IMITATIONAL MODELING OF BEHAVIOR OF LEARNING ECONOMIC AGENTS

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Abstract: *Agent-oriented models (AOM) are well-known and are widely used in imitational modeling of economic processes. AOM allow researchers to take their multicomponent iterative nature into consideration and to avoid difficulties, which may stem from analytical task setting. The article suggests the use Gilboa-Schmeidler agents, which a) have a limited rationality of decision-making process which accompanies resource exchanges; b) learn, while striking deals aimed at exchange of these resources. This is what makes them different from traditional AOM, where learning and relearning is not taken into account. The peculiar feature of the agent interaction environment is the possibility of redistribution of a part of resources through the taxation of deals. The influence of institutions on deal successfulness is also taken into account.. The functioning of the suggested AOM is demonstrated through the use of examples, which admit to simple economic interpretation.*

Keywords: agent oriented model, self-learning agents, partial rationality

***ACM Classification Keywords**: I.2.m Miscellaneous*

Introduction

Agent oriented modeling (AOM) of economic processes is applied in cases, when analytic models are extraordinarily complex. In this case agents are attributed the quality of partially intelligent behavior, and the objective of imitational modeling (IM) is to organize their interaction within a framework of a certain program system. AOM procedure is described in literature assuming independence and partial intelligence of agents [Epstein,2005] . Work [Adami,1998] describes models of evolutionary agents, and work [Makarov, 2006] focuses on models based on agents who are similar to each other and are able to communicate with each other. AOM analysis in economic supplements is carried out in [Bakhtizin, 2008].

One characteristic feature of agents, used in economic supplements, is their so called limited rationality. G. Simon was the first scholar to draw attention to the necessity of taking this limited rationality into consideration. Since then a good number of works have focused on decision making by market players. For example, in Nelson-Winter models agents take decisions based on patterns – routines [Nelson, 1982]. At the same time, the authors' objective was not to analyze their origin and development. I. Gilboa and D. Schmeidler have developed the theory of precedent decision-making. According to this theory, the rules of decision-making by agents depend on what decisions have been taken by them in similar situations and what results they have led to [Gilboa, 1995, Gilboa, 1996, Gilboa, 1997]. It is this model that is under discussion in the present article

Model Description

2.1 Agents' Parameters

Within the developed AOM agents aim to satisfy their needs in the volume, determined by the standard consumer basket. According to A. Maslow's idea, each agent satisfied his needs in the following order: physiological needs, security needs, the need to communicate with a resource-producing group, a need for self-development.

Each agent owns one or several resources, competences and business processes. To continue living he needs to use a given number of resources, whose quantity remains the same for all agents. A business process will be performed resulting in the creation of the relevant resource if its owner has accumulated all the needed competences and resources. Agents strike deals exchanging resources, competences and business processes,

aiming to fill their own consumer basket. When doing so they aim to realize excessive resources, their competences and to execute their business processes.

In the initial position for all agents, resources, competences and business processes belonging to them are given. Initial probabilities of deal successfulness for agents are determined. As a rule this figure equals 0.5. Deal successfulness might also be affected by institutions, existing in the modeled artificial society. Institutions may support deals with certain resources or limit them. Due to this, in the initial position deal successfulness probability is determined for each type of resources. Other factors to be determined are tax payment percentage and standard consumer basket.

2.2 Agent Behavior

The following actions are taken at every step of the modeling. Agent consumes the resources at his disposal in the quantity, determined by standard consumer basket. If these resources are not enough for satisfying the first level needs, the agent dies. Business processes consume resources and create new resources owned by the agents. Some resources are consumed by business processes within several steps of modeling in equal shares. Resources left over after consumption and created at this step are brought to the market. Agents look through these resources in order to find resources to fill their own consumer basket and strike deals aimed at exchanging these resources against the ones they have. The communication of agents takes place via common information field as suggested in [Bandini, 2009].

Resource exchange might take place, when an agent finds the first option which he deems suitable. Deal successfulness depends on successfulness probability of a particular agent, deal successfulness probability in this particular society, and support or limitations regarding this type of deals by the institutions of the society. An element of probability is added to this procedure. Agent learning is modeled by the fact that at a certain modeling step the probability of a success of a deal of a certain kind increases, if at the previous step the deal of this kind was a success. If a deal didn't take place, such a probability decreases.

The result of a single step of modeling consists of calculating the given percentage of a tax, which is distributed among agents in equal shares as resources.

Modeling

Using the suggested AOM we have analyzed the dependence of the quantity of collected tax on the volume of the tax rate and on how 'powerful' tax-collecting institution is. Agents pay the tax upon completing every resource exchange deal. The growth in the number of deals leads to the increase in the volume of tax collected. At the same time there is a decrease: a) in the quantity of resources for future deals at the agents' disposal; b) the productivity of agents, who could not collect resources for their business processes. Fig. 1 indicates the change in manufactured product (the upper curve) and tax (the lower curve) depending on the tax rate. Product and tax are measured in hundreds of standard consumer baskets; tax rate is measured in percentage. The dependence between tax revenues and tax rate is shown in Fig. 2 in greater detail. The upper curve represents agent behavior when the probability of payment of taxes is close to 1 – the institution is 'strong'. The lower curve represents the situation when the tax collection is 'weak'. The outlook of the curve remains unchanged. We can see, that increase of the volume of the non-collected tax is directly connected with the growth in the number of deals in AOM. When the number of deals decreases the curve get closer to each other. The results of the modeling are in line with the criticism of the Laffer curve in [Mankiw, 2004].

