

Performance of Maseca Researching Trading Agents' Behavior in a CDA Environment

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Abstract: *During the last decade, with the increase in the volume of business transactions through Internet, a new field of scientific inquiry emerged which was called agent-based computational economics. This science is the crossing point of computer science and microeconomics. The subjects of study are the economic processes, modeled through dynamic systems of interacting intelligent software agents. In this research, a new feasible method for finding solutions to the problem of allocating scarce resources via electronic auctions is presented. The aim is to investigate the possibilities that agents make deals (purchases and sales) on behalf of their users by means of electronic negotiations. For researching multi-agent negotiations, a continuous double auction is simulated, in which participants are equipped with appropriate strategies for generating bids.*

Keywords: *Simulation, electronic negotiation, CDA, trading agents, agents' strategies, bidding.*

1. Introduction

The initial experimental research on the process of making market decisions and their applications in microeconomic theory in determining equilibrium price and quantity of deals in the market was conducted by V. L. Smith at the beginning of the 1960-s. Smith proved the significance of the investigations on price of deals made under conditions of different types of market institutions [9]. The study of trading agents' behaviors continued during the following decade and experiments were conducted in computerized auctions. The building of a national electronic securities market in the USA made the determination of whether automation will have an effect on the stability and efficiency of commercial institutions a pressing

issue. The emergence of agent-based technology at the end of XX century provided new propulsion to the investigations of decentralized and distributed systems for decision making. The intelligent agents' ability to interact, their reactivity to changes in the environment and their skills of working independently for attaining a certain goal, make them suitable substitutes for people in e-commerce. Research is conducted in several major directions:

- Empirical study of market protocols, implementation of technological innovations, business cycles, etc., through agent-based simulation;
- Search for efficient mechanisms for managing economic objects (policies, processes, institutions);
- Quantitative analysis of the whole behavior of agent-based models over time and generation of new theories for decentralized forms of organization;
- Development of methods and instruments which confirm, via systematic computational experiments, the theoretical research of economic objects [1, 12, 13].

There are many research projects in the field of e-commerce which concern the allocation of scarce resources via auctions, but only a small number of them use software agents in reality and implement various market mechanisms. Kasbah [2] enables agents to engage in bilateral negotiations on the basis of three simple functional dependencies for determining the value of next bid. The system simulates only one double auction and after certain enhancement of some of its functions, it is currently used in training students in MIT under the name of Market Maker. Fish Market [8] is a project of the Artificial Intelligence Institute in Barcelona. It emulates a very narrowly specialized field of e-commerce by supporting only Dutch auction. Michigan Internet Auction Bot [16] is a configurable server for several different types of auctions. It is at the basis of the annual Trading Agent Competition, which stimulates interesting research on the behavior of autonomous agents in bidding for a package of miscellaneous services. The efforts for the creation of multifunctional information systems for modeling, researching, comparing and evaluating of the qualities of agents in alternative market environments continue [4, 7, 14]. However, the shortcomings of the listed systems have not been yet overcome. First, they simulate only one auction type. Exception to this rule is the Auction Bot system, which models many auction types, but the auction there is on a package of interrelated goods and services. The second shortcoming is that these multi-agent systems do not provide any choice among a variety of bidding strategies defined in advance. The third is the lack of an option for creating and experimenting with strategies defined by the users of such a system.

In order for these limitations to be overcome, a Multi-Agent System for Electronic Commerce via Auctions (MASECA) which is a software system for simulating and experimental research of multi-agent negotiations has been developed [6]. The participants act together to maximize the market efficiency by using various built-in bidding strategies. The most commonly encountered in contemporary literature bidding strategies in online auctions have been realized: those with a fixed step of change (Fixed Markup, FM), with zero intelligence – with or without budget constraints (Zero Intelligence Unconstrained – ZIU, and Zero

Intelligence Constrained – ZIC) [5], with intelligence (Zero Intelligence Plus, ZIP) [3] and a strategy which takes risk into consideration (Risk Based, RB) [15].

The purpose of this work is to investigate the agents' behaviors under conditions of on-line auctions via the newly created experimental system. Efforts have been concentrated toward studying the Continuous Double Auction (CDA), for this is the predominant mechanism for currency and security trading. The experimental application of the system will prove that it is an appropriate instrument for evaluation of agent strategies. A number of experiments for studying the behavior of homogenous agent populations have been suggested. The results obtained experimentally show that MASECA is a reliable tool for researching trading agents and that the strategies built-in the system are applicable for bidding in CDA.

