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AGENT MODELING OF ADVERTISING IMPACT ON THE REGIONAL ECONOMIC CLUSTER LIFECYCLE

The aim of the study is the development and testing of an algorithm for modeling the impact of advertising on various stages of the life cycle of economic clusters. It is assumed, that the life cycle of the cluster consists of the stages: a diffuse group, a hidden cluster, an evolving cluster, a mature cluster, a collapsing cluster. Using the agent-based simulation methods, hierarchical clustering and chaos theory, the following results were obtained: a conceptual model of the behavior of cluster members for cluster formation processes at each stage of the cluster life cycle and an imitation model of the influence of advertising on the life cycle of the economic cluster; the patterns of various stages of the life cycle of the economic cluster and the functioning of the cluster without influence and under the influence of advertising were revealed. Advertising reduces the time at the stages of the associated life cycle of the cluster, increases the stage of maturity of the cluster. Companies that do not comply with the principles of clustering are under the influence of advertising and promotional activities. Such enterprises most often arise in the cluster at the stages of its formation.

Keywords: economic clusters, cluster life cycle stages, advertising and promotion, simulation and modeling, computational experiment

Introduction

Nowadays research in cluster formation processes is becoming urgent. Due to the modern economic tendencies, acceleration of scientific and technological processes leads to increasing numbers of start-ups, development of new production systems and, hence, to the formation and development of cluster structures in modern world economy [1, 2, 3, 4, 5, 6, 7, 8].

In modern science despite high elaboration of cluster perspectives, the research in a life cycle of an economic cluster and the impact of various factors on the cluster life cycle stages remain poorly studied. Therefore, it is impossible to consider thoroughly these aspects when managing the processes of cluster formation under conditions of highly changeable modern economy.

The further development of the theory of regional clusters and their management requires to use the methods of simulation techniques and to conduct computational experiments, which in their turn actualizes the development of appropriate methodological tools.

Bibliographic analysis shows that in recent years modern science is actively solving the problems of cluster structures and is developing economic clusters' conceptual models including their life cycle [9, 10, 11]. It is analyzing evolutional changes in economic clusters [12, 13], simulating economic clusters' life cycle with the help of various techniques including chaos theory in order to study regularities in cluster development under different conditions [4, 14, 15, 16, 17].

Special attention in studying cluster formation processes is paid to evaluation of the impact of various factors on formation and functioning of economic clusters, for example the influence of the resources available or how a cluster interacts with other clustered structures.

At the same time, the problems of actors' behavior at the market and the changes under the influence of various factors on the life cycle of an economic cluster are not successfully solved. One of the major factors to modify the actors' behavior is advertising and promotion. Therefore, they influence greatly on the formation and functioning of economic clusters.

All the above-mentioned considerations define the objective of the study, that is, to develop an agent model of the advertising impact on the life cycle of regional economic clusters and its approval by conducting computational experiment.

Methodology

In the research, the regional economic cluster refers to the association of independent non-institualized economic reflexive entities in the joint arrangement, based on proximity (territorial, sectoral, cultural), complementarity (product, resource, and process), interconnectivity (material, immaterial, information) [18].

Hereinafter the regional economic cluster will be referred to as cluster.

The subject of cluster is the agent, whose behavior depends on the vectors of parameters, specifying agent's views and preferences.

In the cluster formation processes two types of agents are involved: agents-manufacturers and agents-consumers.

Agents-manufacturers involved in production and they can be divided into two subtypes:

- Agents-manufacturers producing goods or products of cluster;
- Agent-manufacturers producing necessary resources to produce cluster products.

Agent-consumers purchase and use the cluster products.

Agents-manufacturers' behavior is determined by the ability:

- to purchase necessary resources in sufficient quantities to satisfy their needs (views);
- to manufacture cluster products or resources necessary for production processes of cluster in sufficient quantities defined by the market volumes and predefined indicators maximally relevant to ideas and views of agents-consumers about the products (resources);
- to organize advertising campaign and promotional activities designed to increase the volume of sales of manufactured products or resources;
- to restructure production aimed at amending the indicators of the manufactured products to increase their attractiveness for consumers.

