M@n@gement

ISSN: 1286-4892

■ Isabelle LEROUX
Alain BERRO 2010

Public/private negotiation and strategic co-evolution in a biocluster

M@n@gement, 13(1), 38-69.

accepted by Jean-Luc Arrègle

M@n@gement vol. 13 no. 1, 2010, 38 - 69

Public/private negotiation and strategic co-evolution in a biocluster

Isabelle Leroux

GRANEM – UMR MA 49
Université d'Angers et Agrocampus Ouest
UFR Droit Economie Gestion
isabelle.leroux@univ-angers.fr

Alain Berro

IRIT-UT1, UMR 5505, CNRS
Université de Toulouse
alain.berro@irit.fr

Abstract

Clusters are characterised by partnership practices that lead to a high level of competitiveness. However some of them encounter coordination difficulties due to conflicts over the appropriation of collective gains. This is more specifically the case of bioclusters because of their sectoral particularities and because of the different public policies that apply. Stemming from an analysis of conflicts at stake in a biocluster, this article aims at bringing to light how firms and institutions strategies emerge and co-evolve as their actions are characterised by divergent interests. According to an evolutionary perspective, we propose an exploratory simulation leading to an analysis of the mutual adaptation dynamics developed by the agents involved. The results show on the one hand that firms adjust their bargaining strategies according to uncertainty and to their perception of the gains which might be generated at the collective level. On the other hand, the model shows that local authorities can play a regulatory part in the game. This exploratory research provides insight into management public modalities so as to generate cooperation and innovation within bioclusters.

Key-words

Cluster, biotechnology, co-evolution, adaptative complexe system.

INTRODUCTION

Over the last fifteen years, research on industrial clusters has developed considerably, with growing interest in the phenomena of localisation, industrial organisation and the spread of innovation (Krugman, 1991; Brezis *et al.,* 1993; Porter, 1998). The notion of cluster is defined by Porter (1998) as a group of geographically close firms and institutions, whose activities are complementary and characterised by a high level of specialisation and technological transfer. The cluster is based on dense inter-organisational networks characterised by cooperative and competitive relations. These robust connections produce collective benefits, such as quasi-rents[1] due to the operation of licences or the effects of the agglomeration (Klein *et al.,* 1978; Zucker and Darby, 1997; Dyer and Singh, 1998; Simonin, 1999). As the OECD's 2007 report shows, the most significant development of geographical clusters has come about through voluntarist policies in activities linked to health, the environment or seed production, such as the Medicon Valley on the border between Denmark and Sweden. These policies of developing and supporting bioclusters are giving rise to renewed interest on the part of organisational science researchers.

While the literature on biotechnology clusters focuses mainly on the high level of competitiveness in such systems of innovation, some studies relativise these successes, emphasising coordination difficulties linked to conflicts over the sharing and redistribution of resources and collective benefits (Owen-Smith and Powell, 2003). This is especially the case of biotechnology clusters due to three characteristics specific to them. First, biotechnologies involve strong interconnections between plant, animal and human biology (Argyres and Liebeskind, 2002). This cross-disciplinarity requires that research communities unaccustomed to working together open up to one another. Second, within biotechnology clusters, small firms are particularly dependent on the big industrial groups in pharmaceuticals and seed production, their cooperation forming an asymmetric alliance (Yan and Gray, 1994). This organisation, described by Roijakkers *et al.* (2005) as a dual market organisation, is often marked by a climate of mistrust, with the small firms seeing their negotiating power diminished in the face of the large groups. Finally, since biological research is not easily understood due to its technical nature, those in the public sector responsible for financing research programmes are extremely cautious when making funding decisions (Leroux, 2004). The question of genetically modified organisms is highly controversial, and so potential public reactions to such decisions must be considered. Another difficulty is that they are subject to pressure by the large industrial groups (Bonardi *et al*., 2005). They therefore need to weigh up the demands of local development, the interests of the large groups and the perception of what public opinion might make of support for research in controversial areas.

A complex collection of negotiation strategies emerges from all of this, and the firms' goal is to get the resources or collective benefits for themselves. Following this, the matter for the decision-makers' attentionis that of the co-evolution of strategies in the context of uncertainty

1. The notion of quasi-rent enables the identification of revenues arising from the association of two complementary assets in a cooperative situation. The gains generated by the financial externalities that occur in clusters are thus known as organisational quasi-rents.

about the behaviour of the partners. Co-evolution refers to the fact that the firms and institutions adopt evolving strategies without, however, being autonomous or self-adapting (Koza and Lewin, 1998; Bourguin and Derycke, 2005) inasmuch as they take into account the partners' strategies, and the impact of those strategies on the biocluster. Co-evolution refers to continuous negotiated and situated adjustments between the different actors involved. While the notion of co-evolution is used in research literature to deal with technological diffusion (Suire and Vicente, 2004; Steyer and Zimmerman, 2004) and environmental adaptation (Lewin and Volberda, 1999), it is little used in developing ideas of actors' strategies and their impact on the system as a whole. In reflecting on appropriation conflicts liable to divide firms and instit tions, the objective is to understand how these actors' strategies emerge and evolve during negotiations for the sharing of collective gains. An exploratory study, based on a simulation model, sheds light on the mutual adaptation mechanisms at work. Its results expose the dynamics at work within the different stages of negotiation strategies within a cluster, and reveal the regulatory role of the institutions. This study, therefore, paves the way for several lines of research in the public management domain as applied to clusters, and particularly the management of cooperation and innovation in local systems.
The first section of this article presents the state of the art. In the second section, an exploratory methodology based on simulations is offered, the results of which are presented in the third section. The fourth and final section is dedicated to a discussion of the results.

PUBLIC/PRIVATE STRATEGIC CO-EVOLUTION IN BIOCLUSTERS

Numerous offerings in economics and organisational science raise questions regarding the appropriation and vulnerability of clusters according to different analytical views. Starting with an analysis of technological diffusion (Arthur, 1994), this paper goes on to look at problems linked to public policy decisions (Feldman and Massard, 2002; Bona di *et al.,* 2005) before finally focusing on approaches defining the different sources of opportunism and uncertainty surrounding the behaviour of partners (Klein *et al.,*1978; Zucker and Darby, 1997). Following, an approach to the cluster as the locus of co-evolution of local firm-institution strategies is offered (Arthur *et al.*,1997).

public/private strategies and appropriation conflicts in bioclusters

Cluster vulnerability is often studied in the literature as the result of congestion phenomena (Arthur, 1994; Suire and Vicente, 2004). From this structural perspective, the technological diffusion process re ches a saturation or congestion threshold when one kind of technology becomes dominant through self-reinforcement effects. Brezis *et al.* (1993) present an additional analysis in terms of life cycle. New technologies replace the old ones, and new clusters emerge while other clusters experience a decline. Clusters' survival capacity therefore depends on the actors' ability to ensure knowledge transfer, taking advantage of their geographic proximity.

However, beyond these structural factors, the strategic behaviours of the actors also merit consideration. From the point of view of public policies, the decision-makers are driven to make a choice between the strategy of regional redistribution, based on spatial equity in the redistribution of wealth, and the policy of cluster growth based, on the contrary, on the concentration of economic activities (Feldman and Massard, 2002). Thus, in the short term they face a dilemma between equitable redistribution and supporting innovation, knowing that the elector may express his discontent by 'voting with his feet'. Along similar lines, Bonardi *et al.* (2005) develop the idea of a political market to analyse the links between public and private actors, with the institutions as givers and the firms as seekers of a given policy. In the case of intense rivalry between firms, the policy decision-maker will satisfy the interests of the most powerful group. This concept is limited to a view which reposes upon market-based coordination. In this example, policy is defined as a pre-existing, exogenous given, and the relations between firms and institutional actors are reduced to an exchange rather than a constructed and negotiated process. Furthermore, biotechnologies excite controversy in public opinion, and pose public and private management difficulties in the light of ethical and regulatory issues (Chataway *et al.,* 2004; Dasgupta and David, 1994; Etzkowitz and Leydesdorff, 2000; Lehrer and Asakawa, 2004). Thus, public policy decisions have to be made which ensure the development of relations between firms and public research laboratories while taking into account the possible views of a public which does not accept genetically modified organisms.

As well as approaches which focus strictly on public strategy decisions, coordination flaws within clusters are also studied relative to appropriation conflicts: conflicts about the appropriation of resources, quasi-rents or monopoly rents (Klein *et al.,* 1978; Zucker and Darby, 1997; Simonin, 1999; Hamdouch and Depret, 2001). In this case, it is the opportunism of actors in uncertain situations which is in question.Some actors try to appropriate these rents individually, to the detriment of the others, thus taking advantage of the incompleteness of the rules of the game established at the outset. The problem, then, for the local authorities, is to find a management style which allows the harmonisation of conflicting interests while remaining aware that they are subject to strategic influencing (Bonardi *et al.,* 2005).

These conflicts of interests can be explained, firstly, by the existence of aduality between cooperation and competition within the clusters. While this duality may be emulated (Teece, 1989; Gulati *et al.,* 2000), it can also lead, in certain cases, to a free-riding type of opportunistic behaviour which manifests itself in the unequal acquisition of resources or collectively generated rents (Nooteboom, 1999). This is a particularly frequent occurrence within biotechnology clusters because of their cross-sector nature (health, food-processing, environment) and also the fragmented nature of their activities, as Argyres and Liebeskind (2002) demonstrate. Indeed, the asymmetry of information, linked to the co-existence of the different types of logic at work in the different sectors (plant, animal, health, nanotechnologies), contributes to the emergence of opportunistic behaviours. These conflicts can thus be explained by the heterogeneity of the firms involved (Saviotti, 1998; Powell *et al.*, 2005; Roijakkers *et al.*, 2005). The bioclusters, like the majority of clusters, are organised as dual markets, based on partnerships between big, international 'leader' firms and small and medium-sized companies. Yet these partnerships can lead to unbalanced power relations, opportunistic behaviour and even distrust when a small company enters into a dependence situation in relation to a large group[2].This results in instability which is sometimes 'chronic', and even the compartmentalisation of the links between small and large firms, which might cast doubt on the performance of the biotechnology clusters.

Finally, coordination flaws also arise from the simultaneously public and private, highly regulated and much debated nature of biotechnological innovation activities. Numerous works, such as those of Lawson (2004) and Sherry and Teece (2004), show that conflicts arise over the negotiation of ownership rights to research materials (fragments of DNA) as well as the sharing of rents from the joint operation of licences. Other studies, concentrating on network dynamics, deal with the question of 'partial embeddedness' between public and private spheres. Owen-Smith and Powell (2003), for example, show that research laboratories have to establish a strategic equilibrium between academic priorities (precedence rule) and industrial priorities (secrets rule) in order to avoid 'the danger of being captured – instrumentalised – by industrial interests' (p. 1695).

