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ABSTRACT

The paper presents an agent-based model of networks of firms which decide to collaborate in R&D activities. The aim of the paper is to analyze through simulation which advantages and disadvantages can emerge from the creation of innovation network, network of firms which choose to cooperate with others in the R&D activities.

Keywords: research and development, innovation network, agent-based model, competitive market.

1. PURPOSE OF PAPER

Research and development (R&D) is a strategic activity for a company in order to deal with competing firms by means of the continuous development of new products. For this reason it should be important to know benefits produced by new products in terms of gains and new market shares.

The objective of this study is to understand the advantages a firm can obtain in terms of costs reduction to support the innovation, when it creates a network with other firms interested in introducing new products.

2. RESEARCH APPROACH

The work has been developed in three phases. Initially a literature review has been conducted in order to identify the existing agent-based models which study the dynamics of research and development. The better ones are *Innovation network* di Gilbert et al. (2001), *Industry as an organization of agents* di Pajares et al. (2003) and *Innovate or Not to Innovate?* di Dawid et al. (2001). In particular two models, which are seemed the most suitable, have been chosen among those: *Innovation network* and *Industry as an organisation of agents*. The first model analyses the development of firms' networks for R&D activities. These firms joint their knowledge together and create some coalitions to develop new products. The second one present the dynamics of industries for R&D management. Industries are seen as organisations of firms and consumers and the aggregated behaviour is the consequence of the decisions taken by the individual firms (Pajares et al., 2003).

In the second phase an agent-based theoretical model has been realized. This one contains the best characteristics identified in the two selected models. It allows simulating the politics of R&D activities testing the benefits which can be obtained from a collaborative strategy rather than alone strategy.

Finally this conceptual model is been implemented and simulated in order to test the two strategies and verify the best one which should be followed by the firms.

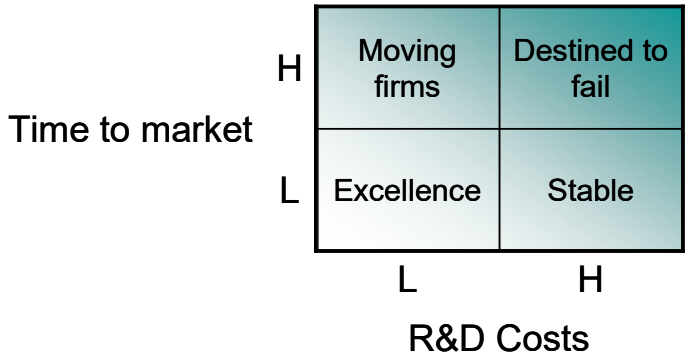
The choice to use the agent-based simulation is suitable because it allows foreseeing possible future situations in virtual laboratories, testing the consequences without venturing one's capital or risking the owned market shares.

3. THE THEORETICAL MODEL

The model simulates a competitive market of firms. The agents of the model are the firms. These are divided in two groups: the collaborative firms, which follow a collaborative strategy, and alone ones, which follow a strategy of isolation. At every moment of simulation the collaborative firms create a network with other collaborative firms in order to make a product innovation. So these firms divide costs for the R&D activities, but also the gains which could earn. Instead the alone firms work alone, they don't create an innovation network. These firms must support every R&D costs, but they will have every gain from the innovation.

The agents are purely reactive, they haven't memory of the previous states of the market, of their actions and the choices which they made, but at every moment of simulation they observe the environment and react to the situations. So at every moment of simulation the innovation network could change with different agents of the previous step.
The market is designed by a matrix 2x2 and symbolizes the business environment in which firms or networks of firms are dynamically placed according to the R&D costs and time to market.

Figure 1 – Structure of the market



The *x* axis symbolizes the R&D activities' costs, while the *y* axis symbolizes the time to market. The evaluation of firm's abilities and capabilities will drive the choice of partners to create the innovation network. After their activities of collaboration the firms and networks will move them in the market in relation with gains and R&D costs.
The aim is to reach the excellence zone characterized by low R&D costs and low time to market. More the firms earn more they have the possibility to survive and to remain in the market reinvesting their gains in new R&D activities.
When firms or networks of firms are in the excellence zone, they will have greater gains, gain market shares, increase the number of customers, etc.
When other firms enter in the zone of excellence, imitating the combination of costs and time to market of the first firms in it, this zone separates its own from the rest of market becoming a new 2x2 matrix and the competition will start again.

4. THE COMPUTATIONAL MODEL

4.1. THE AGENTS

In the computational model the agents are represented by several parameters. These are their position, coordinates *x*, *y*, nature, collaborative firm or alone one, level of experience, competence, capabilities and abilities to use a capability, corporate assets, which vary during the simulation, R&D costs and gains. The initial values are random fixed. At every simulation step the firm's ability changes simulating the firm's need to try new abilities.
During the simulation the aim of every firm is to improve their gains so the firms try to reduce R&D costs and time to market and to increase the gains coming from the commercialization of the new product.

4.2. THE MARKET

It is implemented like a grid: the *x* axis represents the R&D costs, while the *y* axis represents the time to market. The R&D costs increase from left to right along the axis, the time to market increase from the bottom to the top. *0,0* is the optimal position, in the bottom left position.
Every cell of the market has a value of R&D costs, time to market and elevation. Elevation is a value associated to a cell of grid and fixes the gains of a firm in that position in relation with R&D costs and time to market. The elevation isn't distributed uniformly.