The main aim of agents-manufacturers is to gain maximum profit from sale of their products or resources.

Agents' behavior is determined by the ability of consumers to purchase the cluster products satisfying their requirements (needs). This aspect generates the main aim of agents-consumers. Agents-consumers purchase cluster products in case the differences between vectors, characterizing the cluster production and their needs are less than the specified threshold.

The behavior of agents depends on commercial advertising. Advertising is a set of information flows, to increase the number of agents-consumers purchasing the attractive cluster products [19].

Clusters like all economic actors have their own life cycle, which includes the following phases or stages.

- defuse group;
- latent cluster;
- developing cluster;
- mature cluster;
- collapsing cluster [20].

The initial phase in cluster development is defuse group. This stage is the starting and the final point at the same time in cluster functioning when cluster as a system breaks down.

The processes of cluster formation are absent in defuse group. At this stage, an economic entity, which then emerges in the cluster in the course of cluster formation, is only a set of interactions of the above-mentioned agents in a framework of manufacturing and selling activities. There are no information, tangible and intangible flows binding these agents into a unified single system that possesses synergy and emergentment properties. The agents of each type are not involved into the entire net that allows cluster to develop and function.

At the latent stage of a cluster, the processes of cluster formation are starting to develop a real cluster as a result. At the birth stage (cluster formation), cluster products varies significantly in their indicators, the output production by agents-manufacturers remains either constant or slightly increasing. The volumes of purchased products by agent-consumers remain at the same level or slightly increase as well. Also, the indicators defining the use of funds by agents-consumers and product purchase by agents-manufacturers are slightly changed. In the latent stage of cluster formation, the accumulation of cluster resource potential is necessary for the transition to the stage of development. Within this stage, the marketing research is aimed at examining the individual preferences of consumers, and the restructuring processes run aimed at decreasing differences between the products manufactured by the agents-producers of cluster. The restructuring of production processes terminates the latent stage of cluster life cycle. This determines that at the latent stage of cluster the bifurcation points appear on the graphs characterizing various indicators of agents.

At the stage of cluster development, output of manufactured and purchased products intensively grows; differences between the products produced in cluster are minimal.

At the stage of mature cluster, intensity of the processes of cluster formation is maximum, but the volumes of produced and purchased products vary weakly; differences between the products produced in cluster are minimal. The internal capacity of the enterprises that are the members of cluster is increasing. Further development of this capacity increases the entropy of cluster by finding new trajectories of its evolution, innovation, including sabotage. These processes contribute to the transition to the stage of cluster decay and collapse.

At the stage of collapsing cluster, the volumes of produced and purchased cluster products are decreasing; new products appear on the market, the difference between cluster products increases. At this stage of the cluster's life cycle, the processes of cluster formation are slowing and then completely stop, and cluster moves into a phase of the life cycle, in which there is the above-mentioned processes, it is the diffuse group phase.

Results and discussion

As the analysis done by the authors of the article shows, the most significant in the cluster development is the latent phase of cluster. It is the stage when the resource potential is formed determining the terms of the development and maturity phases, and, consequently, the life cycle of cluster. These considerations define the choice of the latent cluster lifecycle stage for modeling and conducting the computational experiment. Study of advertising impact on the cluster life cycle is developed for the above-mentioned stage of the cluster life cycle operation.

We are going to describe briefly the agent model.

For the agent model of cluster formation, the participants are divided into two types: agents manufacturing cluster products and agents consuming products. Resource-producing agents are not included in the model.

When modeling, the accepted assumption is that the agents-manufacturers produce only one cluster product, the agents-consumers purchase it and they spend all their funds available for the purchase, if the cluster products correspond to their needs or views.

When modeling, logistics and warehousing tasks are not considered, i.e. the output is equal to the volume of production purchased by the agents-consumers.