2. General characteristic of the MASECA

The program product Multi-Agent System for Electronic Commerce via Auctions (MASECA) simulates the behavior of a decentralized negotiation system in purchasing and selling in e-auctions. Many auctions are supported at once. Each auction has many rounds. A round is the period of time, necessary for making a deal. An auction ends after the available resources have been allocated or after a predetermined inactivity period has elapsed. The sequence of a predetermined number of auctions forms a trading day. The totality of sequential trading days, conducted under the same market conditions, forms a trading session. Each trading session encompasses a predetermined number of trading days. In the program, statistical data for the biddings and deals made is collected, stored and processed. This way, the infrastructure of MASECA facilitates market participants in making decisions about taking part in an auction. The behaviors of individual auction participants are simulated by intelligent agents. Agents have at their disposal a number of different predefined strategies for generating bids. The system supports the most common strategies for participation in online auctions: FM, ZIU, ZIC, ZIP and RB. An opportunity for using outside strategies has been included and the connection with the system during experiments is conducted by a suitable protocol for sending and receiving messages. The strategies defined by the user are interpreted by a specialized program module, supporting basic program operators. MASECA allows for various negotiation scenarios, depending on market conditions. Under these scenarios, through joint actions, agents make win-win deals and maximize the total profit of all participants in an auction under the given market conditions. The parameters of a series of experiments are given in two ways: by a text file prepared in advance which describes the sequence of experiments and by a specialized interactive Desktop-controller.

After its activation, an agent receives information about current market conditions. On the basis of constraints, given to the agent by its user, the type of used strategy and its parameters, the agent makes its next bid proposal and decides whether to participate in an auction or not. Each strategy for an agent's behavior at an auction can be implemented by the agent autonomously or in a way determined

by its user through the graphic interface of the system. The connection between an agent and market infrastructure is asynchronous and is realized by means of message exchange. Requests and notifications sent to an auction and answers received are transformed by the agent into events, which it processes in order to react in accordance with market conditions. The communication media inspects periodically all acting objects (agents and auctions) and makes a transfer of current messages between them.

Agents in MASECA can perform two roles: they can be *buyers* or *sellers*. An *agent-seller* aims to maximize the revenue of its user, taking into consideration the cost of obtaining a good, attitude toward risk, etc. It attains its goal by preparing and presenting an offer to *agents-buyers* via the market infrastructure. Each offer indicates quantity, price, etc. An *agent-buyer* has the task of maximizing the profit of its owner by managing the process of determining the value of its next bid according to the preferences of its user concerning price, attitude toward risk, etc.

The advantages of the new platform over the aforementioned systems are as follows:

- the system supports many online auctions at the same time;
- both real and virtual bidders – human beings and intelligent agents, can participate in auctions;
 - auction participants interact by means of available bidding strategies and each strategy is calibrated according to user preferences through many parameters;
 - buyers and sellers have the opportunity to define and implement their own (new to the built system) bidding strategies;
 - a new version for online simulation by HTTP protocol has been developed; its features enable the input of simulation scenarios, including: market conditions, choice of built-in strategies, strategy parameters, as well as defining user strategies.

3. Program realization of MASECA

In the software realization of MASECA, Object-Oriented Programming (OOP) is used. At first sight, between the two software technologies – object-oriented and agent, there are significant differences. Software objects are encapsulated (and usually named) parts of code. They are sustainable, are always executed after they are evoked and have static relations between themselves. Unlike them, the agents are software entities having a certain control over their own state and execution. They are dynamic, requested (not invoked), do not always fulfill requests, but not in the expected way, and the relations between them may or may not be static. Consequently, the main difference between objects and agents is that while objects are passive, agents are active autonomous program entities. The development of program modules which change passive objects, allows for the attaining of a certain level of autonomy in object-oriented simulation. Although in this case the autonomy is limited, it can be stated that through OOP mechanisms a program realization of a multi-agent system is possible.

OOP has the capacity to solve the problem of modeling the structure and functions of an e-market in an adequate and flexible manner. Both agents and

objects encapsulate state and behavior; therefore, objects can be used for modeling real phenomena and events during an e-auction. The agents in the system, realized by means of objects, represent the reality in a natural way in terms of individuals interacting in accordance with the condition of the environment and their goals and priorities. Multiple inheritance makes possible the creation of agents with various behavior scenarios, inheritance schemes and attributes, differing from those of their parent classes. The objects in MASECA are not passive, but have rather the capability of independent choice during their interactions with other objects and may decide for themselves whether to perform a certain action or not. Modern object systems support a possibility of layering processes in independent parallel threads and due to the standard Delphi class TThread each agent in MASECA has its own control thread. The objects act together and achieve goals unattainable or not so easily attainable to system participants acting individually. As the goal of electronic negotiations is specifically defined, the environment is determined and agents are purposeful, the system developed by object-oriented programming fulfills all requirements for it to be a multi-agent system.