As suggested by Chataway *et al.* (2004), Leroux (2004) and Rausser *et al.*(2000), stra tegic relations between firms and local authorities are above all asymmetric power relations. Every appropriation conflict masks a power conflict (Dockès, 1999), just as is the case with alliances, particularly asymmetric ones (Yan and Gray, 1994). Working from stylised facts, Leroux (2004) shows that firms develop negotiation strategies aimed at getting collectively generated resources and influencing the decisions of local authorities, guarantors of the general interest. If the firms develop more or less opportunistic strategies to get the quasi-rents for themselves, the local authorities are capable of expressing their discontent through a reduction in the allocation of public aid. Neverth less, the firms can respond to this with a threat of disengagement. In this way, the relationship becomes one of negotiation in the face of ultimatum, and is characterised by uncertainty. The local authorities have to live with uncertainty surrounding the implantation on their territory of the firms concerned, and the firms with uncertainty surrounding the possibility of securing public resources. At this point, the local authorities are in a position where they must make concessions rather than be responsible for a company's relocation. Furthermore, these local authorities develop strategies to get the quasi-rents through taxing, or from encouraging the firms to finance local research. The income from taxes is then redistributed in different ways: direct

2. Asymmetric alliances pose even more stability problems because of the asymmetry of gains which can result. Whatever the nature of the gain that is sought through the alliance, there is always the risk that this gain will be less than the investment that is sought (Kale et al., 2000). Whether we look at a competences approach, or a transaction costs approach, the problem posed is clearly one of appropriation (Prévot, 2007) and of opportunism, as proposed by Williamson (1999). The risk of conflict remains, even alongside the effects of reputation and confidence (Gulati, 1995 ; Doz, 1996 ; Dollinger *et al.,* 1997).

finance (loans, subsidies) or indirect (exemptions); benefits in kind of a private nature (buildings) or public (infrastructure); staff services. Complex and sometimes ambivalent negotiation strategies arise from these inter-organisational relations. The actors, firms and institutions thus find themselves in a doubly uncertain situation: uncertainty over the strategic behaviours of the partners in the short, medium and long term and uncertainty about the cluster's regenerative ability.

While these analyses greatly help to explain firm-institution conflicts, they only provide a snapshot of the most likely situations without de ling with their evolution over time, or their impact on cluster performance.

This is a matter of looking at the links between the adaptation of opportunistic behaviours in uncertain situations and the biocluster's vulnerability. From this perspective, the co-evolution approach can contribute to a dynamic analysis of mutual strategic adaptations within bioclusters.

towards an approach to bioclusters based on strategic co-evolution

Co-evolution, in its widest sense, describes the transformations and reciprocal adaptations between two living species during the course of their evolution. From this viewpoint, the biocluster may be seen as a complex evolving system (Nicolis and Prigogine, 1994; Janszen and Degenaars, 1998). What is interesting in this approach is that it takes into account internal adaptation and decision-making mechanisms, both in their development and their reversal. Based on such a variety of partnerships and strategies linking private and public players, though, the evolutionary trajectory of the cluster can prove to be unstable, or even, in some cases, chaotic (Luukkonen, 2005; Mangematin *et al.,* 2003; Stuart and Sorenson, 2003). Consequently, in the development of lines of questioning on evolutionary trajectories (Mangematin *et al.,* 2003) and on the strategic dimension of coordination (Chataway *et al.,* 2004; Rausser *et al.,* 2000; Etzkowitz and Leydesdorff, 2000), this a proach enables the dynamic analysis of actors' strategies in uncertain situations.

Approaches which concentrate on strategic co-evolution within bioclusters are, in the literature, based on behavioural models from an evolutionary standpoint (Arthur *et al.,* 1997; Kirman, 1997) directly linked to the cognitive paradigm (Simon, 1955; Walliser, 2000). Five major principles govern these coordinations in such models : 1) the principle of the heterogeneity of the agents; 2) the variability principle, which matches the system's endogenous capacity to produce new trajectories dependent on internal behavioural mutations; 3) the path dependency principle, which refers to learning effects and to auto-rei forcement mechanisms leading to some irreversibility in the evolutionary dynamic; 4) the inductive learning principle, according to which the agents are individually part of a cognitive problem-resolution process and learn and adapt their behaviour according to their experience; and 5) the situated rationality principle, according to which agents' rationality is formed through interaction and leads to adaptive agents. The agents are thus part of the relations within which the formalisation of knowledge is 'impregnated with the singularity or the context' (Ponsard, 1994, p.171). Every agent is viewed as an 'acting' subject in the sense that he constructs his own objectives in an intentional and contingent manner. The evolutionary approach is freed, therefore, from the fiction of the representative agent by replacing the notion of limited rationality with the notion of situated rationality (Vriend, 2000).

Viewed from this evolutionary perspective, the biocluster can be understood as a complex, evolving system (Nicolis and Prigonine, 1994; Janszen and Degenaars, 1998). The interesting factor in this approach is that it takes account of internal mechanisms of adaptation and decision-making, concerning both their emergence and their reversal.

However, the co-evolution models arising from this approach, even a ter numerous refinements, deal little with the appropriation strategies of public and private agents. The literature offers many models of network externalities, such as that of David *et al.* (1998), which summons up the neighbourliness of interactions to show the emergence of niche technologies, or the works of Steyer and Zimmermann (2004), who use a relational structure model to show how 'leader' agents influence the evolutionary trajectories of the cluster. Other models show how altruistic behaviours can emerge in a cluster. Mitteldorf and Wilson (2000), for example, argue that dense links are important to the emergence of altruism.

Nevertheless, while these models make a big contribution to cluster analysis, they have difficulty in dealing in a linked way with the questions of mutual adaptation of strategies and of cluster viability in situations of behavioural uncertainty. This remains, therefore, a path to explore. In distinguishing firms' motivations, which satisfy their private interests, and also the motivations of the local authorities, which satisfy the general interest, the question of the co-evolution of strategies aimed at appropriating resources is posed here. What opportunistic strategies are put into action by public and private actors in uncertain situations? How do these strategies evolve over time according to their impact on cluster performance? Here it is necessary to open up a ne line of research into the strategic dynamics of bioclusters, and to extend the analysis to public decision-makers who are subject to firms' influences.

research methodology

Artificial life[3] simulations are enjoying growing popularity in organisational science, as reported by the special editions of the American Journal of Sociology in 2005 and the Academy of Management Review in 2007 attest (Cartier and Forgues, 2006 ; Brabazon and O'Neill, 2006; Davis *et al.,* 2007). The advantage of a simulation is that it enables researchers to study systematically the behavioural patterns to be integrated adaptively into their « world model » (Marney and Tarber, 2000; Vriend, 2000). It consists of a simplified representation of reality which aims to establish links between start and end variables, and which can be used to explain a real situation or to predict outcomes (Gilbert and Troitzch, 1999). The simulation has a triple advantage (Cartier and For-

3. Artificial life was defined by Langton in 1989 as the study of man-made systems which present behaviours characteristic of natural living systems. An artificial life system can reproduce itself ; an artificial life system is capable of adaptation.

gues, 2006; Davis *et al.,* 2007); it allows the simple formalisation of a complex reality and proves to be a powerful tool for the development of theory ; it allows proximity to the experimental conditions, and the study of different cause and effect relationships, by varying the model's outset conditions; it is heuristic, and helps to generate findings by producing artefacts. Artificial life heuristics stage interacting agents, whose actions are based on the rules of autonomous behaviour. Natural selection then acts on these agents' characteristics. The notion of emergence is at the core of the analysis, understood as the spontaneous appearance of a micro-regularity emerging from the interaction (Arthur *et al.,* 1997). Artificial life assigns centrality to the interaction's cognitive element, and more particularly to inductive learning. The agents are involved as individuals in a problem-solving process. They learn and adapt through a variety of cognitive processes which aim to convert the information – resulting from the experiment in a complex and changing environment – into action.

Simulations are constructed based on different methods. The most frequently used are cellular robots, multi-agent systems and genetic algorithms. Cellular robots were born of Von Neumann's (1966) work on self-replicating systems. Today, they are widely used in research on neighbourly interactions, and are particularly suited to the study of local phenomena or competitive market situations (Roehrich, 2006). Multi-agent systems are physical or virtual entities which act in communication with other agents. Each agent optimises individual objectives according to available resources and to his perception of the environment (Ferber, 1995; Wilensky, 2000). This kind of method is applied to concrete problems such as search engines in electronic commerce (Cartier and Forgues, 2006). Genetic algorithms (Holland, 1975) are also much used in management science for modelling emerging complex phenomena. Considered the most standard tools, they consist of the instrumentalisation of an optimising function (Goldberg, 1989) and are based on mutation and crossover operators. From a technical point of view, the principle of the genetic algorithm is to set up an initial population of individuals which then have to evolve and reproduce according to a natural selection process leading to progressively better adapted individuals. In management, they are used to represent the organisation, each gene representing a characteristic of the organisation or of its constituent agents. The internal validity of the results of these different methods has been tested in numerous studies. According to Masuch and Lapotin (1989), the simulation enables the certain identification of causal relations. External validity is harder to determine with this type of method. As Cartier and Forgues (2006) observe, it is necessary to ensure beforehand that the results are not dependent on the model's principal parameters. Moreover, it is necessary to be sure of the representativeness of the simulated reality, aligning significantly with field observations (Cartier and Forgues, 2006).

design of the simulation model

The simulation model presented here is the simplified metaphor of a biocluster. It is a schematic model (Thietart, 2003) in the sense that relationship notions are here restricted only to firms' and local authorities' strategies. It does not attempt to recognise the totality of the research object, which is the cluster, but simply the public/private strategic interactions and their co-evolution. The preferred method within this research is an artificial life simulation based on a genetic algorithm involving mutating and crossover operators (Holland, 1975; Goldberg, 1989). The advantage of the algorithm is that it enables agents systematically to research behavioural coherence to be integrated adaptively into their world model, so that they can pick up any emerging micro-regularities (Marney and Tarber, 2000; Vriend, 2000).

Here, the behaviour of the firms and institutions is formalised through a games theory approach. There are two reasons for this choice of theoretical model. First, the internal validity of game theory models has been widely tested (Ellingsen, 1997). It constitutes a robust mathem tical approach for strategy problems in operational research and economics. Second, it contributes to the study of the behaviour of individuals facing antagonistic situations. It demonstrates more precisely the variety of rational strategies possible in situations where an actor's gains depend not only on his behaviour and the rules of the game but also on that of the other participants, who may pursue different or contradictory objectives (Schelling, 1960). The model is described here according to the narrative method, which consists of deconstructing every action of the agents and reconstituting each one of them in the global adaptive process. According to Goldspink (2002), it is the most appropriate method for presenting the design of simulation models specifying rigorously the nature of the interactions between agents.

