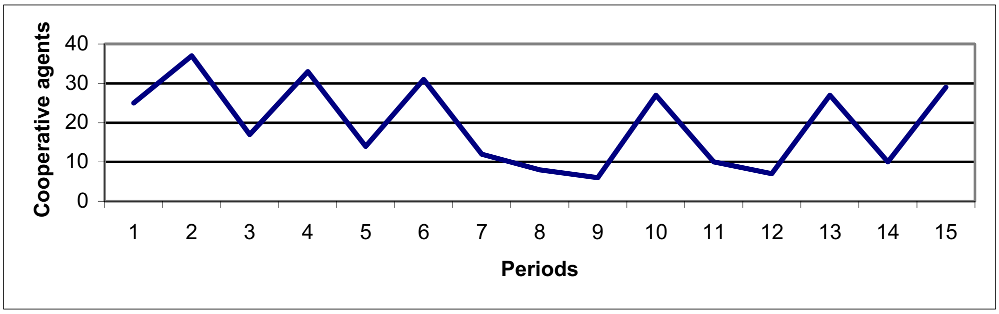

Figure 8

Evolution of prices on the market - characteristic to Scenario 5

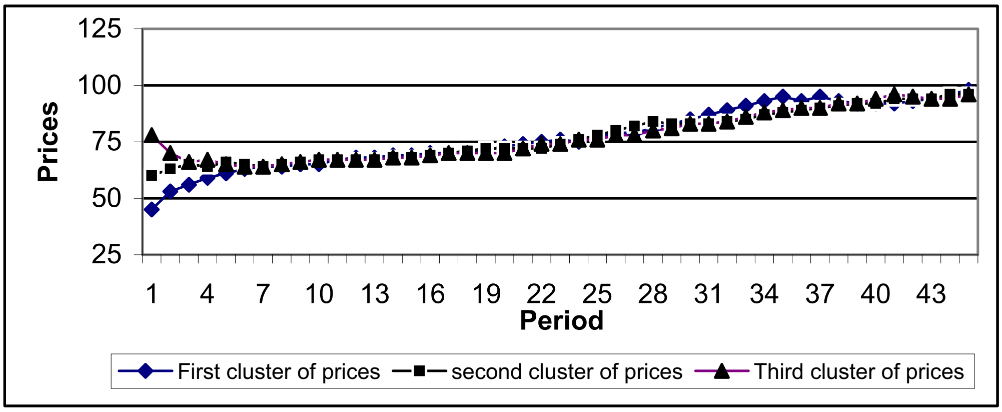

Figure 9

Evolution of the number of cooperative agents in the population - characteristic to Scenarios 5 and 7

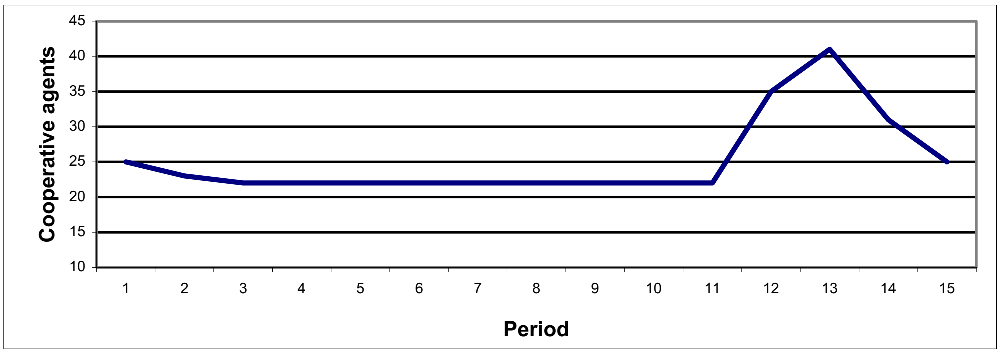

Figure 10

Evolution of prices on the market - characteristic to Scenario 6

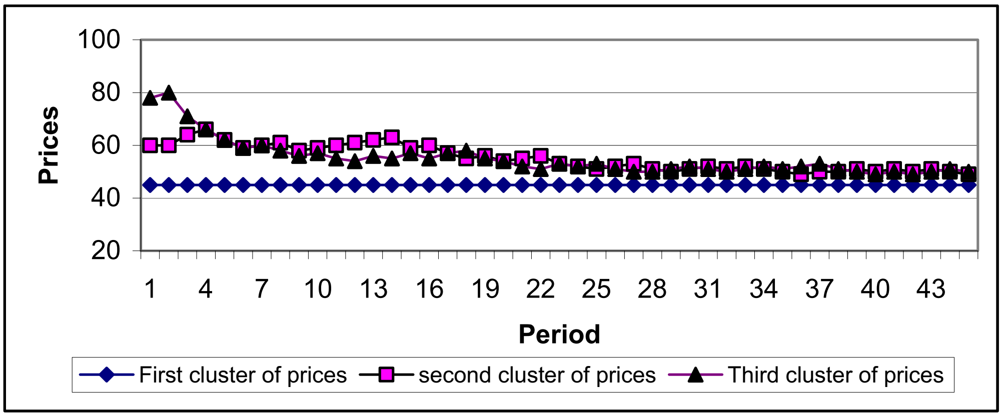

Figure 11

Evolution of prices on the market - characteristic to Scenario 7