The foundation of MASECA is an object hierarchy, based on multi-thread processes supported by the Windows NT⁺ operating system. This hierarchy is built with one grand-parent, direct descendant of class TThread and its class descendants TAuction, TAuctionTurnir, TAgent, etc. In the root of the hierarchy all the basic methods of communication (activation and deactivation of a single thread process, sending and receiving of messages to and from the environment, processing of registered events, etc) are implemented. In the upper hierarchy levels, the functionality of specific objects is presented in detail according to their specification. On this basis, the functions of markets' subjects are realized, such as: auctions and agents, as they exist in separate sub-processes of one complete process and communicate asynchronously using the market environment:

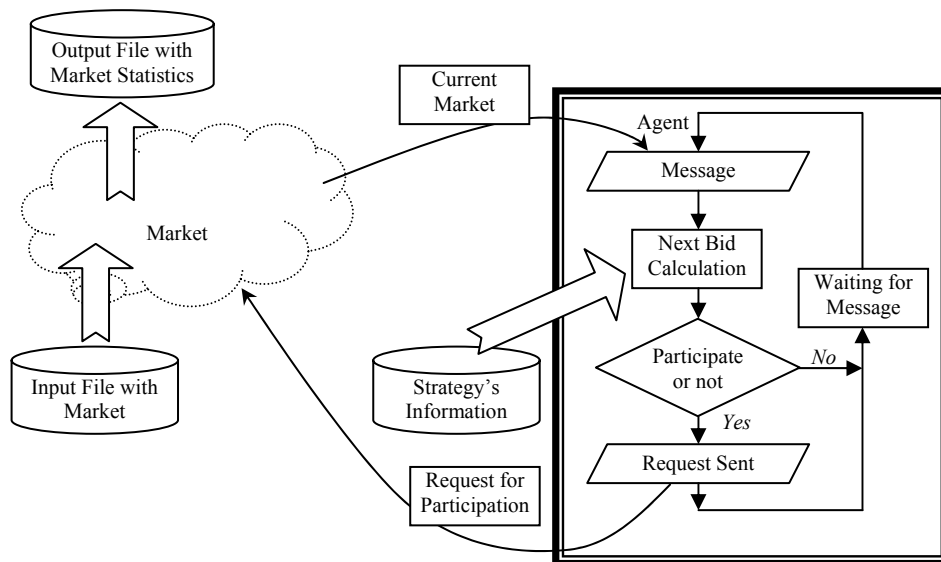


Fig. 1. Structure of a MASECA program package

- objects auctions, realizing the functionality of auctions;
- objects agents-traders, realizing the functionality of auction participants (sellers and buyers).

The objects auctions and agent-traders obtain functional completeness on the next hierarchical level by specifying the supported protocol for information exchange between participants in the environment. Many of the specific object attributes have been implemented as characteristics of their common parent class. Such are, for example, the auction type: one or multi-element, the strategy for generating offers, etc. In this way, via parametrization of already existing instances of the same objects, various behaviors are modeled, depending on the values of the parameters entered with the initial data.

The realized agent instances exist in a communication media, supporting the message exchange between them. For this purpose, an algorithm for traversing agents and exchange of the prepared messages from sender to receiver existing in a given moment has been developed. Furthermore, the following additional capabilities, increase the verisimilitude in simulating the real market:

- order of traversing and communicational servicing of agents (and their activation, respectively) is done on a random principle;
- a certain delay is generated after each traversing cycle, with which a real communication environment is modeled more precisely and in fact the speed of auction conducting is managed.

The functioning communication kernel created in this way provides a foundation for the successful realization of a complex distributed information system. Each participant by its own initiative generates and receives messages and this does not bind it to operate on the same machine or software platform. The possible architectures which the communication kernel allows to be built vary in their complexity and interaction between components: from a solution in which all the agents are on the same platform (machine) together with the communication kernel and only customer tasks are received from outside. A new release will operate under the Service Oriented Architecture (SOA) principles, where only the communication components of the agents are on the communication platform. The agents themselves are positioned and operate on different independent machines (with a different software platform), using Internet Web-services, which define their negotiation strategies (according to the ideas given in [10, 11]).

During the implementation of the negotiation environment for modeling e-commerce an effective protocol for information exchange between market participants has been developed. It contains the necessary minimum of message types which can be exchanged between an agent and an auction. The message mnemonics is typified and the message syntax consists of a code (message name) and a parameter list.

4. MASECA's performance in researching homogenous agent populations

The first series of experiments will investigate the behavior of a homogenous population of trading agents, consisting of 11 sellers and 11 buyers under conditions of CDA. Subjects of trading between them on the auction are items of only one type of good. Each agent-seller has the same number of items of the given good (one) for sale and each agent-buyer has the task to purchase one item of that good. Participants present their suggestions asynchronously. Only those, fulfilling the NYSE-rule, are valid. According to it, only bids which reduce the current market spread are allowed. A deal is made when the bid price becomes greater than, or equal to, asked price. MASECA gathers statistic information for estimating the mean values by trading days for each of the following parameters: deal price, convergence coefficient of the price of deals and market efficiency. The convergence coefficient of price α is estimated using the formula:

$$(1) \quad \alpha = \frac{\sqrt{\frac{1}{n} \sum_{i=1}^n (\tilde{p}_i - p^*)^2}}{p^*},$$

where \tilde{p}_i is the price of the i -th transaction, p^* is the equilibrium price, and n designates the number of the deals made.

