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The impact of organisational complexity in the strategy development process.

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The impact of organisational complexity in the strategy development process

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8.1 Introduction

In the first chapter of this book, it was stated that there is a set of characteristics that lead towards a decision being labelled as a strategic one. One of these characteristics is the complexity and inter-relatedness of the organisational context the strategy decision-maker has to deal with. This chapter focuses on showing how the organisational complexity of the firm affects the strategy development process.

Interest on complexity and, particularly, on understanding the distinctive features that characterize complex systems has increased dramatically during the last twenty years across many disciplines. The study of complex systems focuses on understanding how parts of a system give rise to its collective behaviour, how such collective behaviour affects such parts and how do systems interact with their environment. This focus on questions about parts, wholes and relationships explains the relevance of the study of complex systems in the agenda of biologists, physicists, economists, physicians, meteorologists, financial traders and organisation theorists.

Despite not being a universal notion of what a complex system is, we can characterize them by enumerating their key properties:

- *A complex system contains many constituents interacting nonlinearly*. Nonlinearity occurs when some condition or some action has a varying effect on an outcome, depending on the level of the condition or the intensity of the action. One example of non linearity is the law of decreasing return to scale of microeconomics. Extra labour added to a fixed installed capacity will increase output at varying rates till a point where such extra labour leads output to decline as large numbers of people interfere with efficient operation in a limited space. The dynamics of a market's supply and demand show the same non linear characteristic, leading to frequent abrupt expansions or contractions of production and drastic movement in prices of many goods.
- *The constituents of a complex system are interdependent.* We cannot optimize the performance a complex system just by optimizing the performance of its subparts and "aggregating" them. Interdependencies create conflicting constraints between different organisational designs. This is the reason why the development of "best practices" only in a part of the firm frequently fails, as they don't address their impact on other parts of the firm's process.
- *A complex system possesses a structure spanning several scales.* In a firm, scales can be translated as hierarchical levels: the headquarters, the division, the business unit, and the different functions within each unit, such as sales or operations and the departments within each function.
- *A complex system is capable of emerging behaviour*. A behaviour is said to be emergent, at a certain scale, if it cannot be understood when you study, separately, every constituent of this scale. No matter how well I can understand how different

departments of a firm work, by reading a book, or talking to its executives, I will not be able to copy the strategy of that firm without understanding how those department "blend" in a unique overall strategy.

- *The combination of structure and emergence in a complex system leads to self-organization*. Self-organisation takes place when an emergent behaviour had the effect of changing the structure or creating a new one. Through self-organization, the behaviour of the group emerges from the collective interactions of all the individuals. Even if they follow simple rules of action, the resulting group behaviour can be surprisingly complex and remarkably effective or destructive.

Complexity theory focuses specifically in the two last properties: emergence and self-organization.

8.2 Emergence and Self-organisation

In responding to their own particular local contexts, the individual parts of a complex system can, despite acting in parallel without explicit inter-part coordination or communication, cause the system as a whole to display emergent patterns, orderly phenomena and properties, at the global or collective level. In some complex systems, the constituent parts are not themselves complex systems and are governed by unchanging rules. Moreover, in very complex systems, these complex parts can be governed by rules that evolve.

Self organization happens when an emergent behaviour has the effect of changing the structure or creating a new one in the absence of formal authority. Self-organization is a process in which components of a system in effect spontaneously communicate with each other and abruptly cooperate in coordinated and concerted common behaviour. The development of black markets in centrally planned economies is a clear example of how self-organisation works.

We can interpret self-organization in an organization as the process of political interaction and group learning from which innovation and new strategic directions for the organization may emerge. Senior management create the context in which collaboration can happen through the development of a few simple rules and by creating vehicles that enable managers to exchange ideas and perhaps find collaborative opportunities. Examples of such vehicles are a structure promoting interdependence, systems and processes that disseminate information across units (e.g., a firm-wide intranet), routine strategic planning meetings, the participation of one business unit in the strategic review of another, high mobility across divisions and opportunities to meet informally.

The outcome therefore emerges without central intention and is unpredictable. A well known example of self-organized behaviour with major strategic implications is the change that took place in the strategic focus of Intel from focusing on the computer DRAM memory business to becoming a microprocessors company (Burgelman, 1994). This change was not enforced vertically by senior management, but a result of a myriad of initiatives led by middle managers of the firm who challenged and eventually changed top managers' dominant logic and "emotional attachment" to the DRAM business.

In short we can say that, the distinctive characteristic of complexity theory that differentiates it from other theories related to complex systems such as cybernetics, system dynamics, catastrophe theory or chaos theory is that it proposes an explanation of *how novelty unfolds*. That is the reason why complexity theory has received so much attention in the current business literature concerned with understanding co-evolution processes between and within firms.

8.3 Business firms as complex systems

The study of firms as complex systems poses the challenge of finding an adequate methodology that enables to represent firms as systems composed by many parts with degrees of interdependence that are not "a given" but can be manipulated, and the ability to show emergent behaviour. Qualitative studies based on approaching firms or parts of firms as case studies provide valuable insights. However, due to the enormous number of micro interactions taking place between parts of a firm and across different levels, these insights will not be positive accounts of how firms work as complex systems but, in the best case, smart interpretations of how emergence and self-organising might take place in that firm. (Due to the high number of dimensions involved in strategic decision making, strategy formulation is deemed, from the point of view of algorithm theory, as an intractable problem.) Therefore, this makes any explanation based on following such method highly interpretative.