The agents-manufacturers produce cluster products; the number of the manufacturing agents is 5. Every of them manufacturers the products, characterized by the specified values of vector of indicators of attractiveness of these products for the agents-consumers. We can call this vector as attractiveness vector.

Every agent-manufacturer produces products with the unique attractiveness vector values. The values of this vector are changing in the course of production restructuring by the manufacturing agents.

The following indicators are included into the specified vector:

- adaptability (this figure varies in scores ranging from 0 to 5, 0 corresponds to the minimum value, 5 – maximum);
- quality (the indicator score ranges from 1 to 5 from minimum to maximum);
- price (ranges from 120 to 200 C.M.U.) .

The agents-consumers while purchasing the products of cluster are guided by the values of preference vector when choosing the cluster products, which include the following factors that are similar to the values of the attractiveness vector:

- adaptability;
- quality;
- price.

The agents-consumers purchase products in the case if the values of the distance between the above vectors is less than the specified threshold value. When modeling we use the Euclidean distance calculation.

In the initial cycle of modeling time, agents-manufacturers have zero funds. The increase in funds is due to the purchase of manufactured products by the agents-consumers minus the expenses on manufacturing products, on advertising, on restructuring of production.

The total number of agents-consumers in the initial cycle of modeling time is of 1000. Their number increases by 20 % in a cycle of modeling time when shooting the advertising and promotional campaign; in the next cycles of modeling time, the number of the consuming agents returns to the original values.

The computational experiment is conducted for seven classes of agents-consumers. In each class, the number of the agents-consumers is different: in the first class it is 150, in the second class it is 270; in the third class it is 210; in the fourth class it is 70; in the fifth class it is 120, in the sixth class it is 160; in the seventh class it is 20.

Each class is characterized by the same values of the funds for every agents in the initial cycle of modeling time as well as identical values of preference vector while choosing the cluster products, which defines the agents-consumers' wish or reluctance to purchase cluster products. Each class of all agents-consumers has the same thresholds that characterize the differences between the preference vector while choosing the cluster products and the attractiveness vector.

The funds of agents-consumers spent on purchasing cluster products have the initial value and increase this value in every cycle of modeling time. If a consumer does not use the funds to purchase products in cluster, the funds are saved and can be spent in the next cycle of modeling time.

The latent stage of cluster life cycle begins with the first cycle of modeling time and ends with the production restructuring carried out by all agents-manufacturers based on marketing research conducted.

The marketing research using mathematical clustering method is simulated by calculating the values of generalized preference vectors for consuming agents while choosing cluster products. The Ward hierarchical clustering method is used in the research [21]. For each selected agent-consumer group the generalized preferences vector is calculated with mathematical clustering method to choose cluster products as a mathematical cluster profile. The number of developed mathematical clusters defining the agent-consumer groups taking into account the original agent-consumer groups determines the number of the vectors specified. Independent firms are supposed to do the marketing research. It is free for manufacturing agents and its results are available for them.

Based on the developed generalized preferences vectors for agents-consumers to choose cluster products, the agents-manufacturers run the restructuring of production. The values of cluster product attractiveness vectors are changing through approximating to the agent-consumer generalized preferences

vector while choosing the cluster products in order to reduce threshold value that defines the distance between vectors characterizing the cluster products and the agents-consumers' wish to purchase these products.

Production restructuring is based on capabilities of every class of agents-manufacturers, that is, the agents-manufacturers cannot completely and totally change their products, in such a way that all indicators of the values of product attractiveness vector would coincide with generalized preferences vector for agents-consumers while choosing the cluster products. In restructuring the agents-manufacturers can partially change product attractiveness vector in order to approxiate to the generalized preferences vector for agents-consumers while choosing the cluster products. Production restructuring can be done gradually by partial accumulation of funds - 60% of what is needed.

The simulation is performed with the use of programming language Phyton 3.

Initial data for computing experiment is shown in Table 1.

Table 1.

