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FORECASTING THE BEHAVIOUR OF ECONOMIC SYSTEMS AND AGENTS

Svetlana Lapshina*[1] & Evgenia Yazovskikh[2]
*[1&2]Ural Federal University named after the first President of Russia B.N.Yeltsin, Ekaterinburg, Russia

ABSTRACT
Forecasting based on historical data is well known. The paper presents a method of retrospective forecasting based on the identification of the competitive behavior strategy of economic agents and simulation modeling with the application of cellular automata.

The behavior strategy implies a certain model of the economic agent behavior that characterizes how well it has adapted to the conditions of the constantly changing market. [1]

Keywords: competitive behavior strategy, economic agent, internal and external environment, approaches, forecasting.

I. INTRODUCTION
The following approaches to the classification of agent behavior in the market are well known:
- the managerial approach proposed by Ph. Kotler, M. Porter and etc.;
- the biological approach offered by A. Yudanov and L. Ramensky;
- J. Schumpeter's evolutionary approach and etc.

There is no systematic comparison of these classifications among themselves, thus, it is difficult to choose the necessary approach and the corresponding strategy.

One of the proposed solutions was the classifier of Gunin (Fig. 1), which was supposed to make it easier for the manager to determine the competitive agent behavior strategy. But its application is rather difficult, as a qualitative determination of 15 parameters is required.

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№	Parameters	Type of competitive behavior (Classification of L.G.Ramensky)			
		Violletts	Patients	Expanders	Commutators
		Type of company (The classifier of H. Friesewinkel)			
		Lions, elephants, hippos	Foxes	Swallows	mouses
1	Level of competitiveness	High	Low	Middling	Middling
2	Industry novelty	New	Mature	New	New, Mature
3	What needs are served	Mass, standard	Mass, non-standard	Innovative	Local
4	Production profile	Mass	Specialized	Experimental	Universal small
5	Company size	Large	Large, Middling and Small	Middling and Small	Small
6	Sustainability of the company	High	High	Low	Low
7	R & D expenses	High	Middling	High	None
…					
15	Advertising	Mass	Specialized	None	None

Fig. 1. – A classifier of competitive behavior strategy offered by V. Gunin [2]

Let’s consider the classification of the agent behavior from the positions of the system approach (Fig. 2).

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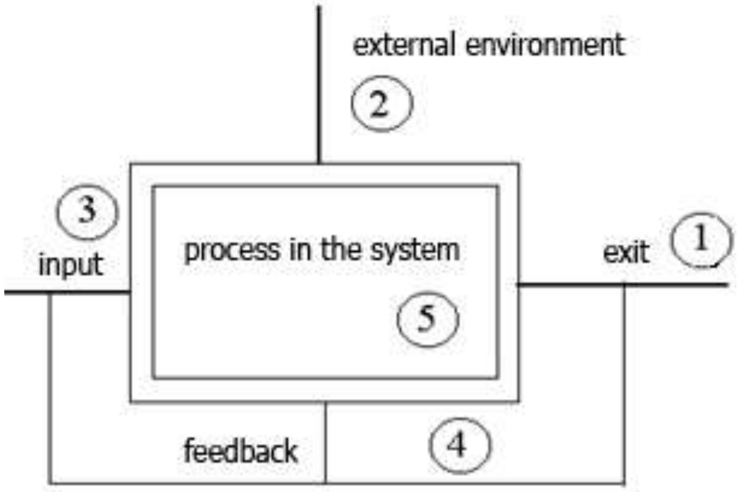

Fig. 2. – The interaction of an economic agent with the external environment

The internal environment of the agent implements the "process in the system" (5), whose result comes to the "exit" (1) of the agent. The "process in the system" (5) experiences the control (informational) impact of the "external environment" (2) and resource flows at the "input" (3) of the system. The "process in the system" (5) and the "input" (3) are also affected by the "feedback" (4) coming from the "exit" (1) of the agent.
Thus, factors of the external environment (2) and (3) determine the conditions for the agent's existence that adjusts his behavior to them.

