An Evolutive Model of Knowledge-Based Organizational Populations

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In this paper we develop an evolutionary agent-based simulation model derived from a knowledge-based theoretical framework and use it to explore the effect of knowledge management strategies on the evolution of a group of knowledge-intensive organizations located in a given geographical area. We then present the results of different runs of the simulation model.
Keywords: *knowledge management strategies*

1 Introduction

The study of organizational populations introduced a new perspective into the organizational literature (Carroll and Hannan, [3]). Instead of concentrating on the characteristics of individual firms, the focus was broadened to accommodate a whole industry or set of firms, selected on the basis of some specific criteria. As organizations have to live in an environment that is mostly made up of other organizations such as competitors, suppliers, clients or institutions, it makes sense to look at the co-evolution of all of the firms belonging to a geographical cluster, an economic sector or a whole industry.
Research on organizational evolution has been driven by two conflicting approaches (Levinthal, [5]). One perspective has focused on the process of adaptation of individual firms to the environment, while the other has emphasized the variation and selection of organizational forms as a way for a population of organizations to survive. To the first group belong two works: The behavioral theory of the firm (Cyert and March, [4]) and an evolutionary theory of economic change (Nelson and Winter, [6]). The second group is represented by the organizational demography perspective (Carroll and Hannan, [3]). Lately, there seems to have emerged a consensus that these two views are complementary (Levinthal, [5]).
The two competing approaches presented above have adopted different attitudes towards knowledge. The broad perspective adopted by organizational ecologists and demographers of organizations is that, as entities, they are seldom able to adapt to their environment because of their structural inertia ([3]). They therefore lack any capacity to learn or create knowledge.
The evolutionary theory of economic change proposed by Nelson and Winter ([6]) adopts a very different approach. In this case, evolutionary mechanisms are applied not to individual firms in a population, but to elements of organizational knowledge that take the form of *routines*. Here, knowledge management becomes, in a sense, the management of routines. Nelson and Winter, however, do not analyze the impact of such mechanisms on the evolution of the organizational population.
In this work we will explore this complementarity by simulating the effects of individual knowledge management strategies on the evolution of organizational populations. We propose to pursue a non-classical analysis of the two different levels through the use of agent-based simulation modeling. Knowledge management strategies are incorporated into the behavior of individual agents, and their effect at the population level is assessed through the analysis of emergent patterns detected in the population of agents once the simulation runs have been performed.

2. Agent-based simulation of Knowledge-based Organizational Populations

The objective of this research is to use agent-based simulation to study the evolution of specific strategic options within a population of organizations as well as the influence on this evolution of progress in Information and Communication Technologies (ICT).

The simulation model we propose in the present work is an extension of *SimISpace* (Boisot et al., [1],[2]). *SimISpace* is an agent-based simulation consisting of a group of agents each possessing different knowledge assets.

Our model modify *SimISpace model* in order to study the knowledge management behavior of firms located in space. In this model, different agents, each representing a firm, hold a number of knowledge assets and interact in a Schumpeterian regime characterized by the obsolescence of knowledge assets, their uncontrolled diffusion, and a general atmosphere of creative destruction (see also Boisot et al., [2]).

Given the importance of spatial factors in the diffusion of knowledge—as mentioned before—we have added a spatial component to the model of Boisot, allowing us to place our agents in a physical space. Then the agents represent interacting firms belonging to a given industrial sector but assigned to different regional locations. Also, since we are interested in the knowledge management strategies pursued by firms, a new feature has been added by us: the option of assigning different knowledge management strategies to a given agent.

3. The proposed evolutive model

This agent-based simulation model is characterized by mixture of competition and collaboration between agents. The model is populated with agents that carry knowledge assets in their heads. Each of these knowledge assets has a location in the Informational-Space that changes over time as a function of diffusion processes as well as of what agents decide to do with them. These have the possibility of exchanging their knowledge assets with other agents or to invest in the development of new knowledge. Knowledge assets can also grow obsolete over time.

Our simulation model represents a population of knowledge-intensive organizations located in a given region of space. As is usual in simulation models ([7]), our representation of the spatial setting is very schematic. We use a grid 80 cells wide by 80 cells high in which to locate the agents. Several agents can occupy the same cell simultaneously. At this stage of the model's development, we take the space that agents occupy to be isotropic—that is, without geographical irregularities.

At the moment of his creation, each new agent is assigned a grid location in the space that is stored as variables X and Y in his set of internal variables. The agent will remain at that grid location for the duration of its life within the simulation. Both agents created at the beginning of the simulation as well as new entrants in different periods are assigned grid locations at random.

Strategies for managing knowledge assets — that is, agent preferences for working either at high levels or at low levels of knowledge structuring—i.e., of codification and abstraction—, and agent preferences for either blocking or not blocking the diffusion of knowledge—are represented by two internal variables for each agent: KSS and DBS. These strategies are fixed for a given agent at the time of its creation and are incorporated in the agent's internal variables.