In the last ten years, strategy scholars interested in understanding the impact of complexity on the strategy development process started to rely on the use of agent-based models. In an agent-based model, individual agents autonomously make decisions based on internal rules and local information. Not being constrained by the imposition of equilibrium conditions, these models offer a degree of flexibility that permit key features of complex systems to be addressed, i.e., the representation of the firm as a reality composed by many parts interacting nonlinearly, the interdependence between such parts and their ability to show emergent behaviour. Additionally, agent based models enabling the modelling of individuals that can evolve and learn in different ways. This permits to overcome a limitation of models developed in the tradition of the neoclassical theory of the firm that assumes that all agents have identical behaviour (Arthur, 2006).

The remainder of this chapter discusses the application of agent-based modelling to organisation and strategy studies. For that purpose, first, we discuss Kauffman's *NK* model, arguably the most frequently used in recent contributions based on agent-based modelling. Next we discuss the theoretical roots that justify the application of the *NK* model to organisation studies as well as some adaptations that the model requires from its original formulation in biology. Third, we review some major contributions for the field of strategic management based on the use of this modelling technique. Fourth, we develop a set of simulation experiments based on the *NK* model in order to examine its main features and highlight its possible applications. Finally, we discuss current research challenges for scholars working with this modelling strategy and suggest promising avenues for the development of research based on agent-based modelling techniques.

8.4 Agent-based modelling

For most of the twentieth century, biologists have assumed that “order” was due to the effects of selection, as developed under the general label of Darwinian “selectionist” theory. The intuitions behind this idea derived from statistical mechanics, particularly the idea of entropy. Entropy measures the amount of order in a system, with increasing disorder corresponding to increasing entropy. Left to themselves, systems are inherently disordered and unstructured. Therefore “selective” work is necessary to achieve and maintain order. In the context of strategic management, selection is translated as competition, the force that makes firms keep “fit” in their quest to survive and develop. Kauffman challenged this unquestioned notion suggesting that while natural selection is a prominent force in evolution, order can also emerge spontaneously due to the self-organizing properties of systems. As the complexity of the system under selection increases, selection is progressively less able to alter the properties of the system. This would be the case, for instance, of a firm stalled as a consequence of excessive bureaucracy or by strong power struggles. Despite being exposed to the forces of the market, this firm remains detached of such imperatives as it is trapped in the logic of its internal processes. In these cases we can say that selection is unable to avoid the *spontaneous* order derived from the properties of the system.

This property of complex systems is clearly observed in firms, most prominently in highly diversified ones. During the 1960s many firms, notably in the U.S., embarked on growth by diversification initiatives with the hope of taking advantage of opportunities for synergy with their core businesses. Extreme versions of these strategies were conglomerates such as ITT, British Oxygen Company or Litton Industries that entered in a wide range of different businesses. Despite it could be argued that such diversification helped these groups to diversify the risk of their portfolios, by the early 1970s, many of these highly diversified companies began to face performance problems due to their inability to manage such a degree of complexity effectively, notably at the time of allocating resources between businesses. These problems were tackled initially through the use of portfolio planning techniques such as the BCG or the McKinsey matrixes, but the limitations of these techniques were soon evident as the inability of these companies to solve their performance problems. During the 1980s, this inability of the companies to address the imperatives of competition (or selection) due to their internal complexity was solved (in a distressing way) by the emergence of raiders who acquired these firms through hostile takeovers, broke them up and sold the different parts realizing huge profits. While many observers considered that these restructurings were in some cases pushed too far, their massive number during the "takeover era" (Useem, 1996) in the U.S. reflected to what extent the complexity of those conglomerates was enabling the firms to release all their potential value.

Kauffman examined the relationship between selection and self-organization and tried to find out under what conditions an adaptive evolution is optimized. This question of to what extent we want differentiation vs. integration in a firm's structure (Lawrence and Lorsch, 1967) as a way to improve performance is one of the most important ones the top manager needs to make at the time of implementing a strategy. The variability in behaviour as the structure of a system is altered can be pictured as characterizing the ruggedness of a fitness landscape.

8.4.1 Performance landscapes

From an evolutionary viewpoint, an entity can be represented by a list or vector of features. By programming this abstraction in a computer we can build a simulation model of the process of evolution. In this kind of models, entities adapt by modifying their existing form in an attempt to enhance their performance in a payoff surface or "performance landscape". A performance landscape consists of a multidimensional space in which each attribute of the entity (policy decisions constituting different strategic options of a firm in a business context), is represented by a dimension of the space and a final dimension indicates the performance level of the firm. Firms typically adapt through small changes involving local search in the space of possible strategic options. In principle, such a process involves complex combinatorial optimization. In such optimization searches, many parts and processes must become coordinated to achieve some measure of overall success, but conflicting "design constraints" limit the results achieved (Kauffman, 1993). For instance, major decisions on the location of production systems cannot be made without considering how these decisions might impact other activities of the firm such as as sourcing, logistics, or finance.

Kauffman demonstrates that the degree of conflicting constraints affecting the evolving entity affects the topography of the performance landscape. Increasing the density of the interdependencies between policies affects the complexity of the landscape and, consequently, increases the number of possible emergent patterns of behaviour that the firm can follow. In order to model such webs of complex interdependencies, Kauffman developed the *NK* model.

In Kauffman's *NK* model fitness landscapes are characterized with, essentially, two structural variables. The first variable is N, representing the number of policy decisions that characterize the firm (for instance, decisions related to marketing, operations, logistics, public relations, R&D, etc). The second structural variable K represents the number of elements of N with which a given policy decision interacts. The higher K, the more interdependent are the parts of the firm and, therefore, the higher is the number of conflicting design constraints.

In the model, only two decisions can be made for each of the N policy variables. These decisions are represented by the values zero and one. Therefore, the performance landscape consists of 2^N possible policy choices, being the overall behaviour of the firm characterized by the vector $X\{X_1, X_2,...,X_N\}$ where each X_i takes on the value of 0 or 1. Another assumption of the model is that all policies have an equal weight on performance.