Strategic interactions within a biocluster or 'world model'

In the model offered here, the actors negotiate for a share of a quasi-rent, represented by a cake. It is artificial life modelling of a game of demand under ultimatum, making players interact and negotiate in pairs (Ellingsen, 1997). Thus, when the players respectively want to get a large portion of the cake, by more or less opportunistic means, the negotiation fails. In the opposite case, everyone goes away with the requested portion.

The firms are modelled as 'obstinate' agents (Obs), whose demands are independent of those of their adversaries. As they participate in the performance of the cluster, they want to get a share of the cake that they decide themselves according to their profitability objectives and their opportunistic tendencies. Some of them ask for a major part of the cake (more than 50%), while others ask for a portion less than or equal to 50%.

The local authorities are modelled as 'sophisticated' agents (Soph) which adapt their demands to the expectations of their adversaries rather than meeting with failure. As guarantors of the general interest they choose to adapt to the firms' demands in situations of uncertainty over the future of the latter. They have a tendency, then, to make 'concessions', their objective being to encourage the implantation of these firms on their territory, to stimulate local research partnerships and thus to support territorial performance. Nevertheless, they remain under the ultimatum of the firms who, when they want to influence the local authorities, threaten to disengage. Furthermore, when two local authorities negotiate together, they share the cake 50-50. This equal share is in keeping with their wish to preserve the general interest and avoid any conflict.

Determining the demand

Each firm's demand di is based on two constituents, the expected size of the cake, and the portion requested :

d_i = expected size of cake (teg) * portion requested (i)

with

T : the real size of the cake

$teg \in [0;\ TG]$, minimum value and maximum value of teg

$i \in I \subset [0;\ 1]$, I all the portions requested

so

$d_i \in D \subset [0;\ TG]$, D final total of possible demands

The strategy consisting of demanding di with $i = 0.5$ is called the fair strategy which a portion such as $i > 0.5$ is demanded is called a greedy strategy. Other strategies, such as $i < 0.5$, they are called modest strategies.

Local institutions, whose strategy is marked r, are able to observe the adversary's demand strategy and to adapt their demand to the expected demand of this adversary rather than endure a failure. Consequently, when an institution meets a firm demanding di, it makes the following demand dr :

$$d_r = teg_r - d_i \text{ avec } d_r \geq 0$$

As with the firms, the institutions can also be led to failure if they overestimate the size of the cake.

The payment function

If firm i demands d_i and firm j demands d_j, then player i gets the following payment :

$$\Pi_{ij} = d_i \text{ if } d_i + d_j \leq T,\ 0 \text{ otherwise}$$

If the sum of di and dj exceeds the real size of the cake T, the negotiation fails, and the two players win nothing. In the opposite case the surpluses are lost, and thus a badly judged negotiation thus contributes the waste of collective gains within the cluster. When an institution negotiates with a firm it obtains

$$\Pi_{ri} = teg_r - d_i \text{ if } teg_r \leq T \text{ and } d_i \leq T$$

And when two institutions negotiate, they obtain :

$$\Pi_{r1r2} = teg_{r1}/2 \text{ si } (teg_{r1}+teg_{r2})/2 \leq T$$

The payment matrix is shown below.

Table 1. Payment matrix

	Obstinate d_i		Sophisticated r_1	
Obstinate d_j	d_j	d_i	d_j	teg_{r1}-d_j
Sophisticated r_2	teg_{r2}-d_i	d_i	$teg_{r2}/2$	$teg_{r1}/2$

Implementation of the genetic algorithm and model validity

Internal validity of the model was sought through the use of three means: the choice of the algorithm and its sequentiality; the robustness of the chosen parameters; the behavioural structure of the game. The genetic algorithm, whose sequentiality is described in **appendix I**, consists of an optimising function (Goldberg, 1989) into which three evolution operators, selection / crossover / mutation are introduced. These operators have a double function (Schoenauer *et al.,* 1996): the genetic process exploits the already-known neighbouring zones and simultaneously explores all the unknown zones beyond this proximity (EVE dilemma – Exploitation versus Exploration). The choice of a genetic algorithm suits this research work's objective, to be able to analyse the adaptive dynamic of different populations of agents, and to identify the mechanisms affecting this adaptation process and the emergence of micro-regularities (Bruderer and Singh, 1996; Davis *et al.,* 2007)[4] . Thus each agent is determined by its genotype (**appendix 1**), which consists of both the expected size of the cake and its sharing strategy.

In the model, the population of firms and institutions amounts to 1000 agents, which corresponds to a real, medium-sized cluster[5]. The initial size of the cake is $T = 1$ and the variation interval is $[0.1; 2.0]$. This finite interval is intended to reinforce the model's realism, since a cluster cannot grow exponentially. The population of firms and obstinate agents (Obs) is divided into seven profiles represented by discrete intervals (**table 2**) between 0 and 100. The choice of seven profiles is large enough to ensure technically the representativeness of possible demands, while guaranteeing the legibility of the results on a histogram. Strength tests carried out on fifteen profiles produced identical results (**figure 6 appendix 3**) but reduced the legibility of the graphs. Each profile was arbitrarily fixed and corresponds to the portion of cake demanded.

4. We invite the reader to refer to these two key articles presenting in-depth analyses of the validity of different tools used in artificial life.

5. Table 3 in annexe 2 offers a synthesis of the parameters used in the different simulations.

Table 2. The seven profiles of firms

profile name	explanation	profile type
Obs 7	Firms whose demand is 7 %	Modest
Obs 21	Firms whose demand is 21 %	
Obs 35	Firms whose demand is 35 %	
Obs 50	Firms whose demand is 50 %	Fair
Obs 64	Firms whose demand is 64 %	
Obs 78	Firms whose demand is 78 %	Greedy
Obs 92	Firms whose demand is 92 %	

The simulations were based on the following evolutionary parameters : a rate of mutation of 10% ; a crossover rate of 50% ; the initial distribution of each profile (Obs and Soph) was 12,5% at the game's outset. According to Schoenauer et al.'s internal validity tests (1996), the choice of these parameters allows the maintenance of both of selective pressure on the population so as to ensure the convergence of the algorithm, and also of the genetic diversity of the population so as to avoid too a rapid convergence, because every algorithm risks generating an excessive duplication of certain individuals which generate high gains. In this way, the loss of genetic diversity can bias the evolutionary process. The technical solution is to introduce, exogenously, a continuous rate of mutation. The ideal mutation rate is fixed at 10% for this technical reason, which is well identified in computer science research (Schoenauer *et al.,* 1996). As for robustness, different mutation rates were tested, from 5% to 12,5%, which brought about no change to these results (**figure 7, annexe 3**). At 2,5% the results were distorted by early convergences ; from 15% the mutation rate disturbed the convergence of the algorithm and, furthermore, rendered the graphs illegible (**figure 7, annexe 3**).
The crossover rate was fixed at 50%, in keeping with classic robustness references (Schoenauer et al., 1996). It corresponds to a so-called 'sexual' reproduction of the population of agents: pairs of individuals – 'parents' – generate 'child' individuals by a genetic process focused on teg. A rate of 50% is usually chosen to maintain the diversity of the population while allowing the convergence of the algorithm: too weak a reproduction rate for the agents prevents the learning process from happening; on the other hand, a crossover parameter of more than 50% contributes to precocious convergence of the algorithm.
Even if there are numerous interconnections, the agents do not systematically negotiate with the whole population, but only with certain partners when this proves to be necessary. Consequently, at each negotiating round, the agents negotiate with a representative sample of 10% of the total population. Then every agent is assessed according to the gains he is capable of generating.
In this artificial world, certain agents are linked by a so-called relational proximity (Grossetti, 1998). As Porter (1998) shows, the cluster is based on interconnected networks of firms and institutions. The hypothesis that certain agents have more direct relationships with each other informs the integration of this characteristic into the simulation model. Thus, although firms and institutions negotiate with all the members of the cluster (notation phase), they only exchange information about the size of the cake with partners they have noticed adopting the same strategy as them during the negotiation phase (crossover phase). Consequently, while some agents are unable to recognise their adversary's strategy at the beginning, they can, nevertheless, learn it from experience during the negotiation process through trial and error. This relational proximity established between agents who opt for similar strategies enables them selectively to exchange information and places them in a single strategic approach.

The model's internal validity is also reinforced by the structure of the ultimatum game. This enables the clear and systematic identification of the links between agents' behaviour and the gains that they generate, that is, the causal relations during an algorithmic sequence (Goldspink, 2002). In this ultimatum game, every instance of strategic interaction and all gains generated by agents negotiating two by two are explicit and readily identifiable in the payment matrix (**table 1**).

In terms of external validity, great importance is attributed to the repr sentativeness of the model, which depends on the stylised facts described earlier (Rausser *et al.,* 2000; Chataway *et al.,* 2004; Leroux, 2004) and aims to be as close to reality as possible. However, it is quite obvious that this type of model, as is currently being debated, would be unable to create an identical reproduction of reality since, as stated at the beginning of this section, it is a schematic model. Nevertheless, its strength is its ability to restrict the analysis to modes of interaction that can be isolated to facilitate the identification of evolution and to observe endogenously generated artefacts.

As argued in the works of Axelrod (1997), any simulation integrating non-linear evolution processes poses the problem of path depende cy. Thus, a simulation can be found to be conditioned by sensitivity to the initial conditions, the system's response to an endogenous distu bance being dependent on the model's structure and the sequential adaptation process. No one simulation, then, will be identical to another. A research work based on this methodology generally reveals a weaker generalisation property than classic statistical analysis (Goldspink, 2002). Its external validity should therefore be moderated according to this sensitivity. However, and this is a significant subject of debate in the social sciences, the authors support the view of Axelrod (1997) according to which a simulation's interest is not in its ability to develop exact predictions, which are valid in all circumstances. The strength of a simulation such as the one used here is that it enables the identification of typical behaviours within a system of agents which constitutes a metaphorical world and whose results are a valuable example of behavioural analysis.

It provides elements to identify the emergence conditions of microb havioural regularities in a system of co-evolving actors, thus building up analytical elements that the researcher can use in the reality of a cluster. It remains true that the external validity of a simulation can be improved. According to Axelrod (1997) and Goldspink (2002), it is imperative to relaunch the simulations and to develop statistical an lyses of the results in order to have the most exact identification possible of the different emerging micro-regularities. From this viewpoint, every simulation should be systematically repeated a thousand times, in such a manner as to be sure of the emerging results. For each simulation, the equilibria between the different populations of agents can be identified using a statistical recognition technique (described in **appendix 1**), thus avoiding any error in the interpretation of the results.