If the *knowledge-structuring-strategy* variable (KSS) for some agent, for example, takes the value 1, each time that the agent makes an investment in research, it goes in the direction of increasing the degree of structuring. If, on the other hand, the value is 0, investments in research go to decrease the degree of structuring and to increase the tacitness of the knowledge in question. The same goes for the *diffusion-blocking-strategy* variable (DBS). If it takes the value 1, the agent's preference will be for blocking the diffusion of knowledge, while if the value is 0 his preference will be for not blocking it.

The effect of Information and Communication Technologies (ICT) dynamic development is implemented in our model by focusing on the diffusion effect. We use our model to explore this phenomenon. For this, we introduce a general variable that reflects the extent to which the diffusion of knowledge—

both intended or unintended—is impeded or not by the physical distance between interacting agents. The general variable β that we introduce into the model measures the level of development of ICT. In effect, β is directly associated with the level of ICT development. Higher values for β thus increase both the diffusion effect and the bandwidth effect, facilitating the diffusion of knowledge between agents at different grid locations.

The calculation of the probability of interaction between agents, therefore, incorporates the influence of spatial distance *r*, taking the form of an exponential probability distribution: $p_{interaction} = \exp(-\frac{r}{\beta})$.

The evaluation of an agent (the *fitness* or utility function) takes place at each step of the simulation. At the beginning, each agent posses an standard valuated asset of knowledge of initial level *KL=1,* and a fixed management strategy formed by a discrete time series of values for the pair (KSS,DBS):

Agent→(*KL*; *KSS[1],DBS[1],KSS[2],DBS[2],…,KSS[n],DBS[n]*).

Each agent can invest half of the value of his asset into the development of the knowledge, obtaining after a time $t1=t0+2$ steps the triple value of the investition, if the variable *KSS[t0]=1*, or can interact with any other agent from the grind at a given time *t* by exchanging knowledge with probability $p_{interaction}$ (depending on distance), if the values of the variables *DBS[t]* is zero for both agents. The exchanged knowledge increase the value of *KL* with the value of received asset. Finally, the level of Knowledge value *KL* for an agent decrease at each step with *d*=10%, to simulate the obsolete information. After *n* steps, a percentage *ob=20%* of the agents are removed and an equal number will be created, in order to keep the most performing strategies (bad performers are removed and goodperformers stay on to spread their characteristics through inheritance). This is the evolutive step of the model.

5. Simulatios and Results

For each run, the simulation starts with a population of firms within which the values for the Knowledge Structuring Strategy (KSS) and the Diffusion Blocking Strategy (DBS) are distributed at random.

The initial distribution of strategies in the population is therefore roughly uniform. Approximately 50% of the agents will have KSS = 0 and 50% will have KSS = 1. The same goes for DBS. The value of *n* (the generation life period) was fixed at 25, and the number of generation fixed at *g=10.*

Among the 1000 agents that are present in the simulation during the last 250 periods, we observed a clear dominance of the "not-blockingdiffusion" strategy (predominant *DBS[t]=1*), and a broad equilibrium between the "knowledge-structuring" (predominant *KSS[t]=1*) and the "knowledge-unstructuring" strategies (predominant *KSS[t]=0*), but one slightly biased in favor of the second one (**Figure 1**).

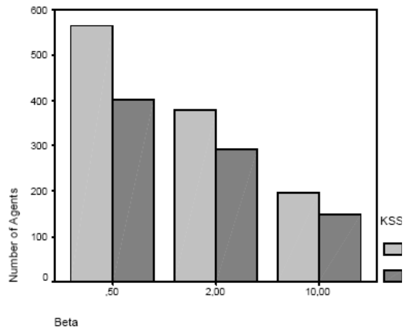

Fig.1. Dependence of the number of dominant strategies on the factor β

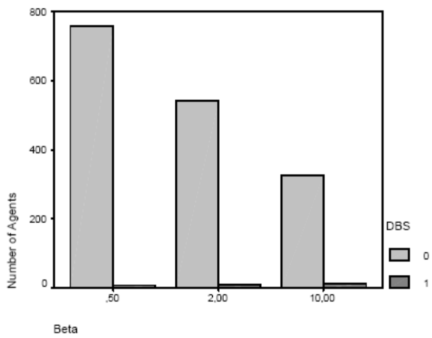

Fig. 2. "not-blockingdiffusion" strate-gies vs. "blocking " strategies

The residence time in the simulation of agents with a preference for blocking diffusion is clearly shorter than that of their non-diffusion-blocking counterparts (**Figure 2**), which is consistent with the fact that they evolve to a very low proportion of the population. However, no significant differences are found between the residency times of “knowledge-structuring” and “knowledge unstructuring agents.”

6. Final remark

Our paper points to some other interesting avenues for further research. The inclusion in the model of a spatial dimension in the interaction of agents facilitates an analysis of the spatial behavior of organizational populations, something highly relevant to the study of industrial clusters or regional economies. The specific influence of knowledge management strategies on spatial location patterns constitutes a promising avenue of research. Applying the simulation to more concrete problems would allow for a better calibration of the model using real data and, consequently, for an easier and more fruitful interpretation of the results.

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