A random number, generated from a uniform distribution ranging from zero to one, is assigned to constitute the performance contribution of each of the policy decisions. A particular firm's overall performance is equal to the average of the performance contributions of its N policies.

Smooth and rugged performance landscapes. As stated above, interactions between attributes affect the topography of the performance landscape. Each attribute can take on 2^{K+1} different values, depending on the value of the attribute itself (either 1 or 0) and the value of K other attributes with which it interacts. When K=0, there are no interactions between the different policy decisions. The landscape tends to assume a single-peak configuration (Figure 8.1).

[Insert Figure 1 here]

In these cases, being the behaviour of each actor independent of that of others, the contribution to overall performance of each attribute is independent from others' behaviour. In this situation the mere aggregation of local improvement of performance always leads to global improvement. In other words, global maximum can be achieved merely by the aggregation of local "best practices". As seen in Figure 8.1, the topography of this landscape is smooth, as neighbouring points in the space have nearly the same fitness value. More precisely, we can say that in these kinds of landscapes the performance value of neighbours strategic options are highly correlated. Knowing the performance value of one point we can infer rather precisely the performance value of neighbouring points.

However, as interactions increase, the landscape becomes more rugged or multi-peaked (Figure 8.2). Multiple peaks are the direct result of interdependences among a set of attributes. When K>0, the contribution of an policy to overall performance is affected by the behaviour of K other policies.

For the largest possible value of K, N-1, each policy is affected by all the remaining ones. In these cases the performance landscape is entirely uncorrelated and the number of local performance optima is very large.

[Insert Figure 2 here]

The implications of a rugged landscape are very much a function of the search behaviour of actors moving on the landscape. If they were omniscient and could readily search globally, they would be able to identify the global maxima as in smooth landscapes. However, a more realistic analysis developed within the behavioural tradition of intelligent local search (March and Simon, 1958, Levinthal and March, 1993) assumes that managers' rationality is bounded. They can identify the positive and negative gradients around and close to their current position, but are not capable of making similar judgements for more distant ones. In a rugged landscape, such incremental search procedure will lead only to the local maxima or *peak* closest to the starting point of the search process, regardless of its height relative to other peaks in the landscape. As a result of this locking in to the first available solution, a strong form of path dependence is observed and, on average, modest performance sometimes referred as *competency traps* (Levitt and March, 1988). In these situations firms achieved the best possible configuration of the wrong strategy. One mechanism to overcome such "traps" is to engage in “long-jumps”, random explorations of more distant portions of the landscape. Long jumps involve the simultaneous alteration of many elements of *N*, the equivalent of a drastic strategic turnaround. This strategy prevents the company from falling into competency traps. However, such distant efforts, by not exploiting wisdom gained by past experience, are likely to result in a deterioration of performance. So, the problem of adaptation strategies in rugged landscapes can be reframed as a familiar dilemma faced by managers organisation theorists: how to get the benefits of exploring new business models without facing the inherent risks and without losing the advantages of exploiting acquired knowledge (March, 1991).

In the following section we discuss the assumptions that underlie the application of the *NK* model to organisation studies. Then we will review some the main academic contributions based on this methodology in the strategy literature.

8.5 Using the *NK* model in organisation and strategy research.

As the previous discussion made apparent, the *NK* model permits to address many central concerns of students of organisational decision making, especially for those rooting their work on evolutionary perspectives. Behavioural evolutionism (March and Simon, 1958; Cyert and March 1963, Nelson and Winter, 1982) conceives firms as entities that engage in problem-solving through processes of search and discovery. Unlike the classic theory of the firm, which treats firms as omniscient rational systems, behavioural evolutionism assumes that, while searching for solutions to their problems, firms adopt some form of adaptive behaviour in response to feedback about their previous performance. Their behaviour depends on the relationship between the performance they observe and the aspirations they have for that performance.

While adapting, firms consider only a limited number of decision alternatives, due to bounded rationality (Simon, 1997). Recent works that rely on algorithm theory (Rivkin, 2000; Moldoveanu, 2004) described strategy formulation as an intractable problem. Being managers unable to write an algorithm enabling them to find the optimal set of decisions in reasonable time, they make strategic decisions trying to *satisfy* some set of criteria rather than to optimize. Their choices depend on certain features of the organizational structure and on the locus of the search responsibility, and are heavily conditioned by the rules within which such choices occur (Cyert and March, 1963).

Brabazon and Matthews (2002) state that the concept of adaptive search developed by evolutionary theorists is meaningful only in the context of a defined search space, a means for traversing such space, and the ability to determine the quality of a proposed solution. Kauffman's *NK* model provided such a context and so has become the mainstream formal modelling strategy for recent work rooted in the evolutionary tradition.

Work based on the *NK* model has been developed and adapted by organization theorists to model organizational problem-solving processes showing features such as bounded rationality in the consideration of decision alternatives, the existence of interdependencies between subunits that can be manipulated by managers, decision making based on reasoning by analogy and the existence of decision rules that bound the set of possible choices (Levinthal, 1997; McKelvey, 1999; Gavetti and Levinthal 2000; Rivkin, 2000; Gavetti, Levinthal and Rivkin, 2005; Siggelkow and Rivkin, 2005; Caldart & Ricart, 2006).