The market efficiency is defined as

$$(2) \quad E = 100 \frac{P_{\text{current}}}{P_e} = 100 \frac{\sum_{i=1}^n |l_i - \tilde{p}_i|}{\sum_{i=1}^n |l_i - p^*|},$$

where P_{current} is the current profit of agents for a trading day; P_e is the profit of agents if they trade their goods at their equilibrium price, and l_i is the marginal price of an agent i .

4.1. Symmetric static market

The first experiment investigates the behavior of a homogenous population of agents with strategies FM, ZIU, ZIC, ZIP and RB in symmetric static market for 10 trading days. From the diagrams in Fig. 2 it can be observed that strategies FM, ZIU and ZIC have the lowest indicators. The reason for this is the fact that the three strategies are not adaptive, but wholly reactive instead.

They do not take into account transaction history and do not try to predict prices. The lowest results belong to ZIU, as in this case the proposals are random numbers and the deal price is very different from the equilibrium price. Strategy FM uses a fixed step in generating the next bid and does not take into consideration the actual auction state. ZIC-agents generate random bids and offers in accordance with the NYSE-rule and the spread between winning offers bids and asks is usually significant. The better results, achieved with the ZIP and RB strategies are due to the fact that they are intelligent strategies, which use historical prices and special learning algorithms. In the latter two strategies there are similar patterns in the movements of transaction prices, their standard deviation and the market efficiency.

ZIP and RB-agents make deals at prices close to the competitive equilibrium price; their convergence coefficient is small and the efficiency – close to the optimal one.

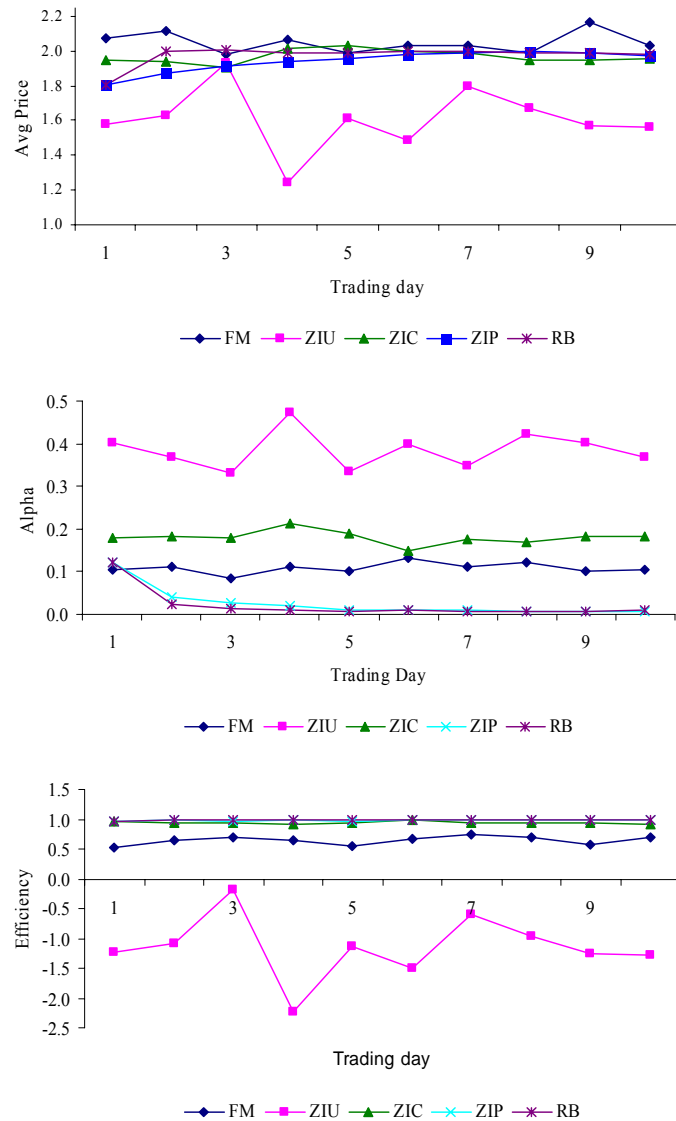


Fig. 2. Average price of a deal, convergence coefficient and market efficiency for strategies FM, ZIU, ZIC, ZIP and RB in Experiment No 1

4.2. Symmetric dynamic market

The second experiment investigates the behavior of a homogenous agent population with strategies ZIC, ZIP and RB in case of symmetric dynamic market for 20 trading days with the occurrence of a market shock after the tenth day. As a result of the market shock, the equilibrium market price increases (Fig. 3).