Input data map for modeling the impact of advertising on cluster life cycle

Agent type	**The number of classes**		**Parameters of death/reproduction**		
Agents-manufacturers	5		Constant		
Agents-consumers	7		Changing when modeling		
	Agents-manufacturers				
	1	2	3	4	5
Indicators of agents-consumers					
Indicators of cluster manufacturing products					
Product manufacturability, score	5	3	5	3	1
Product quality, score	4	2	5	5	3
Product price, conventional monetary units (C.M.U.)	180	130	200	160	140
Product Cost conventional monetary units	100	60	180	90	80
Additional expenses of agents-manufacturers					
Shooting advertising costs, USL. C.M.U.	2000				
Production restructuring costs of, C. M. U.	340000	450000	360000	430000	600000
Restructuring rules[a]					
Product manufacturability, mark	0	0	0	0	+2
Product quality, score	+1	+1	0	0	+1
Product price, C.M.U.	-20	0	-30	-40	+10
Product cost C.M.U.	100	65	140	90	90
Indicators of consumer agents					
	Classes of agents-consumers				
	1	2	3	4	5	6	7
The number of agents in the class, u.	150	270	210	70	120	160	20
Percentage of agents purchasing cluster products before advertising,%	90						

Percentage of agents purchasing advertised cluster products,%	100						
Funding, C.M.U.	1000	1000	2500	1000	2000	3000	4000
Threshold value describing the differences between vectors and preference indicators of cluster products	21	10	8	15	9	5	5
Preference indicators for choosing cluster products							
Product adaptability, score	2	2	3	5	3	5	5
Product quality, score	5	2	3	1	5	5	5
Product price, C.M.U.	150	140	150	120	150	120	180
Modeling time settings							
Number of cycles of modeling time						7	
Model time cycle (tact)						1	
a. These rules are based on the results of mathematical cluster analysis performed on profiles, specifying the attractiveness for agents-consumers. The first cluster includes the agents-consumers of Classes 1, 2, 3, 5; the second cluster includes agents-consumers of Classes 3 and 6. First cluster profile: adaptability of products – 5 scores, product quality is 3 scores, product price – 120 min. C.M.U.; profile of the second cluster: product manufacturability – 3 scores, quality products – 4 scores, product price – 154 min. C.M.U.							

Computational experiment is conducted in two phases.

In the first phase, simulation is developed without promotional advertising aimed at accelerating accumulation of funds necessary for the production restructuring by the manufacturing agents. At this stage manufacturing agents consider advertising as a regular event at the specified cycle of modeling time to change agents-consumers' behavior and increase sales of cluster products.

In the second phase of computing experiment, at the second and third model time cycle, the impact of promotional activities is simulated on the basis of shooting advertising, which changes the number of agents-consumers wishing to purchase the cluster products, thus increasing profits for manufacturing agents.

In the first phase of computing experiment at the simulated life cycle stage, not all of agents-consumers purchase the cluster products. Classes of consuming agents 3, 5 and 6 do not purchase cluster products because of its low attractiveness to them. The agents-consumers of Class 1 purchase cluster products from the agents-manufacturers of Class 4; the agents-consumers of Class 2 – from the agents-manufacturers 5, the agents-consumers of Class 4 – from the agents-manufacturers of Class 2; the agents-consumers of Class 7 – from the agents-manufacturers of Class 1. Therefore, the agents-manufacturers of Class 3 do not sell their products, and therefore they will not be able to restructure production with the necessary rhythm of modeling time and hence go out from cluster forming processes that weakens the whole cluster.

The process of selling-buying the cluster products extends over the entire period that determines the stage of the formation of the cluster life cycle.

The agents 2 and 4 during the second cycle of modeling time accumulate the funds needed for restructuring; during the third cycle, they start restructuring of production in accordance with the rules given in Figure 1. The manufacturing agents 5 accumulate funds in the third cycle of modeling time and start to restructure production during the next cycle of modeling time.