4.3. THE RELATIONS OF THE MODEL

Elevation

The firms during the simulation move themselves in cell with elevation higher to improve their gains and their corporate assets.

The gains are proportionate to the value of elevation of the position taken and the value of firm's experience level. At every step the firms can increase their own experience to simulate the efforts of improvement which every firm makes in reality. Every firm can make R&D activities even if its corporate assets is not much.

The environment, market, is been divided into five different zones in relation with the values of elevation. For low values, negative also, the improvement of experience is minimum. The low level elevation zones are placed in the top right of grid, the high level elevation zones are placed in the bottom left of grid. So moving to lower costs the increase of elevation is more evident.

Partnership

This property is characteristic of the collaborative firms and simulates the creation of partnership for R&D activities.

The collaborative firms create a collaboration with other firms in order to work together in the R&D activities. The selection of the possible partner is a research of firms with the same capabilities and abilities. When a firm meets a possible partner, it checks if it has another collaboration link with other firms and, if it isn't, it creates a partnership.

R&D Costs

During the simulation every firm makes a R&D activity which produces some R&D costs. These are proportionate to the firm's position in the environment and depend to nature of the firms. In fact the R&D costs vary for collaborative firms and alone ones. If the collaborative firm has a partnership with another, the R&D costs are lower.

If firm A, alone, has a position x on the axis of R&D costs, these costs will be: $costs_{R\&D}(Firm_A) = x*200$, 200 is a coefficient. If n collaborative firms, $Firm_{C1}$, $Firm_{C2}$, …, $Firm_{Cn}$, have the same position x on the axis of R&D costs and they are in partnership, their R&D costs will be: $costs_{R\&D}\ (Firm_{C1}) = costs_{R\&D}\ (Firm_{C2}) = costs_{R\&D}\ (Firm_{Cn}) = (X*200)/n = (costs_{R\&D}\ (Firm_A))/n$, where n is the number of firms of network.

A collaborative firm will have the same costs of an alone one, if it isn't in partnership.

Gains

The firm's gains come from the successful R&D activities. These gains are the same for a collaborative firm, not in partnership, and an alone one. These will be: $gains(Firm_A) = experience*elevation$. The gains for collaborative firms in partnership are like: $gains(Firm_C) = experience*elevation/n$, where n is the number of firms of network. So it is simulated the division of gains like real firms.

5. SIMULATION RESULTS

At the beginnings of simulation every firm is placed random in the environment and they have a random values of some parameters, like experience, capability, ability, ect. At every simulation step the firm verifies the level of experience, so it looks for the neighbouring position with value of elevation higher and it move itself calculating R&D costs and gains.

At the beginnings of simulation the first corporate assets value of every firm is fixed proportional to the level of firm's experience. When it is negative, it generates the death of the firm. At every step of simulation the firms have some R&D costs, but they have also some gains in relation with their position in the market (grid) and their level of experience. These values vary the firms' corporate assets.

The parameters varying during the simulation are: the number of firms, collaborative and alone ones, from a minimum of 25 to a maximum of 50, and the number of tries of collaboration, which a firm can try to create, from a minimum of 0 to a maximum of 10.

The parameters evaluated are: the variation of number of firms in the excellence zone, the variation of R&D costs of collaborative and alone firms and the final corporate assets.
The simulation proceeds varying step by step the number of tries of collaboration and number of collaborative and alone firms and calculating for each value the other parameters: number of firms in the excellence zone, R&D costs and final corporate assets.
In this evaluation we consider the case with 50 collaborative firms and 50 alone ones; the most complicated case. If the number of tries of collaboration is 0, the collaborative firms have the same results of the alone. If the number of tries of collaboration increases, the collaborative firms, which reach the excellence zone at the end of simulation, are much more and more than the alone ones.
Three zones of R&D costs and corporate assets are been created. In these zones the firms shall be at the end of simulation. If the number of tries of collaboration increases, it verifies a reduction of the number of collaborative firms in the zone with a corporate assets higher. In fact in this situation there are much more firms in the medium zone, because these firms must divide their gains with the other firms of the network.
If the number of tries of collaboration increases, the collaborative firms can reduce their R&D costs. So they enter in zones with lower R&D costs and higher corporate assets.
So from the simulation results emerges that it more convenient to create network of firms for R&D activities, innovation networks, because the costs are lower, even if the gains are lower cause the need to divide them.
In the complex the collaboration is the better choice.

6. CONCLUSIONS AND NEXT DEVELOPMENTS

The paper presents an agent-based model which studies the dynamics of research and development with the aim to define the most effective politics for the innovation.
It is demonstrated with simulation that the creation of partnership between firms could make better the R&D activities and could reduce the costs. The analysis has underlined like the development of a partnership creates a competitive advantages. So it is possible to reach good positions quickly in the market generating a reduction of costs.
The possible coming developments are the use of cognitive agents which memorize the past collaborations, the use of a environment-market which varies with the actions of firms. It should be interesting to test the validity of the model in the real firms.
Thanks to this model, the firms could anticipate their possible positions in the market, later on to the creation of a new product, or could evaluate the benefits which can come from the collaboration with other firms.
Finally it allows the analysis of the consequences of the cooperative and collaborative behaviours which firms could decide to adopt during the innovation process.

7. SHORT REFERENCES[1]

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[1] Complete references will be available on request.