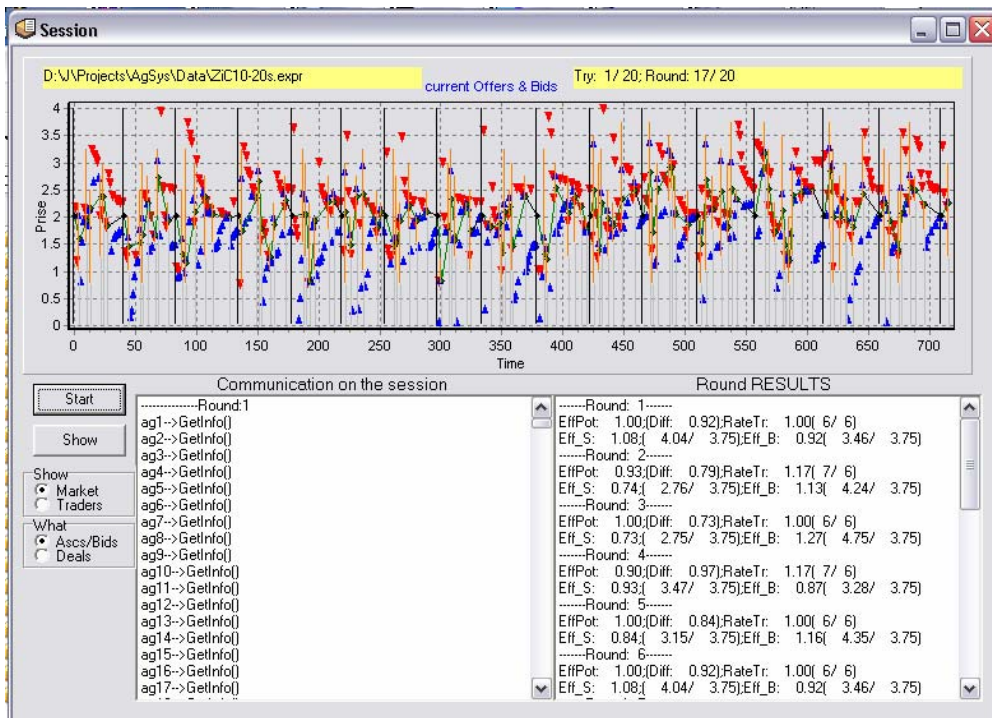


Fig. 3. Window of MASECA during Experiment No 2, visualizing market condition after the market shock (equilibrium price moves from 2.0 up to 2.25)

Three series of experiments are conducted (one series for each of the investigated strategies) and each of them consists of 20 sessions under the same market conditions. The results obtained show similar patterns in the changes of the observed indicators. During the first 10 days, the movements of indicators are more chaotic, but during the second 10-day installment, a sustained tendency towards convergence to the equilibrium market price is visible. In Fig. 4, descriptive statistics of the researched magnitudes are presented graphically. The first row of graphs shows the movement of transaction prices and price corridor and their change, obtained with their standard deviation. Clearly the best convergence both before and after the market shock is demonstrated by RB strategy. It moves the most gradually toward the new value of the price after the market shock. The second row of diagrams shows the advantage of strategy RB before the other strategies in terms of the convergence coefficient and the price of deals α . The third row contains information about the market efficiency. The results about market efficiency are similar to those concerning price convergence and strategy RB has two opposite peaks at the moment of the market shock.