II. FACTORS OF THE EXTERNAL ENVIRONMENT

- Stress is a permanent external factor limiting the agent development (e.g., limited resources).
- High stress intensity is a significant influence of this constantly acting factor on agents (e.g., a significant drawback of the limiting resource).
- Low stress intensity is an insignificant influence of the stress factor (e.g., sufficiency of resources).
- Disturbance is an external factor periodically leading to full or partial agent damage (e.g., global financial crises, natural and / or technogenic catastrophes).
- High disturbance intensity is repetitive and significant damage to the agent impact.
- Low disturbances intensity is rare and weakly damaging agent external impacts.

		Stress intensity	
		Low	High
Disturbance intensity	low	Competitive strategy (C)	Stress-tolerant strategy (S)
	high	Ruderal strategy (R)	Impossible existence

Fig. 3 - Correspondence of strategies to phases of the market life cycle [2]

Displaying strategies in the triangle of competitive behavior strategies
According to the table (Fig. 3), one can determine the stages of the market development in the same way as goods development on the BCG matrix: high disturbance intensity and low stress intensity - R (the origin stage) → low disturbance intensity and low stress intensity - C (accelerated growth stage) → low disturbance intensity and high stress intensity - S (slow growth stage) → high disturbance intensity and high stress intensity (the recession stage).

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III. IDENTIFICATION OF COMPETITIVE BEHAVIOR STRATEGIES FOR AGENTS BASED ON EMPIRICAL DATA

The systemotechnical analysis of the agent behavior and the rationale of the three basic types of strategies enable to establish the correspondence between the previously known classifications, compiled by generalizing the results of empirical observations of the market development.

However, there are secondary behavior strategies, that represent a combination of basic (primary). Secondary strategies are clearly seen on the triangular diagram (Fig. 4).

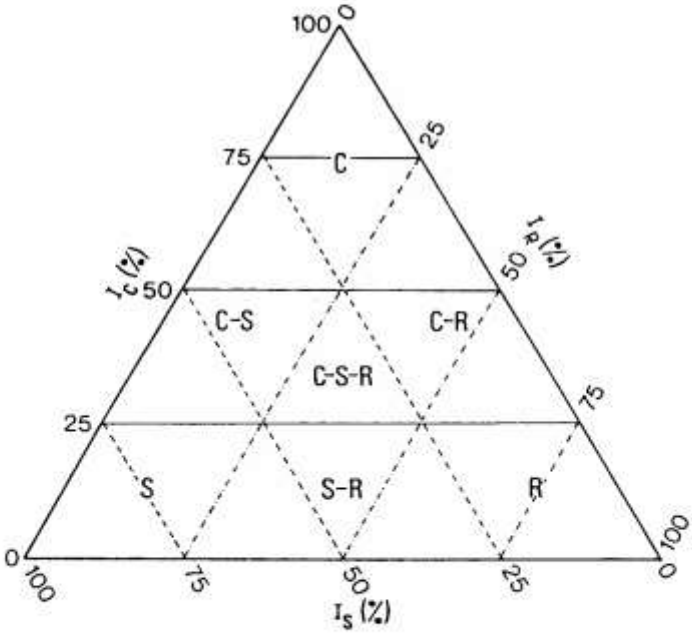

Fig. 4. – A triangular diagram of competitive strategic behavior

Since the agent uses all of his opportunities and efforts to confront these three types of the external impact: stress, ruderal and competitors (S, R, C strategies, respectively), then assuming the total amount of these efforts to be 100%, one can write down

$$I_S + I_R + I_C = 100\%, \tag{1}$$

where *I* - the intensity of efforts to implement the corresponding (S, R, C) strategies in the agent behavior. Only two parameters - stress and ruderal are independent, so one can use the mathematical basis for constructing three-component phase diagrams.

The triangular chart was successfully used to analyze competitive bank behavior strategies; the calculation was carried out according to the value of bank assets in monetary terms [3].