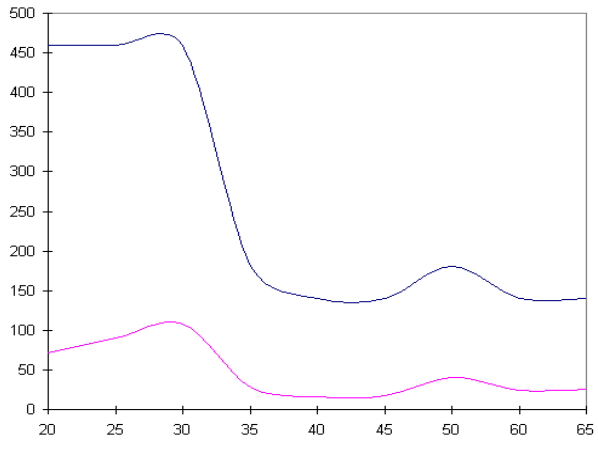

Fig. 1 Dependence of product manufactured and tax collected on the tax rate

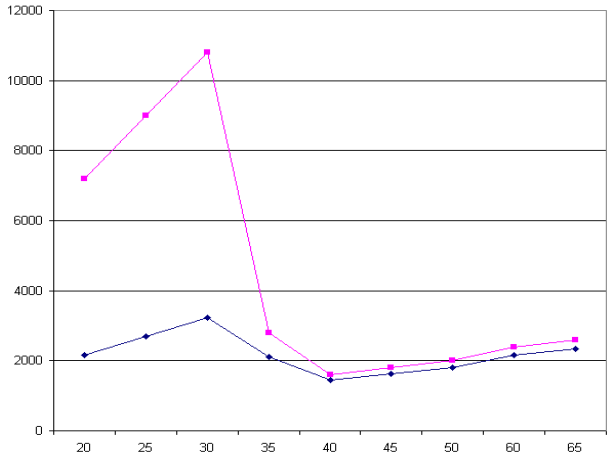

Fig. 2. Dependence of tax collected within systems with strong and weak institutions on tax rate

Upon analyzing the results of the modeling we considered the behaviour of agents when a substituting resource enters the market. The substituting resource has better consumer characteristics than the replaced resource. Its entry was conditioned by unsatisfied demand for the resource required for the completion of the business process. In the initial state agents, who did not purchase the replaced resource had lower productivity. Having purchased a substitute, they increase the productivity of their business processes. Fig. 3 shows the number of successful deals, resulting in the purchase of both resources. Axis X shows the iteration number, whereas axis Y indicates the number of deals. We can see that the substitute is introduced during the 18th stage of the modeling. Within this period agents learned to buy the first resource. That is why the second resource is first purchased by the agents, who could not purchase the first resource. Later they are joint by agents, who at a previous stage had stricken a bad deal regarding the first resource. In a little while the substitute becomes more wanted. The difference in graphs in Fig. 3 is predetermined by the incidental character of the deals' successfulness.

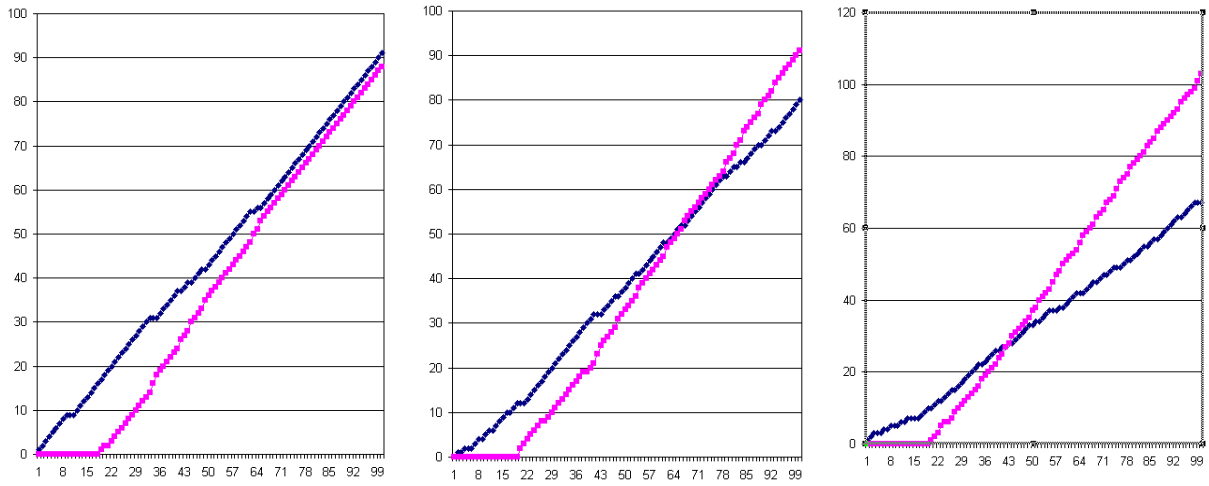

Fig. 3. The number of successful deals with the first resource.

The curves presented here demonstrate the limited rationality of agents' behaviour. Indeed, a rational agent will purchase a better product immediately upon its introduction in the market. But this does not take place, due to the fact that agents make decisions on the basis of what they learn from their previous deals.

Conclusions

The present work suggests usage of Gilboa-Schmeidler agents in multiagent economic systems. A brief description of environmental conditions as well as of rules of behaviour of such agents is also given . we have conducted initial experiments with simple models and they have proven the validity of the undertaken approach.

In the future we are planning to: a) consider more complex models using more complex agent behaviour rules. b) compare the behaviour of AOM with the behaviour of real systems.

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