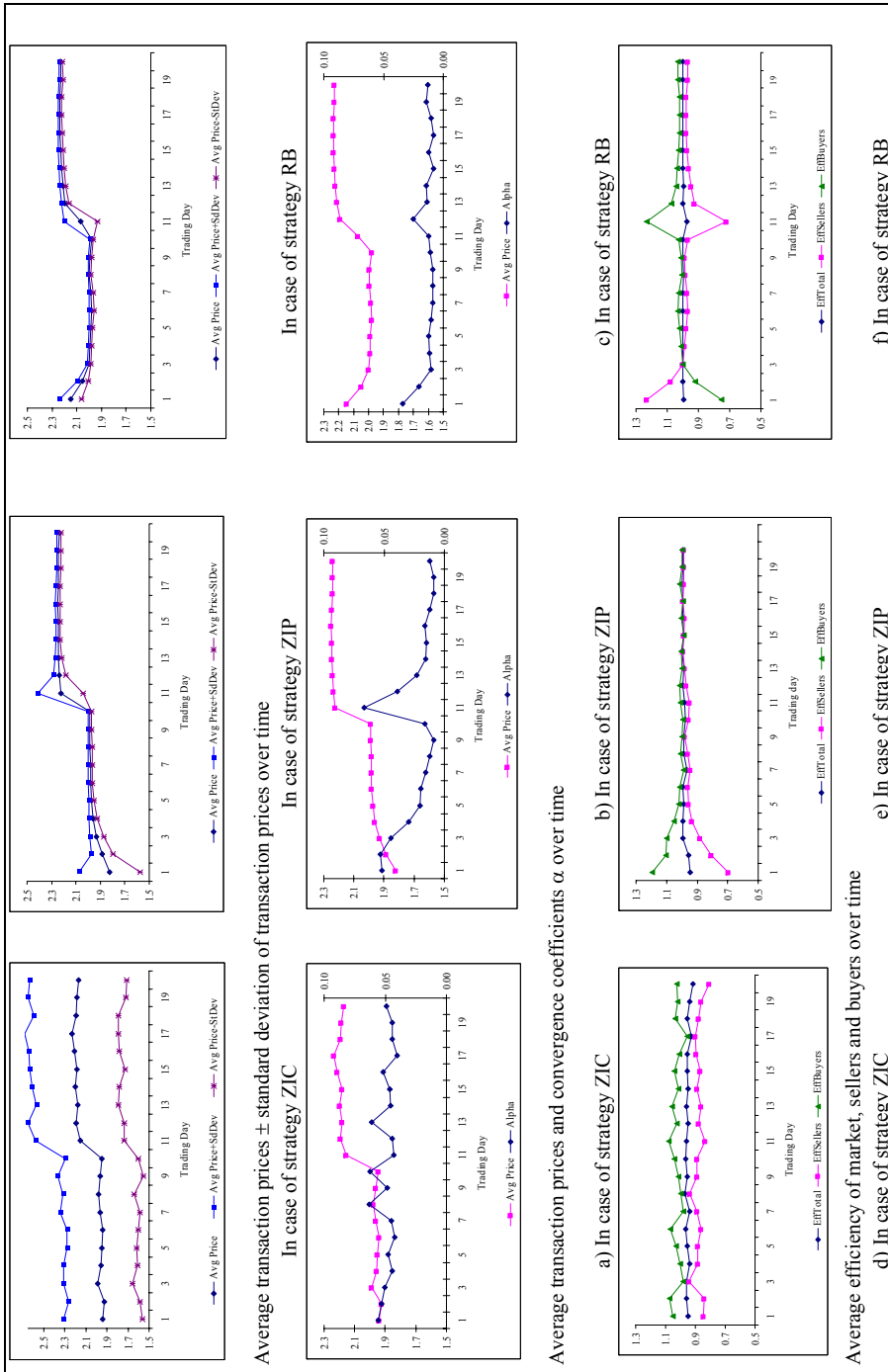


Fig. 4. Time diagrams for Experiment No 2

4.3. Dynamic market with asymmetric supply and demand curves

The third experiment investigates the efficiency of a dynamic market with asymmetric supply and demand curves. For this purpose, the marginal prices of buyers and sellers and the expenses of obtaining the sellers' goods form curves with different slopes and the theoretical profit for buyers is twice as large as that of sellers. A fragment of the file initializing the third experiment with the strategy RB is enclosed. The results regarding market efficiency are visualized in Fig. 5. Agent strategies follow the market supply and demand curves. Profit is correctly distributed between auction participants. The data confirm quantitatively the theoretical forecast – buyers' profits are nearly twice as large as those of sellers. Total profit is close to the maximum possible while strategy RB performs best. Also in the case of asymmetric supply and demand curves with strategy RB peak values are observed in the days of shock price change.

```
[TypeDefinition]
Type=_StepByStep
[StrategyDef]
My_Zip_CDef =Strategy=@MyZip_cStrategy
My_LinDef =Strategy=@MyLinStrategy;MaxSteps=20;CurrStep=0
LinDef =Strategy=LIN;MaxSteps=20;CurrStep=0
RiskBDef=Strategy=RISKB;
Risk=(-0.1,0.1);Beta=(0.02,0.8);Eta=(2,3);Lamda=0.9;N=5;BetaT=(0,1);Tita=-1;Tau=-1;P=-1
[AgentsPopulation1]
StrategyDef=RiskBDef
SellerLimits=1.0,1.1,1.2,1.3,1.4,1.5,1.6,1.7
BuyerLimits =2.5,2.3,2.1,1.9,1.7,1.5,1.3,1.1
[AgentsPopulation2]
StrategyDef=RiskBDef
SellerLimits=1.5,1.6,1.7,1.8,1.9,2.0,2.1,2.2
BuyerLimits =2.5,2.3,2.1,1.9,1.7,1.5,1.3,1.1
[auction]
au0=Duration=0;PriceMin=0.05;PriceMax=4.00
[experiment]
stage1=endRound=10;sit=AgentsPopulation1
stage2=endRound=20;sit=AgentsPopulation2
[try]
tryNumber=20
```