However, the use of a triangular model to determine the competitive behavior strategies of an economic agent is not always possible. To do it, we propose to apply a simulation model of the agent behavior taking into account the changes in parameters of the external environment.

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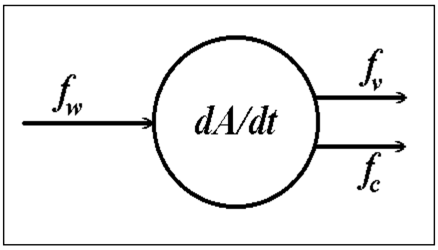

Fig. 5 - Interaction of the economic agent with the external environment

The basis of the mathematical model is the representation of the economic system as an open one, whose development is based on the interaction of input and output resource flows: the input resource flow *fw* (e.g., gross revenue) is distributed to cover the variable *fv* and fixed costs *fc*, and the increase *dA / dt* of own assets *A* of the economic system (Fig. 5).

If there is an external source of resources, the agent input receives the flow *fw* of this resource - the competition object. Of all this flow, the agent transforms as much as his production capabilities allow - that is, assets. In the simplest case the potential volume of transformation is directly proportional to the assets. Variable costs in this case are proportional to the volume of resources being converted.

Thus, the mathematical formulation of the task is based on the “income-cost” agent model and reduces to solving the N (t) system of differential equations, where (N (t) is the number of agents in the system in the time interval [0-t]) (fig. 6)

$$\begin{cases} dA_1/dt = fp_1(A_1(t), AStr_1(t), t) - fv_1(fp_1(t), fw_1(t), A_1(t), AStr_1(t), t) - fc_1(A_1(t), AStr_1(t), t) \\ dA_i/dt = fp_i(A_i(t-\tau_i), AStr_i(t-\tau_i), t) - fv_i(fp_i(t-\tau_i), fw_i(t-\tau_i), A_i(t-\tau_i), AStr_i(t-\tau_i), t) - fc_i(A_i(t-\tau_i), AStr_i(t-\tau_i), t) \end{cases}$$

fvi = fvi(fpi(t), fWi(t), Ai(t), AStri(t), t) – variable costs;
fci= fmi(Ai(t), AStri(t), t) - fixed costs;
fpi = fpi(Ai(t), AStri(t), t) – potential capacity of resource conversion by the agent;
fwi = fwi(Ai(t), AStri(t), L(t), STR(t), t) – resource flow to the agent.

Fig. 6. – The system of differential equations

The system closure is ensured by the condition of saving the resource.

IV. SIMULATION MODEL

The solution of the system of differential equations is replaced by numerical calculation in the medium of cellular automata [4].

The possibilities of cellular automata as the computing environment enable to realize the evolution of complex dynamical systems with a large number of elements that interact nonlinearly with each other.

Parameters of the simulation model

To build the model, the control parameters and the response of the system are set (Fig. 7).

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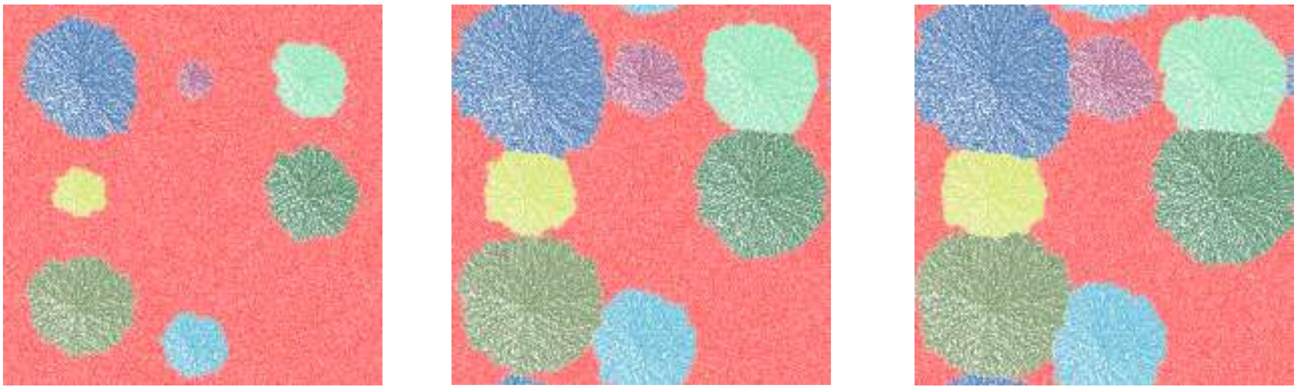