In order to make the *NK* model suitable for research of organizations some adaptations of the model are necessary. First, we need to address the fact that organizations are not fully decomposable systems, as implicitly assumed in the pure form of the *NK* model. Organisational problems tend to have a nearly decomposable structure (Simon, 1996). Tasks tend to cluster into subsystems, being interaction within such subsystems, on average, stronger than interactions across subsystems. For instance, on average, we will always see more interaction within Marketing than between Marketing and Operations. Recent contributions based on the *NK* model, such as Gavetti, Levinthal and Rivkin (2005) address this issue by defining a hierarchy of decisions and clustering decision variables in subgroups or units. Second, in social systems we cannot neglect the issue of deliberateness of behaviour. Managers may freely choose to change the firm's strategy, clearly an ability that the genotypes referred in biology models don't have. Therefore, models may include decision rules followed by managers at the time of, for instance, deciding whether to maintain a current strategy or to modify it (Siggelkow and Rivkin, 2005; Caldart & Ricart, 2006).

8.6 Major contribution to the strategy literature based on the *NK* model

Work based on the *NK* model has contributed to long lasting debates from the strategic management literature. Next, we discuss two examples of recent and influential works from this research perspective. First we discuss Rivkin's work on the imitation of successful strategies. Then we review work that explores the relationship between cognition and experience during a firm's strategic evolution and how reasoning by analogy can nurture management's cognitive representations.

Imitating strategies. Rivkin (2000) used agent based simulations based on the *NK* model to show why firms find it difficult to imitate strategies from successful companies. He shows that "complexity makes the search for an optimal strategy intractable in the technical sense of the word" (Rivkin, 2000, pg. 824). Incapable of relying on algorithmic solutions, copy cats need to rely on heuristics or learning to match a successful firm's strategy. However, due to complexity, firms that follow simple hill-climbing heuristics are likely to be trapped in "local peaks", and firms that try to learn and mimic the strategy of a successful firm suffer large penalties from small errors. The importance of this model is that it explains why, despite being exposed to public scrutiny through case studies or business articles, winning strategies remain unmatched. For instance, the strategy of DELL, based on the outsourcing of manufacturing and direct sale, is widely known and understood. Something similar happens with other firms such as Microsoft, or Toyota. Yet, their business models have not been copied effectively at such scale by any competitor.

Strategy making. Gavetti and Levinthal (2000) used an adaptation of the *NK* model to study the role and interrelationships between search processes based on cognitive representations that are articulated in strategic plans (that they label “forward-looking”) and search processes based on the lessons learnt in previous experience (“backward-looking”). Following the notion of bounded rationality, the authors simulated cognition as a representation of the performance landscape that, being grounded on the actual landscape, has a lower dimensionality. In this way, as firms know the expected performance values associated to the value of certain attributes of the firm, they are able to identify more or less attractive sub-areas of the problem space. However, as their representation has a lower dimensionality than the real problem, they cannot foresee the most attractive peaks within each of those sub-areas, therefore suffering the risk of falling in a competency trap despite following the right strategy with respect to the attributes they understand well. This would be for instance the case of a car manufacturer that, despite understanding that his business needs to have a global market scope, a competitive manufacturing cost based on work on a limited number of platforms and global sourcing and high R&D budgets (success factors central to this business) fails to achieve high performance. Despite the strategy is broadly right, it fails to deliver because of what Rivkin (2000) identified as large penalties due to small errors, due to the ruggedness of the industry’s performance landscape. It is interesting to note that most of the strategy “framework” constituting the mainstream of the field, such as the SWOT analysis or Porter’s five forces are characterized by the same feature of Gavetti and Levinthal’s model: an effort to make sense of reality based in reducing the dimensionality of the problem in order to make it understandable for decision makers. The difference between the two approaches to modelling relies on the fact that, for instance, the 5 forces framework represent the competitive situation of the firm at a particular point of time, while *NK* models represent the *process* followed by the firm in its attempt to improve its strategy.

Gavetti, Levinthal and Rivkin (2005) further developed the study of the relationship between cognition and strategic decision making through the development of a highly sophisticated model of how managers reason by analogy. They show how the depth and the breadth of managers' "portfolio" of experiences can help them to make sense of novel situations and develop superior strategies reasoning by analogy. For instance, Charles Lazarus founded Toys 'R' Us in the 1950s, relying explicitly on the supermarket analogy. The basic supermarket formula, exhaustive selection, low prices and margins and high volume, has been applied by analogy across a wide range of retail categories such as consumer electronics, books or furniture.

In the following section, we present two simulation models that will help the reader to understand more thoroughly the logic and characteristics of the model, its advantages and limitations and their implications for strategic management and organisation.

8.7 Simulating the evolution of firms using the *NK* model.

In this section we describe the experiments, settings and results of two simulations of firms' evolution based on the simplest version of the *NK* model. Our aim is to analyse the sensitivity of the model to values of the parameters *N* (the size of the organization modelled) and *K* (the degree of interdependence between the decisions made by the company). Each of the firms has being simulated 30 different times so that we can get robust results.

The model we developed for the purposes of this chapter follows the following architecture, for any given experiment:

1. Randomly generate the decision vector representing a firm's strategy for a given *N*. We define as a strategy to any possible combination of choices of policy decisions.
2. Evaluate the current state: generate the value of the current performance for the player, for a given *K*. The firm's performance is equal to the average of the contributions to performance of each of the N policy decisions.
3. Start the game. While the maximum number of iterations is not reached:
    a. Generate the current state's neighbour states, for a given *NK*
    b. Evaluate the neighbouring states, for a given *NK*
    c. Move to a new state if its value is higher than the current one, otherwise stay in the current state.

The algorithm used to simulate the *NK* model is represented in Figure 8.3.