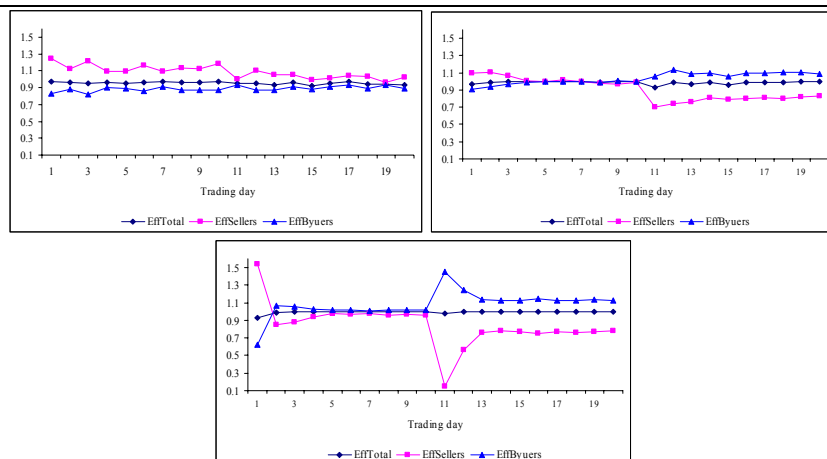


Fig. 5. Deal efficiency with strategies ZIC, ZIP and RB in Experiment No 3

4.4. Static and dynamic markets under conditions of constant supply and/or demand

The purpose of Experiment No 4 is to explore the behavior of homogenous populations with strategies ZIP and RB in static markets: M1 (market with symmetric supply and demand), M2 (asymmetric market with constant supply) and M3 (asymmetric market with constant demand) and in dynamic markets: M21 (asymmetric with constant supply and symmetric market), M31 (asymmetric with constant demand and symmetric market) and M23 (two asymmetric markets) (the diagrams in the leftmost part of Fig. 6 visualize the main types of markets and their combinations).

First we explore the efficiency of strategies ZIP and RB in static environments – markets M1, M2 and M3 (Fig. 6, trading days from 1 up to 10). In case of symmetric market M1, strategy RB surpasses ZIP in average efficiency – 99.57% against 98.21% (Fig. 6, Table 1). Transaction prices to RB-agents approach p^* closely and faster in comparison with those to ZIP-agents. Efficiency and convergence coefficients of RB at the beginning of the experiment are better than those of ZIP, since, due to a lack of information, RB-agents start with relatively small goal price. ZIP-agents do not make such an assumption, but rather use a randomly chosen profit margin. Over time, after a few days, the efficiencies of both strategies approach the optimal and in RB it is higher. RB approaches optimal efficiency faster than ZIP. In case of asymmetric markets M2 and M3, strategy RB also surpasses ZIP in average efficiency – 99.3% against 98% for M2, and 99.2% against 96.3% for M3. Moreover, RB is better than ZIP in asymmetric markets M2 and M3 even to a greater extent than in the symmetric market M1. The reason for this is that here the range of proposals is smaller and the goal price of RB is closer to p^* . In asymmetric markets, α remains greater than in symmetric. In market M2, where buyers' efficiency is smaller than that of sellers, prices have to be greater than p^* , so that buyers could make better profits. This means that in case of horizontal supply curve buyers will aim at increasing deal prices to increase income. The situation is analogous in M3, but there sellers aim at prices lower than p^* . In both cases the results is greater α as compared to that of the symmetric market M1.

In dynamic markets, strategies have to react to the market shock and adapt to new market conditions fast. Under scenario M21, the investigation starts with a horizontal demand curve and continues under symmetric market conditions. Under these circumstances, RB is a more efficient strategy and also shows greater flexibility and adaptivity (with a smaller coefficient α). The convergence coefficient is smaller as compared with that of market M14, where p^* changes significantly. ZIP worsens its indicators considerably and demonstrates lower efficiency and insufficient adaptivity. The reason for this is that ZIP uses the profit goal of the tenth day under the changed market conditions in the beginning of the eleventh day. This inappropriate profit goal in the case of new marginal prices worsens the strategy's efficiency. The decrease in efficiency depends on the difference in conditions in markets M2 and M1 (in this case there is a significant change in sellers' preferences). Similar patterns can be found in market M31 and in that case the dominant strategy is again the most flexible and adaptive RB.