t= 50 t=150 t=300

Fig. 7 - Growth of agents in the simulation model

Setting the laws of local interaction results in avoiding the explicit assignment of the goal of the entire model system development (a necessary condition for evolution).

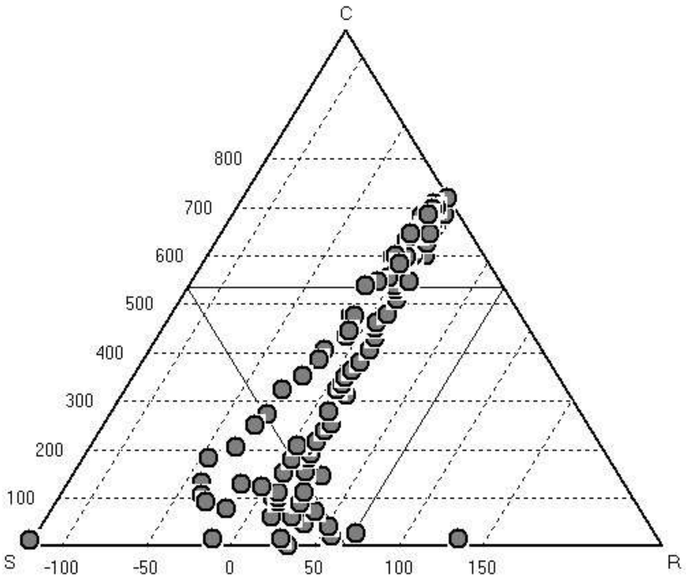

Fig. 8 – A trajectory of changing competitive behavior strategies

When processing the data obtained as a result of the experiments, curves of life cycles of economic agents are constructed. Figure 8 shows the changes in sales volume and the model of changes in competitive behavior strategies in the bending coordinates.

Analysis of individual stages

The analysis of the initial stage of the life-cycle curve obtained, applying a simulation model, is carried out. It corresponds to the stage of "gazelles" development (Fig. 9).

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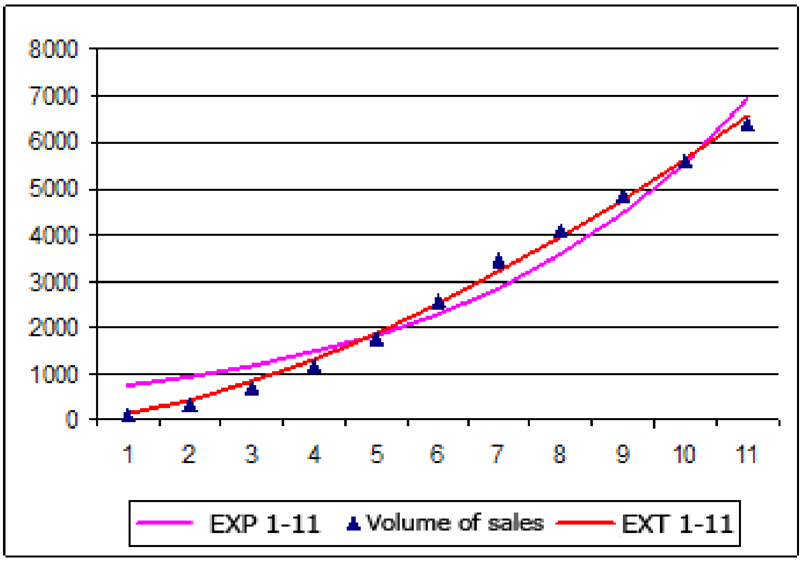

Exponent 1-11		Extent 1-11	
b	606,32952	d	147,4003
a	0,2214878	c	1,581513
SSE	2354123,7	SSE	205727,6
R^2	0,9568219	R^2	0,99624
СКО	709795	СКО	62029,19

Fig. 9 – The analysis of the initial phase of the life-cycle curve

The American economist David Birch defined “Gazelle" as firms growing at a rate of no less than 20% annually, for at least 5 consecutive years.