[Insert Figure 8.3 here]

In all the experiments discussed below, firms move across the landscape according to the following algorithm. Once positioned in the performance landscape at M_0, in all cases, firms evolve following a local or "neighbourhood" search strategy. In Kauffman's model, local search takes place when the set of business attributes are varied only incrementally. In our model, local search works as illustrated by the following example (for N=4). From an initial configuration of the vector X, for example {0,1,1,1}, with an associated performance value P_0, the firm explores a configuration adjacent to the initial one, for example {1,1,1,1,}, with an associated performance value P_1. If $P_1 > P_0$, the firm adopts the new form{ 1,1,1,1} P_1 and from there explores another adjacent configuration, for example{1,0,1,1}, with a performance value P_3. Otherwise, if $P_1 < P_0$, the firm does not adopt the configuration associated with P_1 and explores another configuration, for example {0,0,1,1}, with an associated performance P_2. This process is repeated from M_0 through M_{30}. In this way, the company engages in local "hill-climbing" or neighbourhood search (March and Simon, 1958) towards a peak of the performance landscape. This strategy allows firms to evolve till they reach a local peak where they stay till the end of the simulation.

In order to obtain a complete picture and understand the sensitivity of the model to changes in the parameters, we simulated firms with five different sizes, in terms of number of policy decisions (N = 5, 10, 15, 20, 40), and six different degrees of interdependence between such attributes or organisational complexity (K = 0, 1, 2, 3, 5, 10). (In all the modelled firms the restriction $K \le N$ holds.)

8.7.1 Analyzing the relationship between firm's complexity and performance.

Figure 8.4 shows the evolution of the performance of firms of equal number of attributes (*N*=20) and different levels of organisational interdependence or complexity (*K*=0, 1, 2, 3, 5 and 10). As the reader can see, the performance of the different kinds of firms increases at a decreasing rate of growth and eventually reaches a peak, i.e., converges to a steady state, till the end of the simulation.

[Insert Figure 8.4 here]

The most interesting result derived from this experiment is that there is not a linear relationship between the mean performance of local optima obtained by a firm and its level of organizational complexity (or interdependence, measured by *K*).

Figure 8.5 represents the performance at the steady state of the experiments for the average of the thirty independent simulations for N = 20 and K = 0, 1, 2, 3, 5, 10. It shows that there is, in fact, a non-linear (quadratic) relationship between performance and complexity, implying that there is an optimal level for the complexity of an organization (given its size). In this case, for a firm with size *N*=20 the optimal level of complexity is *K*=2.

[Insert Figure 8.5 here]

This ability to achieve the highest mean performance at moderate levels of complexity is a property that characterizes many complex systems. This led some management scholars to label this degree of complexity as “the edge of chaos” (Brown and Eisenhardt, 1998; Pascale, 2000). The edge of chaos implies a degree of organisational complexity that is neither too low to lead the firm to an “error catastrophe” (Kauffman, 1993), i.e., the inability to cope with the environmental complexity that firms face (K=0 in our case) nor too high to lead it to the opposite extreme, a “complexity catastrophe” (Levitt and March, 1988) the inability of the firm to evolve beyond modest performance due to the high number of conflicting design constraints (K=10 in our case). The highest levels of performance appear to be achieved for moderate levels of interdependence. This outcome confirms the idea of organisational “ambidexterity”, understood as the need to find a balance between the firm’s need of order, reliability, consistency, efficiency, alignment that demands clear authority lines, bureaucratic procedures and standards, and the need of innovation, creativity and change, that demands loose links, exploration, organisational slacks and conflict. For instance, Amgen Inc., a pharmaceutical firm, manages its R&D according to these principles. On the one hand Amgen only initiates exploratory research projects under approval from top research-related senior executives in regards to budget, and headcount. On the other hand the company grants “bootleg time”, equivalent to one day a week, to scientists to work on any projects they desired. In this way, scientists were able to continue working on projects they considered important, despite the company didn’t find them very promising.

This simulation also shows that, despite not achieving the highest mean performance maxima, relatively complex firms tend to evolve faster in the short term. The rate of growth of performance in the beginning of the experiments is higher for *K*=10 and *K*=5, and lower for *K*=0 and *K*=1. This suggests that not only different levels of complexity lead to different levels of performance but that the relative performance of these difference configurations vary in the short and in the long term. In other words, firms interested in short term profits should benefit from different architectural designs than firms that give prominence to long term results.

8.7.2 Analyzing the relationship between firm's size and performance.

The following experiment aims at understanding the relationship between the size of the firm and performance, for a certain level of organisational complexity (*K*). For this purpose we modelled firms of different size (understood as number of attributes, measured by the parameter *N*) having the same degree of interdependence (*K*=3).

Figure 8.6 plots the mean performance maxima achieved by players of different sizes (*N*=5, 10, 15, 20, 30 and 40) with *K* = 3. The results show that performance increases with the value of *N* achieving a maxima mean performance, in this case, at a threshold level of *N*=15. From then on the mean performance has no relation with size, remaining stable. These results show that the optimal level of interdependencies within a firm is contingent to its size and that firms get benefit from their ability to grow in size without increasing their complexity proportionally. This convenience of managing complex firms through a set of "simple rules" (Eisenhardt and Sull, 2001) is consistent with accounts from successful companies such as General Electric. In 1983, the CEO Jack Welch dismantled the laborious and complex strategic planning system of GE and, replaced it by a strategy playbook where businesses needed to provide simple one page answers to five questions concerning current market dynamics, the competitors' key recent activities, the GE business response, the greatest competitive threat over the next three years and GE's planned response. Additionally he mapped the complex portfolio of GE's businesses under the "Three Circle Concept". Under this concept, all businesses were divided into (1) core, (2) high-technology and (3) services. Only businesses that dominated their markets, i.e., being number one or number two, would be placed in one circle or another. Those outside the circles had to come up with a strategy or be divested. This initiative led to a major turnaround of the GE portfolio, with 200 businesses being sold till 1990, while 370 new ones were acquired.