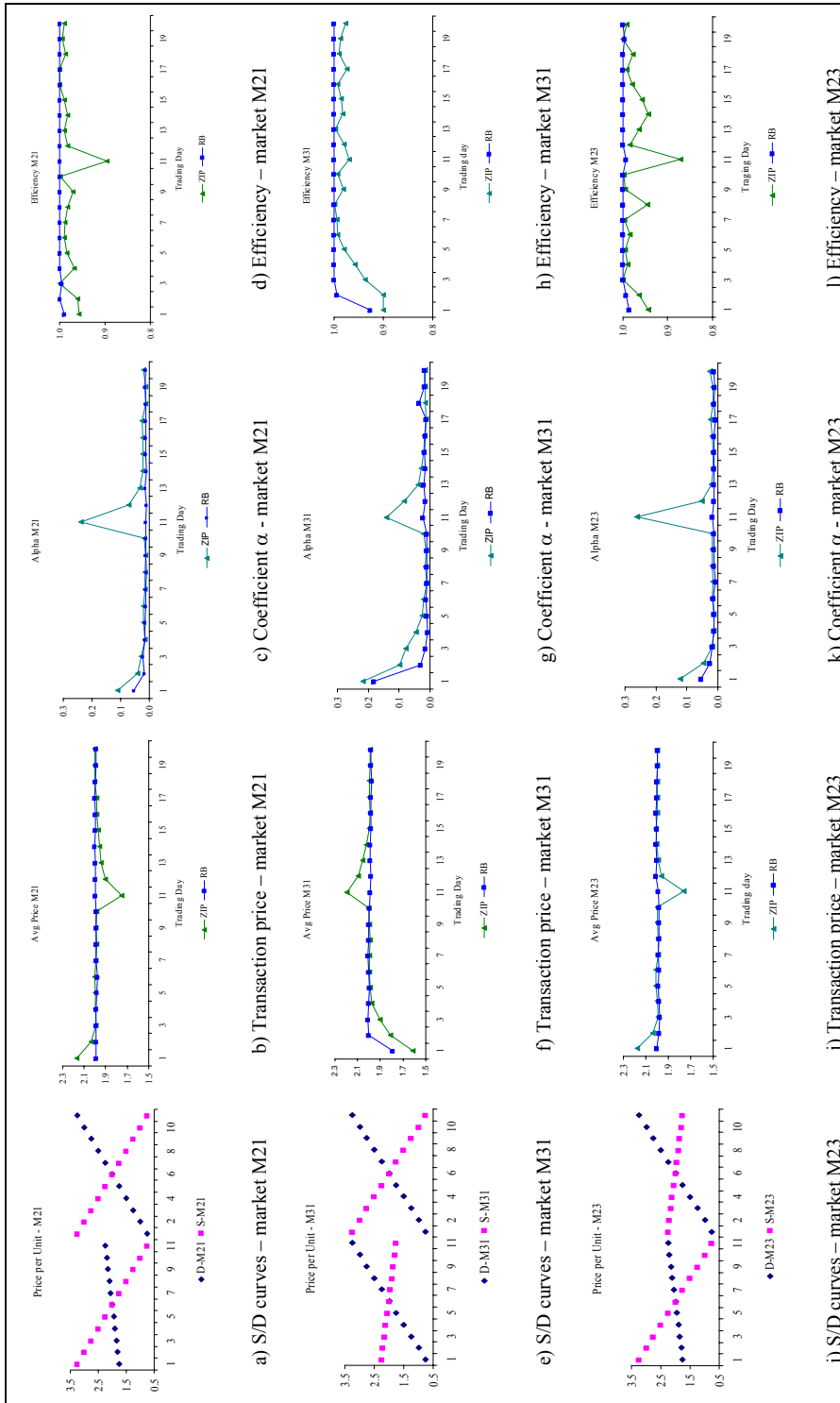


Fig. 6. Time diagrams for Experiment No 4 with strategies ZIP and RB

Table 1. Efficiency and convergence in static (M1, M2 и M3) and dynamic markets (M21, M31 and M23)

Market	E-ZIP	E-RB	Alpha-ZIP	Alpha-RB
M1	0.982	0.996	0.0528	0.0127
M2	0.980	0.993	0.0299	0.0187
M3	0.963	0.992	0.0542	0.0296
M21	0.981	0.992	0.0390	0.0156
M31	0.973	0.996	0.0463	0.0230
M23	0.974	0.993	0.0382	0.0157

Under scenario M23, the horizontal supply has been substituted by a horizontal demand. ZIP again cannot react on time, as after the change it continues to use the obsolete profit margin. The supply curve, now in the range between 0.75 and 3.25, in combination with the old sellers' profit margin generates offers inappropriate for the market. RB does not change its coefficient α so dramatically after the change in the conditions of the market M23. The change here is in times smaller than that in markets M14, M21 and M31. The explanation is as follows: In M14 there is a drastic change in the margins of buyers and sellers. In markets M21 and M31 only sellers, respectively buyers, change their preferences. As market behavior is a function of the behaviors of buyers and sellers, these changes lead to changes in market efficiency and α . Since in M23 there are no important changes in supply and demand as in M14, the decrease in efficiency is relatively small, and α changes gradually, without a peak (Fig. 6, Table 1).

5. Conclusion

In this work, an application of the program system for simulating e-market MASECA with homogenous agent populations has been described. By means of the practical experiments, the applicability of the system for online negotiation simulation has been proven. The results that have been presented in previous publications on classical bidding strategies in CDA have been confirmed. This is a piece of proof that the system has potential and can reliably fulfill its given tasks. MASECA demonstrates stability in a large number of simultaneously functioning participants in the form of homogenous agent populations and a multitude of strategies under conditions of both static and dynamic markets. Its graphical user interface is comfortable and easy to work with. MASECA generates detailed information about the analysis of the conducted experiments in different market situations. The system uses new information technologies (software intelligent agents, in particular) combined with computer modeling for complex analysis of market participants' behavior registering many factors, which allows for the discovery of hidden dependencies, for making forecasts about future market conditions, for exploration of anomalies, etc.

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