RESULTS

As Cartier and Forgues (2006) assert, the advantage of a simulation is that it enables the variation of the starting conditions, or of the exogenous rules of the game, in order to analyse the effect on the final result. Consequently, the results presented here are those that emerged from three simulations which were gradually increased in complexity. In a cordance with the initial questions being examined, these three simulations aim to find out the mechanisms of firm-institution strategic co-evolution in uncertain situations: (1) the aim of the first simulation (S1) was to study the strategic co-evolution of the firms and institutions in the absence of uncertainty over the size of the cake, in such a way as to be able to compare this certain situation with situations characterised by uncertainty; (2) the aim of the second simulation was to study the strategic co-evolution of the firms and institutions when uncertainty about the size of the cake was introduced; (3) the aim of the third simulation was to study the strategic co-evolution of the firms and institutions in the presence of both uncertainty about the size of the cake and of opportunistic behaviours contributing to a reduction in cluster performance.

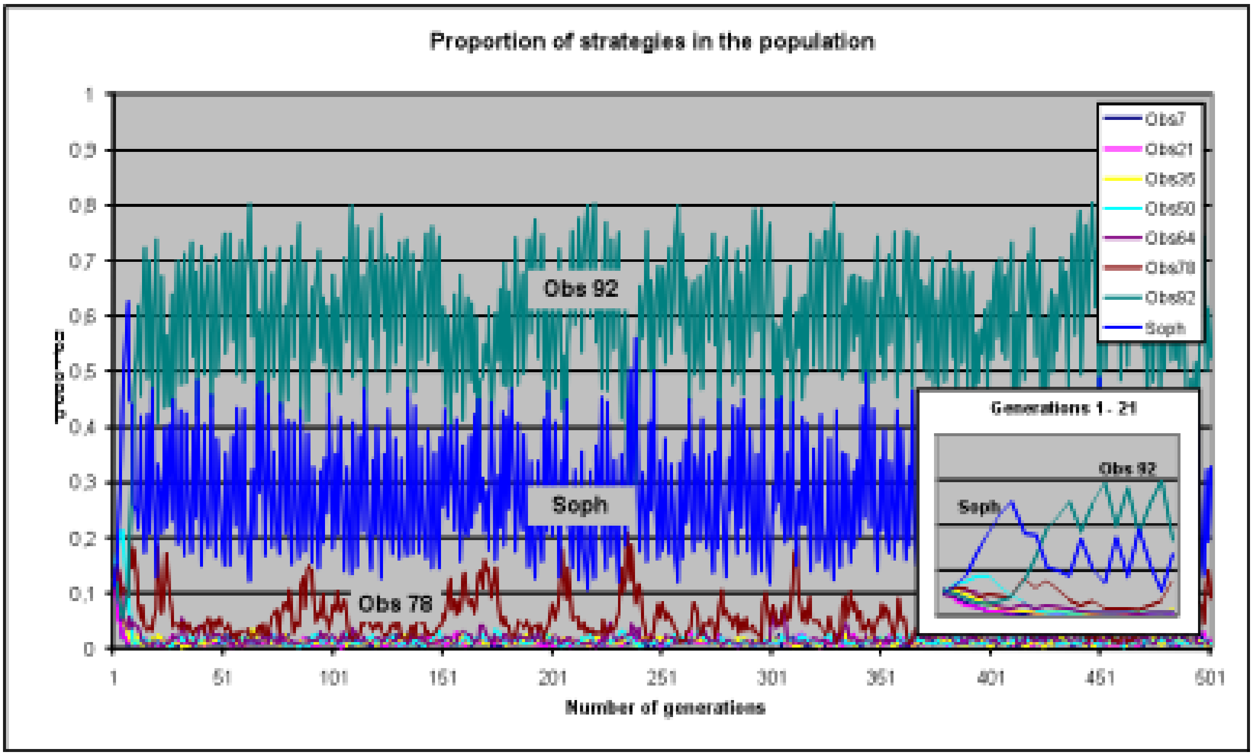
simulation s1: the size of the cake is known and invariable

The size of the cake is $T = 1$ and does not change during the negotiation process. The simulation enables observation of the strategies adopted by the agents, their co-evolution and possible changes of direction, stage by stage, over 500 periods or generations. The simulations were relaunched a thousand times and turned out the same way in 100% of cases. The results show that the negotiation strategies evolve in two distinct phases (**figure 1**). First, the local institutions constituted the majority of the total population during the first 20 periods. These negotiations ended in equal shares of the cake, that is 50/50. Then, this very large presence of concession-making institutions contributed to the emergence of the greediest strategies (92% of the cake) which constituted, in the end, the majority of the population represented, besides a small proportion of firms whose demand was 78%.

With no uncertainty about the size of the cake, then, it can be seen that the most opportunistic strategies take the lead in the negotiations. The local institutions are not unfamiliar with this, and unintentionally play a distributive: in making concessions they contribute to the increase in the most opportunistic strategies to the detriment of fair or modest strategies.

S1 outcome results: When the quasi-rents are known and stable over time, the firms tend to opt for very opportunistic strategies. In this, they rely on the concession-making institutions which involuntarily play a distributive role.

Figure 1. Example of the evolution of negotiation strategies adopted by the agents in simulation S1



simulation s2: the size of the cake is unknown which leads to uncertainty

The size of the cake is unknown and the agents have to estimate it. Any overestimation will be damaging to them, this being an ultimatum game. Here the firms and the institutions have an endogenous capacity to modify their respective demands d. They estimate the size of the cake according to a learning process focused on teg and made possible through recourse to mutating and crossover operators. In this way, each agent has the capacity to assess teg, and every new assessment leads to a modification of demand d. The chance of failure is high, therefore, since the agents can overestimate or underestimate the size of the cake. This, however, is fixed at $T = 1$.

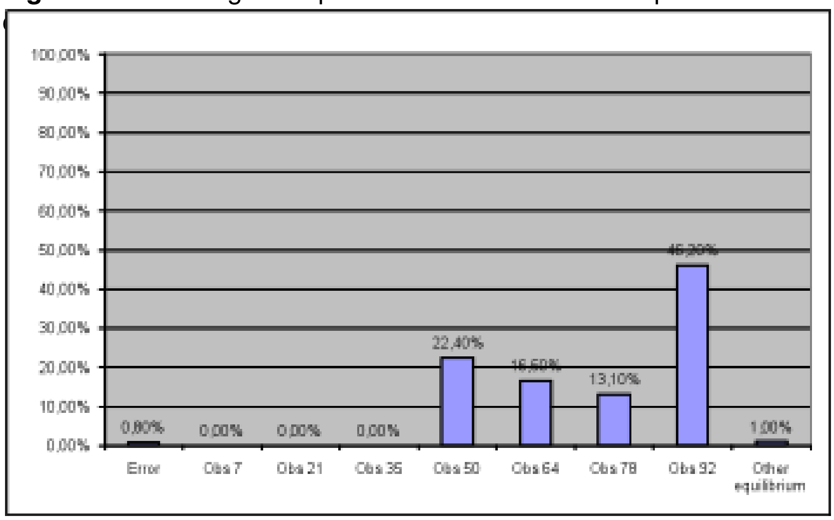
The launching of 1000 simulations produced the following resulting variations (figure 2):

i) In 46,2% of cases the negotiation process stabilised around the most opportunistic firms, whose demand was 92%, and the local institutions. As in simulation 1, the most opportunistic strategies were made possible due to the strength of the presence of local institutions during the first phases of the process.

ii) In 29,6% of cases, the negotiation process stabilised around the firms whose demands amounted to either 78% or 64% on one side, and the local institutions on the other.

iii) In 22,4% of cases, the negotiation stabilised around the firms whose demands are described as fair, that is 50% of the cake, and the local institutions.
iv) In 1% of cases, the negotiation process stabilised around the firms whose demand amounted to 35% of the cake. In these very rare cases, the local institutions disappeared, to the benefit of the firms making the most modest or fair demands.
v) In 0,8% of cases, an evolutionary process accident can be seen, which makes it impossible to interpret the results of the simulation, and which constitutes an incompressible error margin.

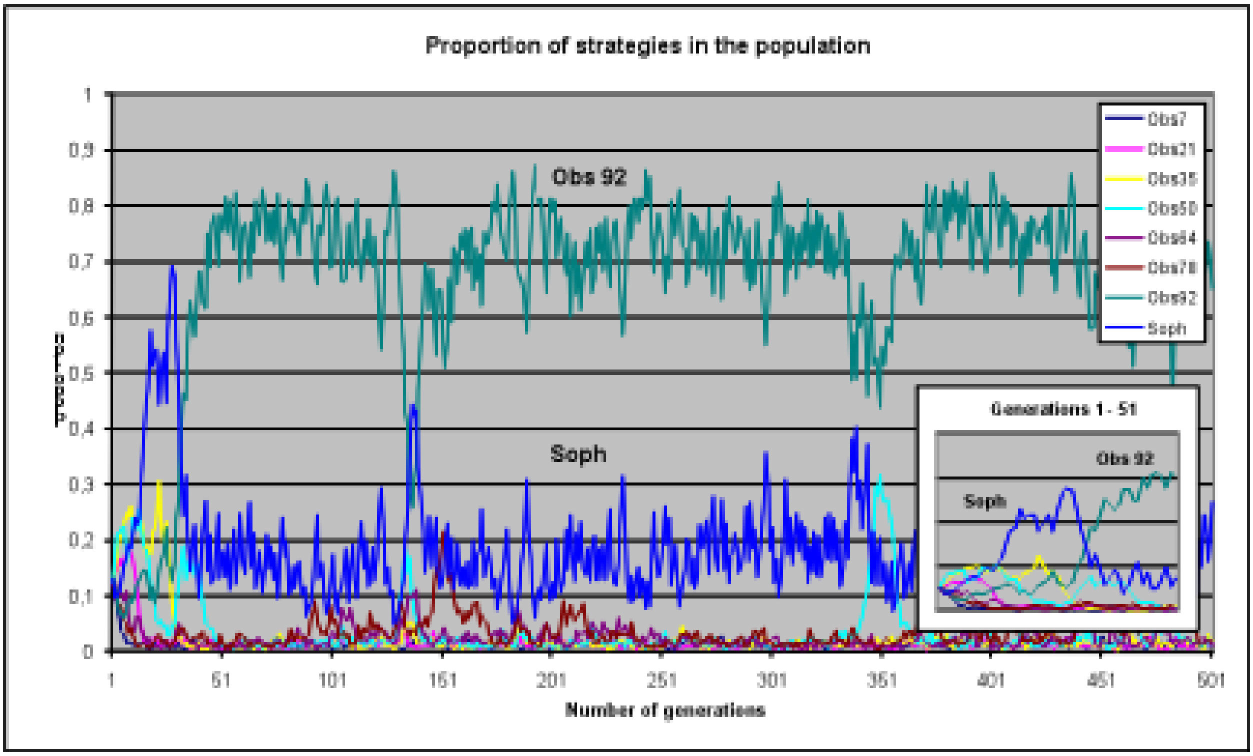
Figure 2. Percentage of equilibria obtained between sophisticated and



When the size of the cake is unknown and the agents have to estimate it, the results vary and depend on the endogenous capacity of these agents to find it as quickly as possible. The winners are those who make the nearest assessment as quickly as possible, while also exchanging this information with the partners who have the lowest failure record in the evaluation process. In 46.2% of these simulated cases, the most opportunistic firms very rapidly drew benefit from the large presence of local institutions in the first 40 periods (**figure 3**). In the other cases, the majority, the development of much more cautious strategies can be seen. In the absence of precise knowledge about the real size of the cake, the firms made less opportunistic demands. The role of the local institutions remained just as important in this simulation because they reduced the possibility of failure in the phase of assessment of the size of the cake. In this way, when the size of the cake was unknown, the institutions also played a distributive role. In very rare cases (1%), the firms whose strategies were the most modest were able to survive without the local institutions, as they themselves played a distributive role.