Characterizing Russian “gazelles”, Professor of the Financial University under the Government of the Russian Federation A. Yudanov notes that the success of such companies results from the fact that each of them found some sort of a highlight for their positioning in the market. It is believed that there is a tendency to exponential growth for “gazelle” development [5].

Approximation of the obtained experimental data at the stage of the accelerated life cycle growth of the economic agent with the help of extent and exponential functions showed that the accuracy is higher for the extent function than for the exponential one.

The exponential growth curve is borrowed from the biological approach when the population development of biological organisms is meant.

The development of “gazelle” firms is due to the maximum coverage of the market segment in geographically remote areas, i.e. opening branches or developing individual “projects”. This development is confirmed by the hypothesis of the possibility describing “gazelle” development as the extent function.

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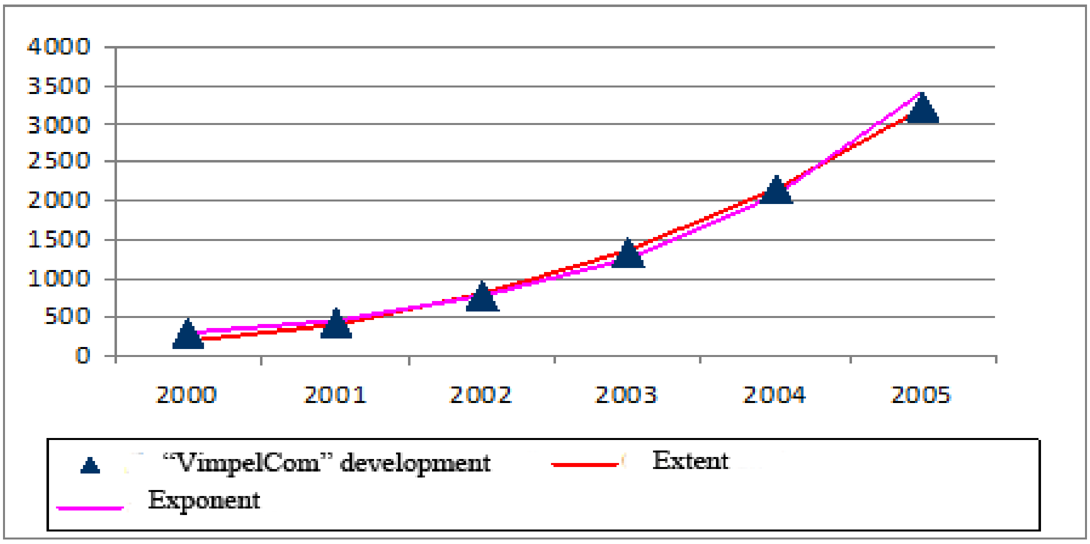

Extent		Exponent	
x	2,96	alfa	0,5
SSE	14442,23	SSE	48848,32
CKO	20,029	CKO	36,836
R^2	0,998225	R^2	0,994888

Fig. 10 - Approximation of "VimpelCom" graphs

We tested the hypothesis of power growth to determine the origins of dynamic "gazelle" development based on "VimpelCom" one (Fig. 10) and approximated the growth dynamics of the company using two kinds of functions: exponential and extent.

The results were similar to those obtained from experimental (model) data. The extent function better describes the stage of accelerated growth of economic agents by a number of criteria. The "gazelle" dynamic growth is associated most often with developing and launching new projects, as the power function evidences.

V. CONCLUSION

The presented tools allow forecasting both on the basis of retrospective data and the simulation method, by changing model parameters. Using the life cycle theory of the economic agent development, it is possible to predict changes in agent development for the prospective period.

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