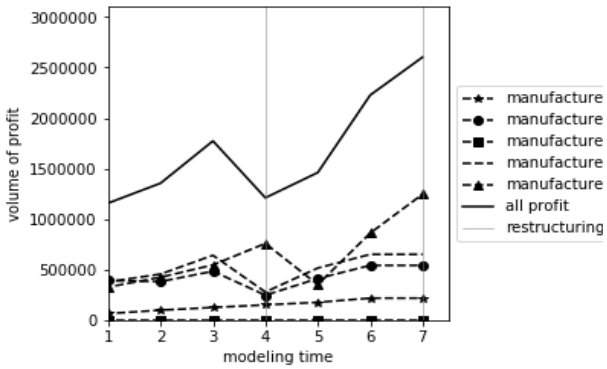
The manufacturing agents 1 during the period studied (seven cycles of modeling time) can accumulate only a portion of funds – about 60 % – needed for the restructuring of production, therefore, they will not be able to change the parameters of manufactured products. If these agents-manufacturers accumulating sufficient funds start changing gradually their production, nevertheless, by the seventh cycle of modeling time, they will not be able to finish completely the production restructuring. In the first case, the agents-

manufacturers cannot transit to a new stage and therefore will leave the cluster. In the second case, these agents-manufacturers with some degree of probability will be able to enter the cluster on the next stage of its development.

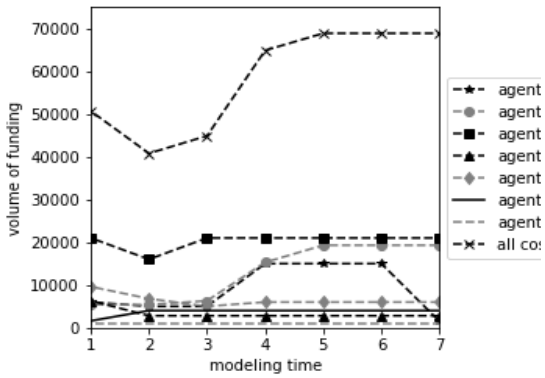
The manufacturing agents 3 do not run the production restructuring due to lack of profit. The agents emerge from the cluster.

The restructuring of production for the agents-manufacturers 2, 4, 5 ends at the sixth cycle of modeling time. At the seventh cycle, preparations start for the transition from the latent stage to the stage of development.

Fig. 1 (a-b) shows the changes in the basic parameters of the agents-manufacturers and agents-consumers when conducting computing experiment at the first stage.



a) Dynamics of profits for manufacturing agents in a modeling time cycle



b) Dynamics of funding changes for agents-consumers

Fig 1. (a-b). Dynamics of changes of the basic parameters of the agents-manufacturers and agents-consumers when conducting computing experiment at the first stage

The second phase of the computing experiment reveals that under the influence of the shooting promotional advertising the period for the cluster formation is shortened. Due to the shooting advertising and promotion, the period of accumulating funds for the restructuring is shortened. The manufacturing agents 2 and 4 at the first cycle of modeling time have already accumulated the sufficient funds for the restructuring of production. After the third model cycle, these agents-manufacturers present products to the market with new cluster indicators after restructuring. The agents-manufacturers 2 have improved the product quality, and the agents-manufacturers 4, in turn, have reduced the cost of production. Using advertising, two agents-manufacturers have managed with one cycle of modeling time to start earlier restructuring with the positive impact on increasing profits in the future.

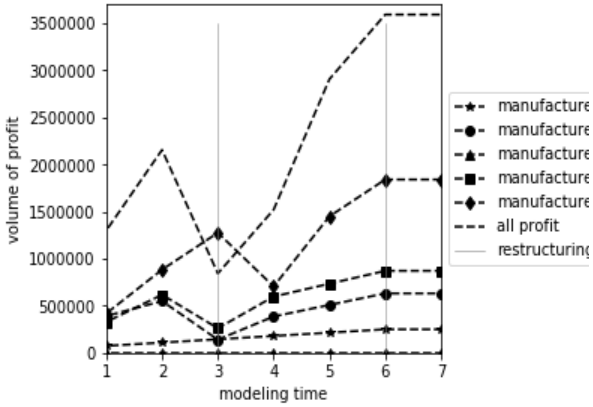
Promotional activities and advertising also affect agents-manufacturers 5, who can accumulate enough funds at the third cycle of modeling time and by the beginning of the fourth cycle of modeling time start the restructuring of production, which allows them to bring the products with the new parameters to the market. Product adaptability has been improved, as well as its quality; its price has risen slightly. This will increase the sales of cluster for this class of agents-manufacturers, which benefits their profits.