S2 outcome results: Generally, the firms develop less opportunistic strategies in situations of uncertainty about future collective benefits, while taking advantage of «the concession-making» institutions.

Figure 3. Example of a negotiation process stabilising around the most opportunistic sophisticated and obstinate profiles, S2 simulation

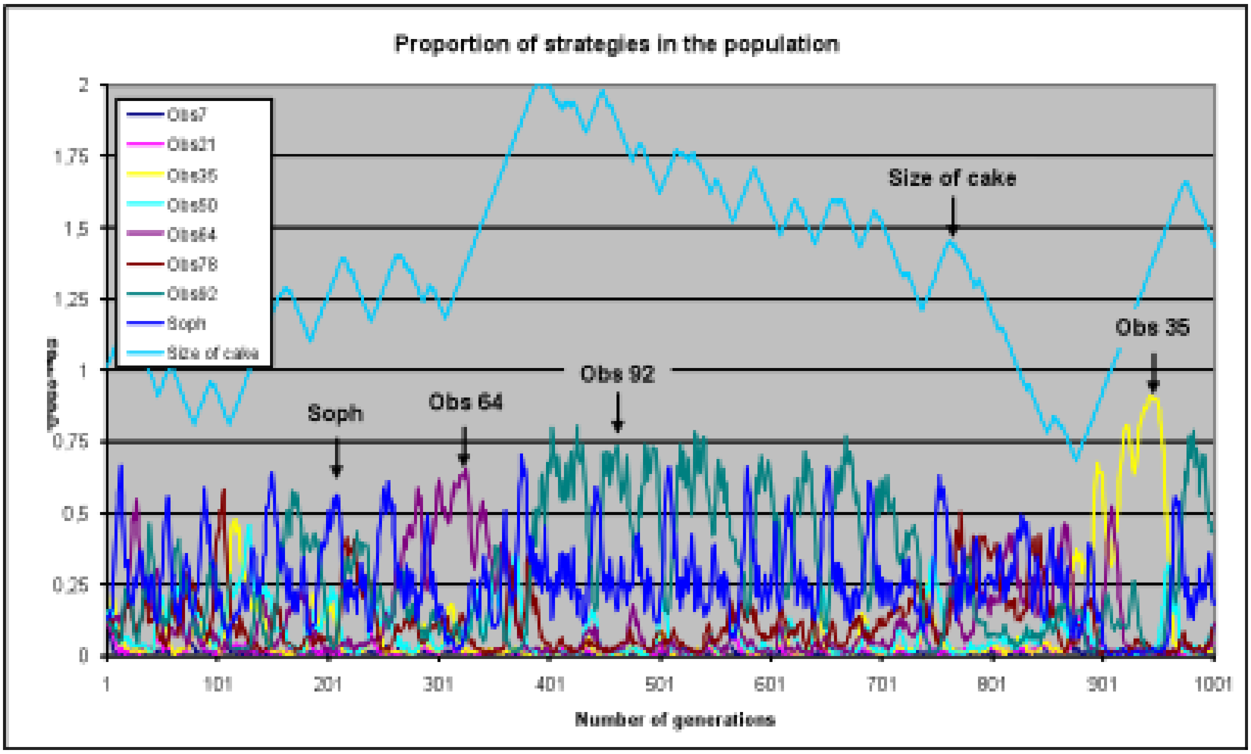


simulation s3: the size of the cake varies according to the strategies adopted

The size of the cake, which here is analogous to the cluster's performance, becomes variable. The suggested is that when a firm opts for opportunistic strategies leading to the failure of the negotiation, this contributes to the reduction of the size of this cake. Conversely, when the agents choose strategies which are less opportunistic, or only slightly opportunistic, this contributes to the augmentation of the size of the cake. It is therefore necessary to observe how the strategies co-evolve in these conditions, which of these strategies will be developed, and what the role of the institutions is going to be. In technical terms, a parameter called influence k was applied to `T`. If in the previous round `(n - 1)` the number of successful negotiations was greater than the number of failures, then T increased from 0.01. In the opposite case, it reduced from 0.01. The choice of this parameter `k = 0.01` was arbitrarily fixed at a low level. The objective was to establish a causal link between the agents' behaviour and the modification of the size of the cake, without provoking a radical collapse of the system. The underlying hypothesis is that coordination flaws can cause a disturbance in the system, but cannot cause its total collapse as may be the case at the time of a major economic crisis (buyers backing out, etc.).

The results show that the agents adapted their behaviour according to its impact on the size of the cake. Because of this, the negotiation process did not stabilise over time and evolved according to different phases (**figure 4**). The firms modified their behaviour in such a way as to maintain the size of the cake or make it grow. They opted for cautious, fair or modest behaviours when this outcome was threatened (when it shrank dramatically) and opted for the most opportunistic strategies when the cake reached a size close to the upper limit.

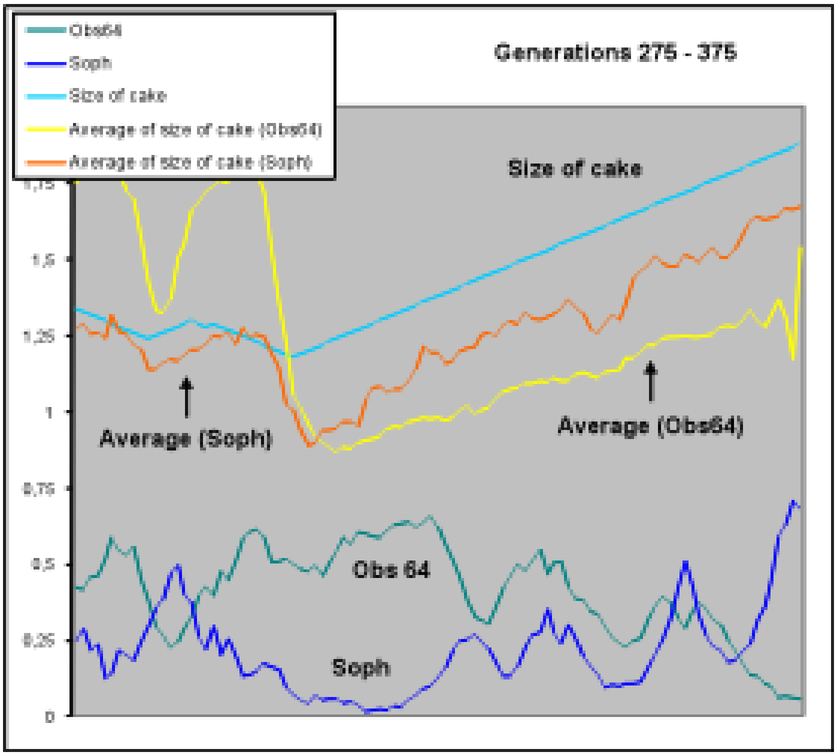
Figure 4. Example of the evolution of negotiation strategies, simulation S3



For example, period [275; 375] is marked out by a considerable presence of cautious firms whose demand was 64% (**figure 5**). These cautious behaviours contribute significantly to the growth of the cake to the upper limit. Once this was achieved, a change from cautious strategies of 64% to highly optimistic strategies of 92% could be seen. However, this was made possible by the presence of the local institutions which contributed to the reduction of negotiation failures, consequently avoiding any radical reduction in cluster performance. Thus, when the latter was threatened by behaviours which were largely too opportunistic, the local institutions emerged and played a regulatory role, allowing the cake to grow again. In this simulation, the performance of the cluster was maintained thanks to the local institutions.

S3 outcome results: When there is uncertainty about the gains that may be generated, and the cluster performance is threatened, the local authorities help to compensate for the effects of the most opportunistic behaviours.

Figure 5. Evolution during period [275 ; 375], simulation S3



DISCUSSION

These simulations provide some factors upon which to reflect concerning firm-institution strategic co-evolution within a biocluster. Broadly speaking, the co-evolution approach contributes to an initial consideration of the phasing dynamics of negotiation strategies within a biocluster. The agents adjust their strategies according to the effects of their own behaviour on the performance of the system. This type of simulation model could be very useful for further investigation into the coordination relations intrinsic to bioclusters, which until now have been difficult to grasp (Chataway *et al.,* 2004; Saviotti, 1998). Whereas the model's internal validity hinges on the adoption of crossed validation factors, its external validity needs to be dealt with in a particular way because of the path dependency phenomenon inherent in all non-linear simulations. More precisely, the representativeness of the model was understood on two levels. At the micro-behavioural level, conformity of the modelled behaviour of the firms and institutions to reality was ensured by drawing on stylised facts developed by Chataway *et al.,* (2004), Leroux (2004) and Rausser *et al.* (2000). At the level of emerging regularities, the results correspond to the real behaviours resulting from interaction within clusters: behavioural phase dynamics and strategy reversal and collective management of uncertainty and its possible opportunistic exploitation. As Axelrod (1997) points out, the systematic statistical analysis of results contributes to a very precise identification of the situated behavioural micro-regularities. These micro-regularities constitute as many new analytical elements as the researcher in management could find in the real situation of a cluster.

The results moderate the hypothesis according to which the principle of cooperation-competition systematically produces emulation (Teece, 1989) and they raise the question of the vulnerability of clusters. The artificial life paradigm thus allows stage by stage observation of how the agents instrumentalise their relations (Owen-Smith and Powell, 2003) and modify their strategies in a complex and changing environment. At any moment, a system accident, seen as an artefact, may considerably challenge the cluster's evolution dynamic. Here we are opening up a line of thought on the link between the nature of inter-organisational strategic relations and the cluster's potential vulnerability.