[Insert Figure 8.6 here]

We can also analyse the dynamics of the adaptation of the different players for different values of firm size and a complexity of K=3. On Figure 8.7 we can see that *there is* a relationship between firm size and the speed of adaptation as, for example, the performance of the firm with size N=20 and N=40 grows slower than the one of every other firm, but the performance of the firm with size N=5 was the one exhibiting faster growth. These results show that smaller firms reach faster a steady state, whereas bigger firms explore more of the state of possible strategies, as they have more possible combinations of policy decisions to explore.

[Insert Figure 8.7 here]

A final an interesting analysis of this simulation relates to the risk associated with state space exploration. The future of a firm is not dependent upon average performance only; risk is also an important component of its valuation. The risk associated to each firm can be estimated by looking at the standard deviation of the performance achieved by each one of the thirty firms analysed for each experiment.

Figure 8.8 illustrates our results for the standard deviation in the mean local maxima achieved by firms with K= 3 and N = 5, 10, 15, 20, 30, 40. It shows that for constant levels of complexity the ability of the company to achieve a certain level of performance presents a lower risk as the size of the company increases. The reason for this is that the smaller the company keeping complexity constant, the shorter the length of its walk to local optima and therefore, the higher the probability of reaching peaks with a wider range of performances than firms with longer walks. Bigger firms tend to converge to very similar performance levels in the long run, whereas smaller firms converge more quickly and can end-up with very different performance levels.

[Insert Figure 8.8 here]

In conclusion, this set of experiments, based on the basic formulation of the *NK* model, clearly illustrate the ability of the model to provide valuable insights on the relationship between organisational complexity, its size and performance. Additionally, it illustrates the importance of Monte-Carlo simulation as a tool to average-out randomness, allowing a better analysis of the long-term relationships between the different variables.

8.8 Conclusions

The purpose of this chapter was to focus our attention on complexity as it is one of the distinctive characteristics of strategic decisions. Being firms complex systems, we discussed agent based modelling as a method that permits to do formal research that addresses the main features of such systems, such as nonlinearity, interdependencies between subsystems and emergent behaviour. We reviewed the generic architecture of the model and reviewed the theoretical roots that enable us to apply this model, with some modifications, to the realm of social science. Then, we discussed some of the most relevant and recent contributions to the strategy and organisation theory literature based on this modelling strategy. Finally, we programmed a set of simulation experiments based on the basic form of the *NK* model in order to show its potential as a formal research tool that permits to model the complex relationships between the firm's size and complexity on its performance.

The *NK* model proved to provide valuable insights at the time of understanding how the relationship between firm's size and complexity affects its performance.

However, despite the great progress made in *NK* simulation modelling applied to social studies there are still some major challenges to be addressed by scholars in their attempt to increase the relevance of this modelling framework. A major example of such a challenge is the need to address the fact that the direction of a firm's evolution and its performance are affected by the behaviour of other actors, prominently, its competitors. This *interdependent rationality* between actors constitutes a distinctive feature of Strategic Management in practice. Strategic initiatives from the different actors are responded by initiatives from other actors making strategic management essentially a *dialectic process*.

These problems can be addressed by the inclusion of an additional parameter, called *C* in the context of Kauffman's work, which indicates to degree of interdependence between the policy decisions of different firms, in contrast to the parameter *K*, discussed extensively in this chapter which indicates the degree of interdependencies within the firm. In this way, in a market where Firm A competes with Firm B, as Firm A evolves on its performance landscape, it both changes the performance of Firm B and deforms B' performance landscape. As Firm B responds to this move from Firm A, the performance of Firm A's current strategy changes and its performance landscape deforms.

The *NKC* model has been discussed conceptually in the management literature (Levinthal and Warglien, 2000) as a model that permits to simulate the co evolution of an ecosystem of firms. However, the development of work applying such model as a way to understand competitive interaction between multiple players is still in its infancy.

In addition to the development of models to analyze and describe formally competitive interaction between multiple firms, there are several other debates within the strategy literature where evolutionary studies based on the *NK* model could make a valuable contribution. For instance, this model could be used to analyze the relative performances of proactive vs. failure induced strategic change. A variation of the model based on a hierarchy of decisions, could be developed in order to understand the relationships between two different decision levels when strategies are originally developed at the lower level, in an emergent fashion.

The experiments we discussed above plus the agent-based model based research described in section 8.6 and the emergent work based on the *NKC* model address in a formal way all of the six essential elements of the Strategy Development Process as discussed in chapter 1: a sense of direction and purpose, formulation of strategic options (based on cognitive representations of the performance landscape), the (rationally bounded) evaluation of such options, addressing the impact of exogenous uncontrolled inputs (in the *NKC* model), a feedback system and strategic control. By formalizing these six elements using simple computational agent based models based on a few parameters, we can discover how these elements relate to each other and understand the principles underlying such relationships.

Finally, these models enable practicing managers to grasp very valuable intuitions on important strategic management issues such as why are successful strategies so difficult to imitate (Rivkin, 2000), why and to what extent can analogical reasoning can inform strategy development in novel industries (Gavetti, Levinthal and Rivkin, 2005), why firms need to engage in periodical organizational restructurings in order to improve performance (Siggelkow and Levinthal, 2005), how different ways of managing the headquarters-business unit relationship affects performance (Caldart and Ricart, 2006) and how managers' dominant logics affect organizational strategic development processes including the development of capabilities (Gavetti, 2005)