Promotional activities and advertising have affected slightly the manufacturing agents 1; profit growth comes slowly, which does not allow accelerating the accumulation of funds at earlier date what having been observed with other agents. The agents-manufacturers 1 will be able to run restructuring of production only on the fifth cycle of modeling time, which negatively affects the profits. Since most classes of agents-manufacturers have already completed the restructuring at the fourth cycle of modeling time, there is a possibility that manufacturing agents 1 will emerge from the cluster at the stage of its formation.

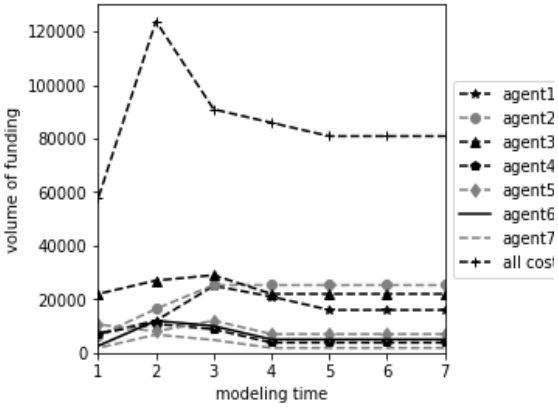
Therefore, without the manufacturing agents 1 and 3 the process of transition from the latent stage to the development stage will start at the fifth cycle of modeling time.

Manufacturing agents 3 do not run the restructuring and emerge from cluster. Promotional advertising has not been effective.

Fig. 2 (a-b) shows dynamic changes of the basic parameters of agents-manufacturers and agents-consumers when conducting computing experiment at the second stage.



a) Dynamics of profits for manufacturing agents in a modeling time cycle



b) Dynamics of funding changes for agents-consumers

Figure 2 (a-b). Dynamics of changes of the basic parameters of agents-manufacturers and agents-consumers when conducting computing experiment at the second stage

Computing experiment reveals the following regularities in impact of advertising on the life cycle of clusters.

1. Advertising promotes growth of profits for manufacturers resulting from sales at all stages of life cycle of cluster that enhances the formation of its resource potential.
2. Advertising and promotion enhance cluster formation by coordinating behavior of consumers, and increasing their number, as well as reducing the time of transition from the stages related to the formation and development of cluster, to the stage of its maturity.
3. For businesses that do not meet the criteria of cluster, advertising and promotion impact is weak, or has no effect. These companies emerge from the cluster at one of the stages of cluster life cycle, most often at the stages of its formation and development.

Conclusion

The research done by the authors of the article identifies the patterns and regularities in the cluster formation process in modern economy as well as the impact of advertising on the life cycle of economic clusters. Advertising shooting positively influences economic cluster functioning and developing accelerating its formation and increasing its life cycle period through increasing the potential of the enterprises involved into economic cluster. That favorably influences not only the enterprises themselves but the consumers of the cluster products as well, as they purchase the products which are more relevant to their needs and which reach the market in earlier time than it could be if the cluster formation processes developed less intensively and the process of cluster formation deaccelerated.

With this, the companies and firms that do not comply with the principles of the functioning of cluster are influenced by advertising and promotional activities either rather poor or not influenced at all. Such firms emerge from the cluster more often at the stages of its formation and development.

The discovered patterns can be used to develop economic activities within regional clusters which form the economic potential of the countries contributing to the industrial development, including innovation, as well as developing the sixth technological mode.

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