These simulations also enable an exploration of the very complex relations linking the firms and the local public institutions while also casting light on their regulatory role. Implicitly, it appears that the latter have a power that one could associate with the power of the weak presented by Schelling (1960) and underlined by Dockès (1999). This is because, without the institutions, the durability of the cluster could not have been assured in simulation S3. They are the key figures in strategic coordination, even if the situation (withdrawal threats and concessions) is not in their favour at the outset. Later, the model confirms one of the major ambiguities which can be found in stylised facts, and which concerns the public/private relationships in a biocluster (Leroux, 2004). On the one hand, the local institutions bring the firms their aid, particularly financial aid, so as to encourage their establishment locally. On the other hand, this support frequently contributes to the emergence of opportunistic strategies, the firms gaining the most benefit being those with great negotiation power due to their credible threat strategies. This then opens a line of research devoted to questions of territorial governance and strategic management in uncertain situations (Powell *et al.,* 2005; Gulati *et al.*, 2000). From a management point of view, particularly where public-sector management is concerned, the task of the researchers is to engage in reflection on the nature of systemic risks with the aim of offering local authorities a better understanding of the strategic relations in clusters.

However, while the studies conducted thus far emphasise the importance of uncertainty to the behaviour of firms in a cooperation-competition context (Argyres and Liebeskind, 2002) and heterogeneity (Saviotti, 1998; Powell *et al.,* 2005; Roijakkers *et al.,* 2005), these simulations assist in refining their role in the coordinations. When the firms are in a situation of uncertainty concerning the gains that might be generated, they tend to opt for less opportunistic appropriation behaviours. If the public actor does not want to be subject to pressure by the more powerful groups (Bonardi *et al.,* 2005), it could be in his interest to withold some information on the gains which may be collectively produced and redistributed. A line of thought opens up here: should the public actor

maintain a certain level of uncertainty to reduce the risk that opportunistic behaviours might emerge?
However, these simulations can be refined technically. The first refinement would be to include more heterogeneous agents (e.g.research laboratories) and interactions in order to reinforce the model's realism. The second refinement is the integration of geographic proximity to allow the study of the impact of distance on actors' strategies. Furthermore, this simulation model paves the way to new explorations of the nature of public/private conflicts within the bioclusters. A suitable approach would be to develop longitudinal empirical analyses from a sample of several clusters, so as to achieve a deeper analysis of those conflicts, the resolution processes adopted, and the impacts on the evolution of the system.

CONCLUSION

The objective of this article was to use the results of artificial life simulations to understand the strategic co-evolution of the firms and institutions in a biocluster, when there is behavioural uncertainty. Considering the research trails developed and the refinements possible, the analysis and discussion of the results consist of three principal classes of implications: theoretical, methodological and practical. From the theoretical viewpoint, this research contributes to reflections on the vulnerability of clusters, approaching the subject not from a structural perspective focused on the phenomena of technological diffusion, but in the context of the strategic paradigm. The simulations enable a better understanding of the public/private actors' games by adopting an innovative approach to the role of behavioural uncertainty in strategic decisions. Moreover, they help in the analysis of conflict, power and the definition of the strategic rules of the game which are endogenous to a complex evolving system. This approach allows, for example, a glimpse of possible new ways of understanding the alliances, particularly for explaining competition phenomena or to shed new light on asymmetric alliances and their co-evolution. From the methodological viewpoint, the simulation proved to be a powerful and original research method, even though it is still underused in management science. Genetic algorithms are particularly suited to the analysis of emerging strategic phenomena, as is argued in the work of Lee et al. (2002) on the maintenance of strategic groups, or studies from marketing (Roehrich, 2006) mentioned previously. A promising line of research is opened up for researchers in management who want to involve themselves more in research on the strategies of actors within clusters in general. From the practical viewpoint, this simulation continues the work carried out on the relations between firms and institutions and the strategies for the sharing of gains. For this reason, it allows a better understanding of the way local authorities manage resources and how it may be possible to exploit uncertainty to reduce the risks of opportunism. The trains of thought which follow from this fit naturally into the current question of the management of competitive poles / French clusters (OECD Summary, 2007), that is, the role of public actors in the creation of conditions that are favourable to cooperation and innovation.

Isabelle Leroux is a lecturer in industrial economics at Angers University in France. Her research, at the intersection of economics and management, deals with the analysis of territory governance as well as the strategic analysis of firms and local governments' behaviour. More specifically, she works on strategic alliances, coalitions and bargaining games in local networks. The application of her work is mainly in competitive clustering; however, she also works on strategic networks in social economics.

Alain Berro is a lecturer in computer science at Toulouse Capitole University in France. His main research interests are multi-objective optimisations and optimisations in dynamic environments. His analyses are focused on the study of robustness tests and on the improvement of the different existing methods of optimisation. His research lead to new heuristics based on evolutionary techniques applied to economic and managerial problems.

Acknowledgements : First, we would like to thank Alain Desreumaux and the reviewers and sub-editors of M@n@gement, who contributed to many improvements since the initial paper and simulation. We are also keen to thank Frédérique Chédotel from Tours University, Paul Muller from Haute Alsace University, Camille Baulant from Angers University and Eric Rigamonti from ESSCA Angers Business School for the precious advice they gave us at the various stages of writing and reviewing.

REFERENCES

- Argyres, N., and Liebeskind J. (2002).
Governance inseparability and the evolution of US biotechnology industry, *Journal of Economic Behavior and Organization, 47*, 197-219.

- Arthur, B. (1994).
Increasing returns and path dependence in the economy. Ann Arbor; University of Michigan Press.

- Arthur, W. B., Durlauf, S. N., and Lane, D. (1997).
The economy as an evolving complex system II, SFI Studies in the Sciences of Complexity, 27, Addison-Westley.

- Axelrod, R. M. (1997).
The complexity of cooperation: agent-based models of competition and collaboration, Princeton University Press.

- Berro, A., and Leroux I. (2005).
A simulation of strategic bargainings within industrial clusters : towards the « power of the weak » emergence ? , 45th congress of the European Regional Science Association, 23-27 august, Amsterdam.

- Bonardi, J. P., Hillman, A. J., and Keim, G. D. (2005).
The attractiveness of political markets : implications for firm strategy, *Academy of Management Review, 30*(2), 397-413.

- Bourguin, G., and Derycke, A. (2005),
Systèmes interactifs en co-évolution. Réflexions sur les apports de la Théorie de l'Activité au support des pratiques collectives distribuées, *Revue d'Interaction Homme-Machine, 6*(1), 1-31.

- Brabazon, A., and O'Neill, M. (2006).
Biologically inspired algorithms for financial modelling. Berlin: Springer.

- Brenner, T. (2001).
Simulating the evolution of localised industrial clusters. An identification of the basic mechanisms, *Journal of Artificial Societies and Social Simulation*, *4*(3).

- Brezis , E. S., Krugman, P., and Tsiddon, D. (1993).
Leapfrogging in international competition : a theory of cycles in national technological leadership, *American Economic Review, 83*(5), 1211-1219.

- Bruderer, E., and Singh, J. S. (1996).
Organizational evolution, learning and selection : a genetic-algorithm-based model, *Academy of Management Journal, 39,* 1322-1349.

- Cartier, M., A and Forgues, B. (2006).
Intérêt de la simulation pour les sciences de gestion, *Revue Française de Gestion, 6*(165), 125-137.

- Chataway, J., Tait, J., and Wield, D. (2004).
Understanding company R&D strategies in agro-biotechnology : trajectories and blind spots, *Research Policy, 33,* 1041-1057.

- Dasgupta, P., and David, P. (1994).
Toward a new economics of science, *Research Policy, 23,* 487-521.

- David, P. A., Foray, D., and Dalle, J. M. (1998).
Marshallian externalities and the emergence and spatial stability of technological enclaves, *Economics of Innovation and New Technology, 6*(2 & 3), 147-182.

- Davis, J. P., Eisenhardt, K. M., and Bingham, C. B. (2007).
Developing theory through simulation methods, *Academy of Management Review, 32*(2), 480-499.

- Dockès, P. (1999).
Pouvoir et autorité en économie, Economica, Paris.

- Dollinger, M. J., Golden P. A., and Saxton, T. (1997).
The effect of reputation on the decision to joint venture, *Strategic Management Journal, 18*(2), 127-140.

- Doz, Y. L. (1996).
The evolution of cooperation in strategic alliances : initial conditions or learning processes, *Strategic Management Journal, 17*, 55-83.

- Dyer, J., and Singh, H. (1998),
The relational view : cooperative strategy and sources of interorganizational competitive advantage, *Academy of Management Review, 23*, 660-679.

- Ellingsen, T. (1997).
The evolution of bargaining behavior, *Quaterly Journal of Economics, 112*(2), 581-602.

- Etzkowitz, H., and Leydesdorff, L. (2000).
The dynamics of innovation : from national systems and mode 2 to a triple helix of university-industry-government relations, *Research Policy, 29,* 109-123.

- Feldman, M. P., and Massard, N. (2002).
Institutions and systems in the geography of innovation, Berlin: Springer.

- Ferber, J. (1995).
Les systèmes multi-agents, vers une intelligence collective. Paris: InterEditions.

- Gaffard, J. L. (1990).
Economie industrielle et de l'innovation, Paris: Précis Dalloz

- Gilbert, N., and Troitzsch, K. (1999).
Simulation for the social scientist. Philadelphia; Open University Press.

- Goldberg, D. E. (1989).
Genetic algorithms in search, optimization and machine learning, reading, MA : Addison-Wesley.

- Goldspink, C. (2002).
Methodological implications of complex systems approaches to sociality : simulation as a foundation for knowledge, *Journal of Artificial Societies and Social Simulation, 5*(1).

- Grossetti, M. (1998).
La proximité en sociologie : une réflexion à partir des systèmes sociaux d'innovation. In M. Bellet, T. Kirat & C. Largeronleteno (Eds), *Proximités : approches multiformes* (pp.83-100). Lyon: Editions Hermès.

- Gulati, R. (1995).
Does familiarity breed trust ? The implications of repeated ties on contractual choice in alliances, *Academy of Management Journal, 38*, 85-112.

- Gulati, R., Nohria, N., and Zaheer, A. (2000);
Strategic networks, *Strategic Management Journal, 21*(3), 203-215.

- Hamdouch, A., and Depret, M. H. (2001);
La nouvelle économie industrielle de la pharmacie. Structures industrielles, dynamiques d'innovation et stratégies commerciales, BioCampus, Elsevier, Paris.

- Holland, J. H. (1975).
Adaptation in natural and artificial systems : an introduction with application to biology, control and artificial intelligence, Ann Arbor; University of Michigan Press.

- Janszen, F., and Degenaar, G. (1998).
A dynamic analysis of the relations between the structure and the process of National Systems of Innovation using computer simulation; the case of Dutch biotechnological sector, *Research Policy, 27*, 37-54.

- Kale, P., Singh H., and Perlmutter, H. (2000).
Learning and protection of proprietary assets in strategic alliances : building relational capital, *Strategic Management Journal, 21*, 217-237.

- Kirman, A. P. (1997).
The economy as an interactive system. In W. B. Arthur, S. N. Durlauf & D. Lane (Eds), *The Economy as an evolving complex system II,* SFI Studies in the Sciences of Complexity, 27 (pp. 491-531). Santa Fe: Addison-Wesley.