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Figure 8.1

A single-peak performance landscape

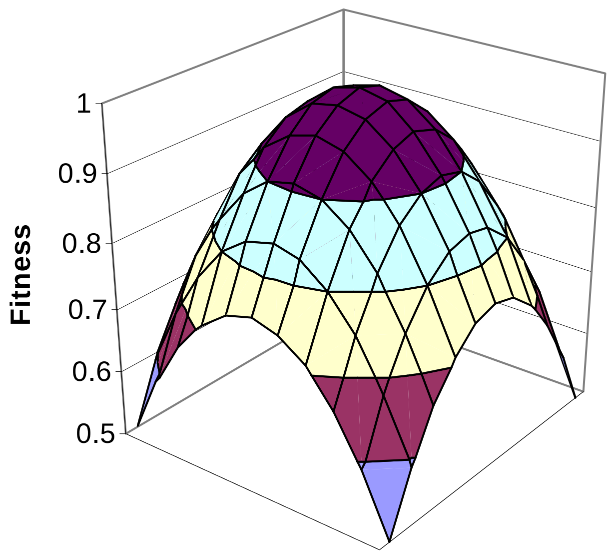

Figure 8.2

A rugged performance landscape

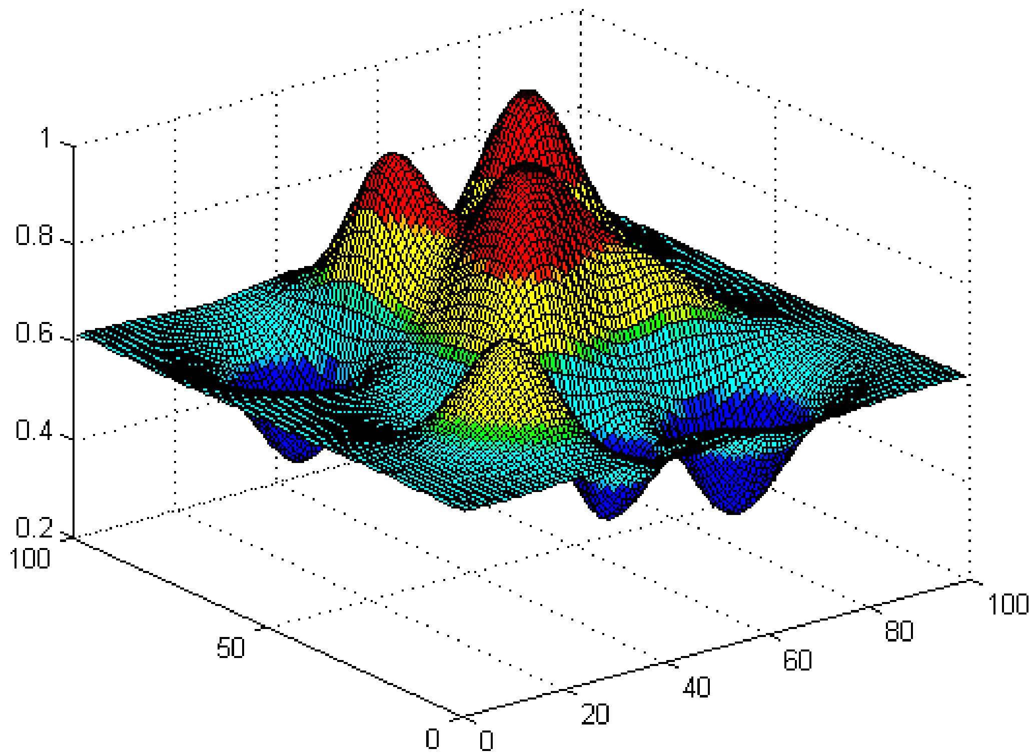

Figure 8.3

Scheme for the *NK* algorithm

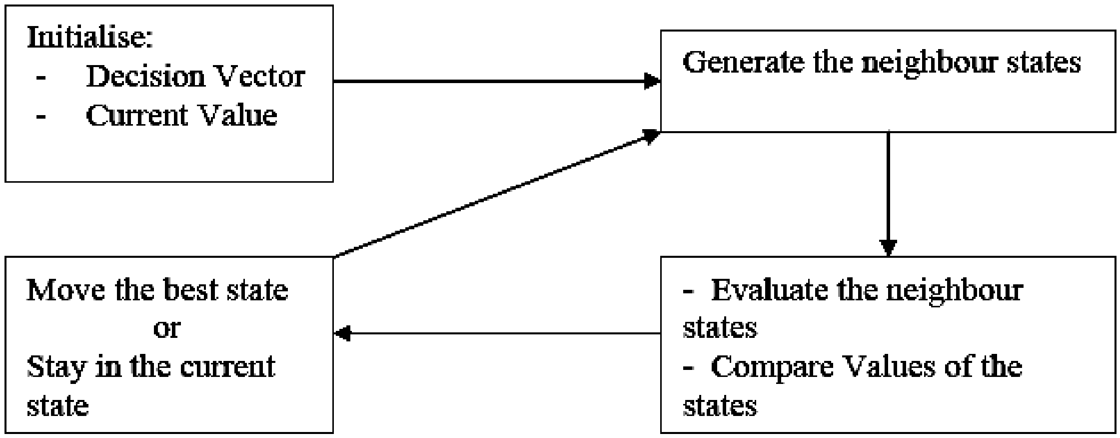

Figure 8.4

Average Performance for *N* = 20 and *K* = 0, 1, 2, 3, 5, 10

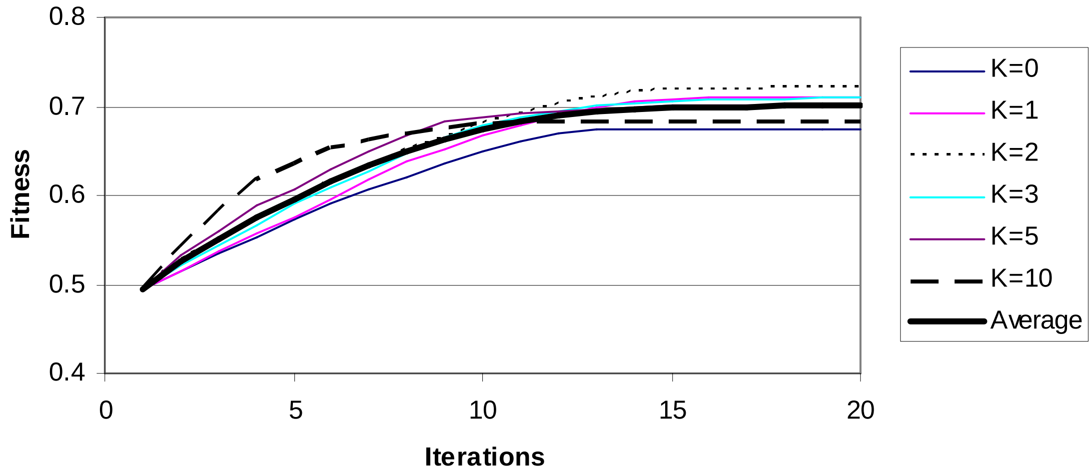

Figure 8.5