- Klein, B., Crawford, G., and Alchian, A. (1978).
Vertical integration, appropriable rents and the competitive contracting process, *Journal of Law and Economics, 21,* 297-326.

- Knuth, D. (1998).
The art of computer programming, 3, Addison-Wesley, United-States.

- Koza, M. P., and Lewin, A. Y. (1998).
The co-evolution of strategic alliances, *Organization Science, 9*(3), 255-264.

- Krugman, P., (1991).
History and industry location. The case of manufacturing belt, *American Economic Review, 81*, 80-83.

- Langton, C. G. (1989).
Artificial life, the proceedings of an interdisciplinary workshop on the synthesis and simulation of living systems held. Santa Fe Institute in the Sciences of Complexity : Addison-Wesley

- Lawson, C. (2004).
Patenting genetic materials' unresolved issues and promoting competition in biotechnology, *Information Economics and Policy, 16,* 92-112.

- Lee, J., Lee, K., and Rho, S. (2002).
An evolutionary perspective on strategic group emergence : a genetic algorithm-based model, *Strategic Management Journal, 23*, 727-746.

- Lehrer, M., and Asakawa, K. (2004).
Rethinking the public sector : idiosyncrasies of biotechnology commercialization, *Research Policy, 33,* 921-938.

■ Leroux, I. (2004).
Les ambivalences des coordinations locales entre négociation, conflits et enjeux de pouvoir. Le cas des partenariats constitutifs d'une génopole à Toulouse, *Revue d'Economie Régionale et Urbaine, 4*, 513-538.

■ Lewin, A. Y., and Volberda, H. W. (1999).
Prolegomena on coevolution : a framework for research on strategy and new organizational forms», *Organization Science, 10*(5), 519-534.

■ Luukkonen, T. (2005).
Variability in organisational forms of biotechnology firms, *Research Policy, 34,* 555-570.

■ Mangematin, V., Lemarié, S., Boissin, JP., Catherine, D., Corolleur, F., Coronini, R., and Trommetter, M. (2003).
Development of SMEs and heterogeneity of trajectories : the case of biotechnology in France, *Research Policy, 32,* 621-638.

■ Masuch M., and Lapotin, P. (1989).
Beyond garbage cans : an AI model of organizational choice, *Administrative Science Quaterly, 34*(1), 38-67.

■ Marney, J. P., and Tarber, F. E. (2000).
Why do simulation? Towards a working epistemology for practitioners of the dark arts, *Journal of Artificial Societies and Social simulations, 4*(3), October.

■ Mitteldorf, J., and Wilson, D. S. (2000).
Population viscosity and the evolution of altruism, *Journal of Theoretical Biology, 204,* 481-496.

■ Nooteboom, B. (1999).
The dynamic efficiency of networks, in Grandori (Ed), *Interfirm networks : organization and industrial competitiveness,* London Routhledge, 91-119.

■ Nicolis, G., and Prigogine, I. (1994).
The fourth european framework program and research on complex systems, The university facing up its european responsabilities, Pisa, 23-26, November.

■ OCDE (2007).
Vers des pôles d'activités dynamiques : politiques nationales, Synthèse, Juin.

■ Owen-Smith, J., and Powell, W. (2003).
The expanding role of university patenting in the life sciences : assessing the importance of experience and connectivity, *Research Policy, 32,* 1695-1711.

■ Ponssard, J. P. (1994).
Formalisation des connaissances, apprentissage organisationnel et rationalité interactive, in Orléans A. (sous la direction de), *Analyse économique des conventions,* PUF Economie, Paris, 169-187.

■ Porter, M. (1998).
Clusters and the new economics of competition, *Harvard Business Review, 76,* 77-90.

■ Powell, W., White, D., Koput, K., and Owen-Smith, J. (2005).
Network dynamics and field evolution : the growth of interorganizational collaboration in the life sciences, *American Journal of Sociology, 110*(4), 1132-1205.

■ Prévot, F. (2007).
Coopetition et management des compétences, *Revue Française de Gestion, 176*, 183-202.

■ Rausser, G., Simon, L., and Ameden, H. (2000).
Public-private alliances in biotechnology. Can they narrow the knowledge gaps between rich and poor ?, *Food Policy, 25,* 499-513.

■ Roehrich, G. (2006).
Simulation du marché et de la concurrence par les automates cellulaires, International Congress « Marketing trends », Venice, 20th-21st January.

■ Roijakkers, N., Hagedoorn, J., and Van Kranenburg, H. (2005).

Dual market structures and the likelihood of repeated ties – evidence from pharmaceutical biotechnology, *Research Policy, 34*, 235-245.

■ Saviotti, P. (1998),
Industrial structure and the dynamics of knowledge generation in biotechnology, in Senker (ed), *Biotechnology and competitive advantage,* Edward Elgar, Cheltenham, 9-43.

■ Schelling, T. (1960).
The strategy of conflict, Harvard college: Harvard University Press.

■ Schoenauer, M., Sebag, M., Jouve, F., Lamy, B., and Maitournam, H. (1996).
Evolutionary identification of macromechanical models. In P.-J. Angeline & K.-E. Kinnear Jr. (Eds), *Advances in genetic programming II* (pp.467-488). Cambridge, MA: MIT Press.

- Sherry, E., and Teece, D. (2004).
Royalties, evolving patent rights, and the value of innovation, *Research Policy, 33,* 179-191.

- Simon, H. (1955).
A behavioral model of rational choice, *Quaterly Journal of Economics, 69,* 99-118.

- Simonin, B. L. (1999).
Ambiguity and the process of knowledge transfer in strategic alliances, *Strategic Management Journal, 20*, 595-623.

- Steyer, A., and Zimmermann, J. B. (2004).
Influence sociale et diffusion de l'innovation, *Mathematics and Social Sciences, 4*(168), 43-57.

- Stuart, T., and Sorenson, O. (2003).
The geography of opportunity : spatial heterogeneity in founding rates and the performance of biotechnology firms, *Research Policy, 32,* 229-253.

- Suire, R., and Vicente, J. (2004).
Les dynamiques de proximité de la net-économie : formation et stabilité des clusters TIC, 4èmes Journées de la Proximité, juin, Marseille, France.

- Teece, D. J. (1989).
Competition and co-operation : Striking the right balance, *California Management Review, 31*(3), 25-37.

- Thietart, R-A (2003).
Méthodes de recherche en management, 2ème édition, Paris: Dunod.

- Von Neumann, J. (1966).
Theory of automata : construction, reproduction, homogeneity, in *The theory of self reproducing automata,* Champaign: University of Illinois Press.

- Vriend, N. J. (2000).
An illustration of the essential difference between individual and social learning and its consequences for computational analyses, *Journal of Economic Dynamics and Control, 24*, 1-19.

- Walliser, B. (2000).
L'économie cognitive. Paris: Odile Jacob

- Wilensky, U. (2000).
Modeling emergent phenomena with StarLogo, working paper, Northwestern University.

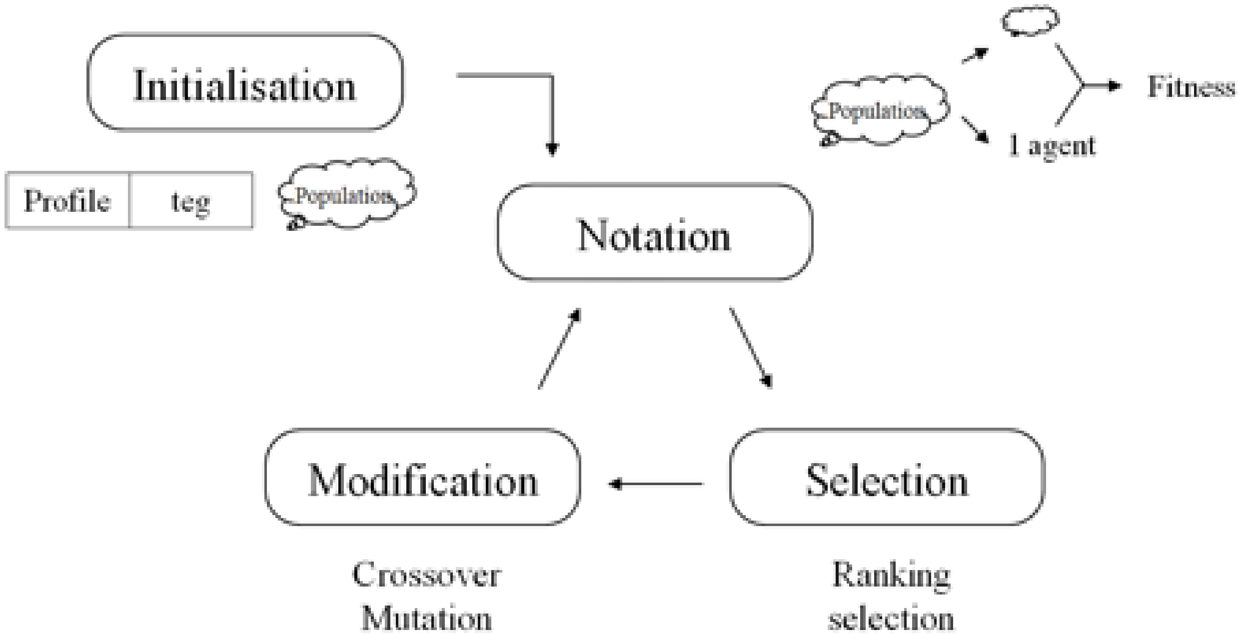
- Williamson, OE. (1999).
Strategy research : governance and competence perspectives, *Strategic Management Journal, 20,* 1087-1108.

- Yan, A., and Gray, B. (1994)
«Bargaining power, management control, and performance in United States – China joint venture: a comparative case study», *Academy of Management Journal, 37*(6), 1478-1517.

- Zucker, L. G., and Darby, M. R. (1997).
Present at the biotechnology revolution : transformation of technological identity for a large incumbent pharmaceutical firm, *Research Policy, 26,* 429-446.

APPENDIX 1 : SIMULATION PROCESS ALGORITHM

The diagram below shows the operation of the genetic algorithm used.



1. The initialisation phase attributed to each agent in the population, in a random or a guided way, a value which related to its genetic characteristics, in other words its profile (its negotiation strategy) and the expected size of the cake.
2. The notation phase determined a mark for each agent, representing the agent's gain expectation in a negotiation. This phase allowed the evaluation of the quality of each agent's strategy. In order to do this:
    a. A 10% sample of the population was randomly selected.
    b. Then, one by one, every agent in the population negotiated with every agent in the sample and thus obtained some gains (see paragraph entitled The payment function).
    c. By dividing the sum of an agent's gains by the number of negotiations effected, we calculated the agent's expectation of gains.
3. The goal of the selection phase was to choose the most highly performing agents, in other words those who have a high expectation of gain, and therefore had a good strategy. A ranking selection was used because this ensured that the probability of

selecting an agent was close to said agent's mark ratio, and to the total of the marks of all the agents in the population. The selection by rank first sorted the population by fitness; next, each agent was ascribed a rank according to a positioning relative to the others. In this way all the agents had a chance of being selected.

4. The modification phase effected a genetic intermixing of the selected agents by means of the crossover operator, and maintained the genetic diversity by means of the mutating operator.
    a. Crossover only operated between two agents with the same profile. The children resulting from this inherited the profile of the parents. The value of the expected size of the cake then either equalled that of one of the parents or was a different value. To calculate this different value, a number x between -0.25 and 1.25 was randomly selected, then tegchild = x * tegparent1 + (1-x) * tegparent2 was calculated.
    b. Mutation randomly modified one or several genetic characteristics of an agent. Following a mutation, then, an agent could change strategy or the expected size of the cake. In this case it was an exogenous mutation.
5. Return to phase 2.

Language used

The model was implemented in Java. The specification of the Math. Random function [specification java.util.random], which enables the generation of random numbers between [0; 1] guarantees that the seed of the pseudo-random number generator is new and unique at each launch of the program (Knuth, 1998).

Equilibrium detection technique

In the cases of simulations S1 and S2, the evolution in the proportions of each strategy can be seen for each generation, for 500 generations. To detect equilibrium, the average and the interval of its proportion in the population for the last 100 generations was calculated for each strategy. Next, the two highest averages were identified to find the established equilibrium. But this equilibrium was only confirmed definitively if the following two conditions were fulfilled: 1) the standard deviations associated with the two strategies participating in the equilibrium situation were less than 0,25; 2) the smallest proportion of strategies participating in the equilibrium was over 5%. Regarding the first condition, this is because too large a standard deviation can lead to the supposition that a change of equilibrium occurred in the last 100 generations. In this case, as the equilibrium had not been stable for long enough, it could not be confirmed. The second condition was established so as to eliminate the cases of very early convergence linked to a loss of genetic diversity.

APPENDIX 2 : THE SIMULATION PARAMETERS

Table 3. Common parameters, rates of mutation and crossover.

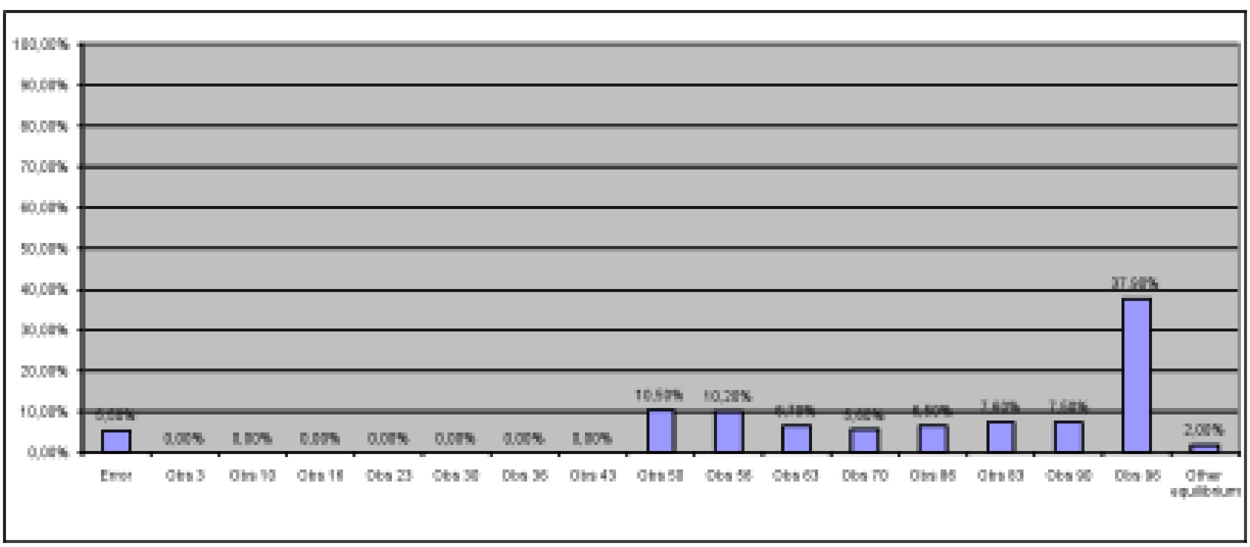
	Simulation S1	Simulation S2	Simulation S3
Common parameters	Initial size of the cake : `1` Variation interval of the size of the cake : `[0.1 ; 2.0]` Number of agents in the population : `1 000` Initial distribution of each profile : `12.5 %` Ranking selection		
Mutation rate	`10 %` Modification of agent's profile.	`10 %` Modification of agent's profile or of the expected size of the cake.	
Crossover rate	`0 %` All the individuals know the size of the cake so they are not seeking its expected size.	`50 %` There is only crossover between two « parents » with the same profile. The « children » take after them. The value of expected size of the cake therefore equals one of the expected sizes of the cake of the « parents » or a different value.	

APPENDIX 3 : ROBUSTNESS TESTS

1. Number of profiles

The choice of 7 profiles is sufficiently large to ensure the representativeness of the possible demands while guaranteeing the legibility of the results on a histogram. The simulation was tested with 15 profiles, obtaining identical results; using 15 profiles provided no additional elements of analysis and rendered the graphs barely legible.

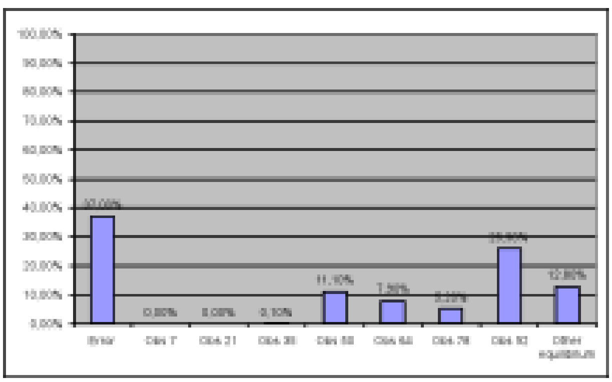
Figure 6. Percentage of equilibrium obtained between sophisticated and obstinate over 1 000 S2 simulations with 15 profiles



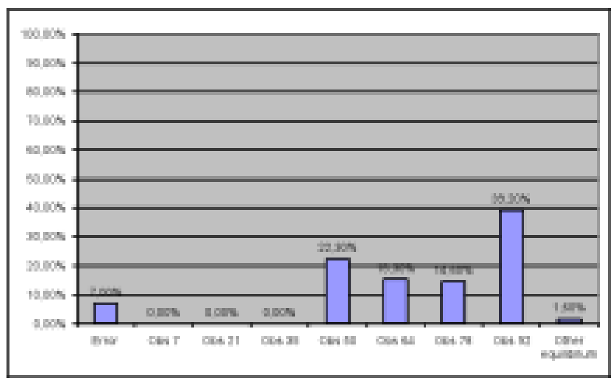
2. Mutation rates

The following graphs show the equilibrium percentages between sophisticated and obstinate obtained with 1000 S2 simulations. For each graph, the mutation rate used is indicated. As can be seen, from 5% to 12,5% the graphs give similar results. When the mutation rate is 2,5%, the errors (left-hand column) are essentially due to cases of early convergence. With a mutation rate of 15%, it can be seen that the proportion of equilibrium between the Obs 92% population and the Soph population becomes very high. Too high a mutation rate which is too high disturbs the evolution by modifying the genetic characteristics of too many individuals and artificially favouring the individuals with an elevated expectation of gains. Therefore, below 5% and above 15% the results cannot be used, for purely technical reasons.

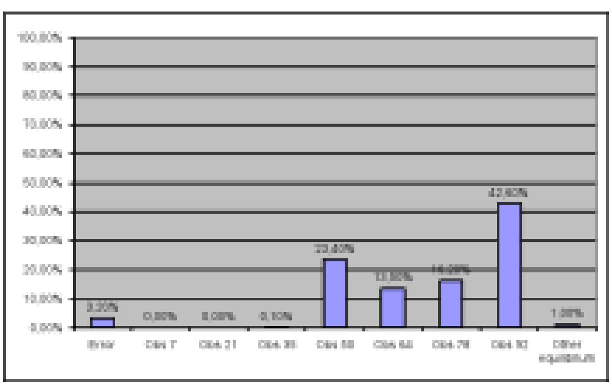
Figure 7. Graphs obtained with modification of the mutation rates



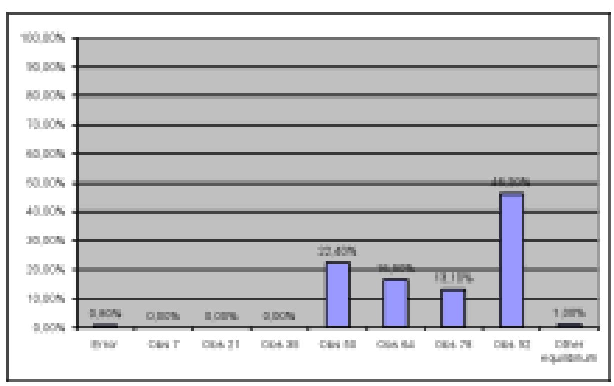
2,5 %



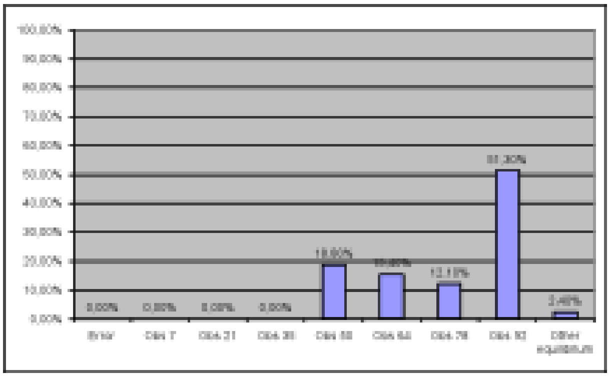
5 %



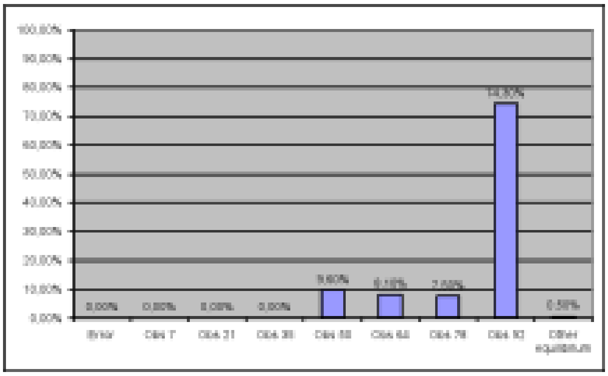
7,5 %



10 %



12,5 %



15 %