Final Average Performance for *N* = 20 and *K* = 0, 1, 2, 3, 5, 10

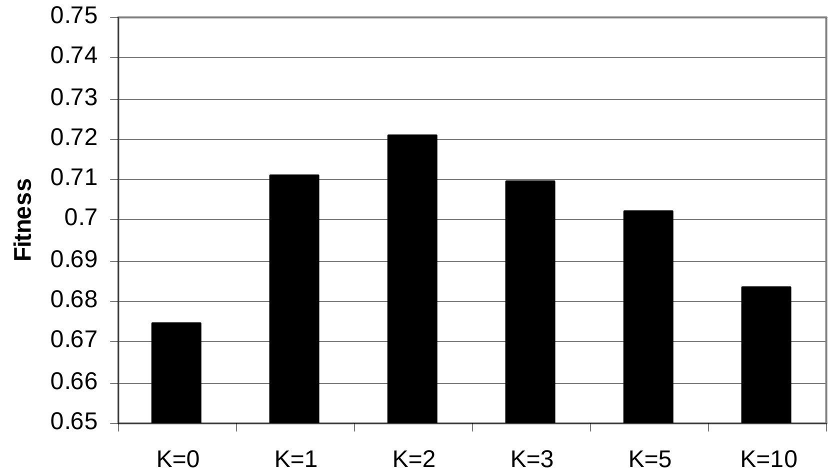

Figure 8.6

Final Average Performance for *K* = 3 and *N* = 5, 10, 15, 20, 40

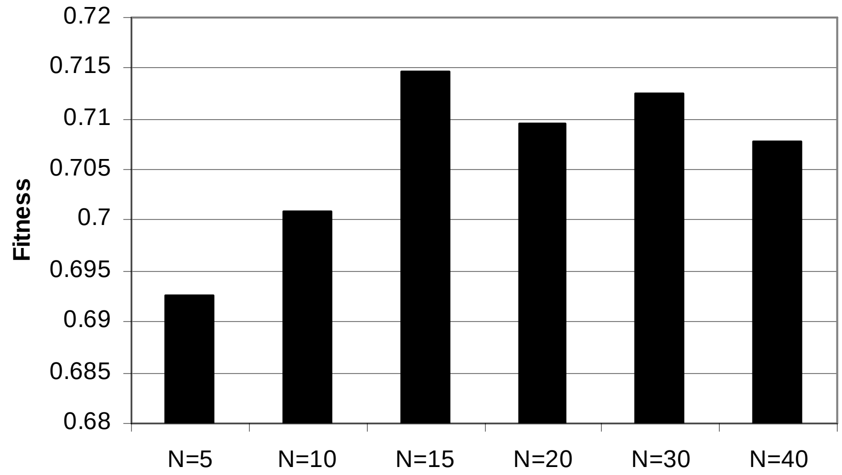

Figure 8.7

Average Performance for *K* = 3 and *N* = 5, 10, 15, 20, 40.

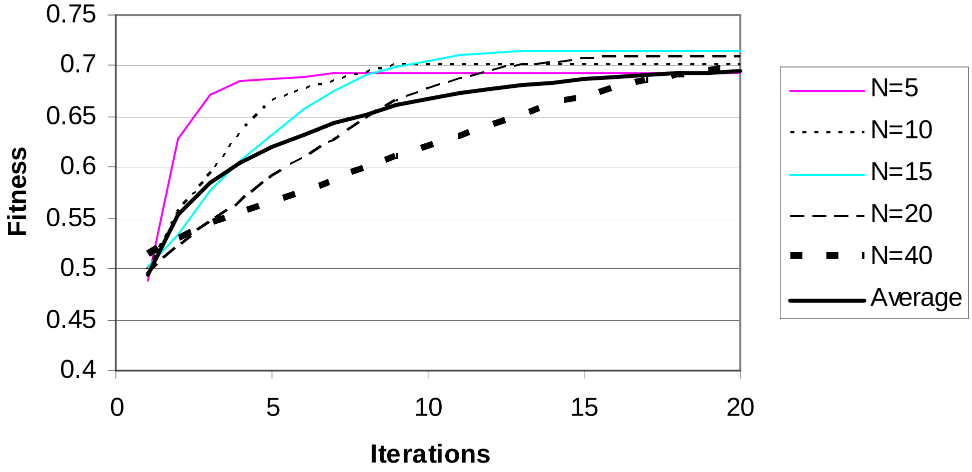

Figure 8.8

Final Standard Deviation of Performance for *K* = 3 and *N* = 5, 10, 15, 20, 30, 40