Exploration and exploitation strategies. What kind of analytical models?

Nadia Jacoby

Exploration and exploitation strategies.
What kind of analytical models ?

Nadia JACOBY, MATISSE

Exploration and exploitation strategies.
What kind of analytical models?

Nadia JACOBY
Université Paris I Panthéon – Sorbonne
MATISSE-ISYS
106-112 bd de l'Hôpital, 75013 Paris – France
Phone :+33.(0)1.44.07.81.45
Fax :+33.(0)1.44.07.83.36
e-mail : jacoby@univ-paris1.fr

Abstract:

This paper gives some insights related to the combination of exploration and exploitation behaviors. A recurrent question for firms deals with this blend of exploration and exploitation mechanisms. Firms are engaged in new activities like research and at the same time in more routine ones like development and production. Thus, they should find a satisfying arrangement between exploration and exploitation. But in order to do that, they should better understand their working. This paper analyzes adaptive systems through exploration and exploitation behaviors of firms. In order to better understand the temporal articulation of those behaviors, we refer to a mapping representation of search processes using *NK* models (Kauffman, 1993).

Key words: Evolutionary approaches of firms, Exploration and Exploitation behaviors, NK models

Stratégies d'exploration et exploitation. Quel modèle analytique ?

Résumé :

Une question récurrente pour les firmes concerne la combinaison des mécanismes d'exploration et d'exploitation dans leur comportement stratégique. Les firmes sont engagées à la fois dans des activités nouvelles de recherche et dans des activités plus routinières de développement et de production. L'enjeu pour les firmes consiste alors à trouver une combinaison satisfaisante entre exploration et exploitation. Pour cela, il convient de bien comprendre comment fonctionnent ces deux mécanismes.
Cet article analyse les systèmes adaptatifs à travers l'alternance des comportements d'exploration et d'exploitation des firmes. Afin de mieux saisir l'articulation temporelle de ces comportements, nous considérons une représentation cartographique des processus de recherche à l'aide des modèles *NK* (Kauffman, 1993).

Mots clés: Approches évolutionnistes de la firme, Exploration, Exploitation, Modèles *NK*

JEL classification: C63, L21

Evolution is a method of search among a great number of possible "solutions". If, in biology, this set of possible solutions is the set of possible genetic sequences, evolution can also be seen as a method for designing innovative solutions to complex problems. The environment changes and thus, it is necessary to search continually new sets of possible solutions. Even if the evolution rules seem to be very complex, in particular because they are responsible for variety and complexity of species, in fact, there are rather simple. "*Species evolve by means of random variation, followed by natural selection in which the fittest tend to survive and reproduce, thus propagating their genetic material to future generations*", (Mitchell, 1998).

In the evolutionary perspective, a central point in the study of the firms' evolution concerns adaptation and selection behaviors. Changes in the economic environment incite firms to adapt themselves. But, to analyze these adaptive processes, the relation between the exploration of new possibilities and the exploitation of old certainties[1] should be observed.

This paper focuses on adaptive systems engaged in exploration and exploitation processes. Exploration strategy of firms includes search, variation, innovation, ..., whereas exploitation behavior concerns choice, efficiency, selection, ...[2] But how can the firm combine at once exploration and exploitation? What is the right trade-off between exploration and exploitation? (March, 1991).

An useful starting point to analyze adaptation processes is to consider a mapping representation of the population. The concept of ″fitness landscape″ developed by Wright (1931) is defined as a representation of the space of all different possible configurations of the population according to their fitness. Each individual of the population is represented by a dimension of the space associated to a fitness value, which depends on how well that individual solves the problem at hand. However as the economic rationality of agents is bounded and because they cannot observe all the possible positions over the landscape, an accurate representation has to consider a limited space within which components can move. Thus, the search process has to be local, as suggested by Wright (1931).

Among several kinds of analytical models available, "*NK* model" (Kauffman, 1993) is a simple formal model of rugged fitness landscape that demonstrates the fitness landscape topology is determined by the interdependence degree of the fitness contribution of the various attributes of the organism. These interactions refer to epistatic effects[3] (Smith, 1989). *N* represents the number of parts of the system, i.e. the number of individuals in the population, whereas *K* is the number of other attributes with which each individual interacts. Thus, the contribution of each

---

[1] Schumpeter (1934), Holland (1975), March (1991).
[2] March (1991).
[3] Epistatic effects refer to the action of a specific gene on another one non-allele.

element to the fitness landscape depends upon its own fitness level and upon the *K* other elements among *N*. Interdependency models like *NK* make easier the understanding of exploration/exploitation behaviors.

I – Exploration and exploitation strategies

The firm evolution refers to exploration and exploitation strategies and then to innovation processes. In the economic literature, organizational learning is understood at first and second order. The first order learning allows to do existing things better, whereas the second concerns the capability to do news things. This notion is clearly linked with those of parametric (Langlois and Robertson, 1995) and architectural changes (Abernathy and Clark, 1985; Henderson and Clark, 1990). The way Holland (1975) but above all March (1991) pose the dilemma between exploration of new possibilities and exploitation of old certainties sums up very well this question. This section will be devoted to the exploration/exploitation problem and its study proposed by the economic literature.

1°) Exploration, exploitation behaviors in the economic literature

To survive in the short run, firms need to exploit in an efficient way the existing resources. In the long run, it is necessary for the firm to explore new possibilities and to develop new competencies. The firm competitiveness can be guaranteed only thanks to its innovation process, which allows surviving to the market competition.

✓ *Exploration strategy*

As March describes, "*exploration includes things captured by terms such as search, variation, risk taking, experimentation, play, flexibility, discovery, innovation*" (March, 1991). Exploration is an adaptable and flexible process, which has to adapt itself to the new configuration the firm can discover and arises from individual deviance as a source of innovation (Nooteboom, 1999). The study of the innovation process combining the theory of innovation cycle with the theory of product life cycle (Vernon, 1966) leads to the identification of an innovation process in two stages. The first stage of innovation, characterized by volatility, concerns the creation of "Schumpeterian novel combinations", whereas in the second, "dominant designs", characterized by economies of scale and routinization, can emerge. At this second stage, the firm exploitation behavior is essential. The innovation developed in the first stage is consolidated in the second one. The degree of coordination between actors and the limitation of their autonomy depend on the innovation cycle stage. The best firm organizational structure for the exploration strategy is a disintegrated one. Members of organization should be able to operate independently without a too tight coordination process. The firm should be able to create some discontinuities in order to discover new possibilities.

Holland (1989) is interested in the way firms explore. How firms explore while maintaining exploitation and existing resources? So, two underlying questions are raised. The first concerns creation with minimum of destruction, the second asks for the optimal discovery process. The model presented in the second section will try to answer those questions. The use of current competencies in novel contexts allows preserving exploitation while exploring new possibilities. Existing routines are necessary for the exploration strategy of the firm. Abernathy and Clark (1985) define two kinds of innovation. Innovation which "enhances the value or applicability of the firm's existing competence", and innovation that disrupt and destroy the firm's existing competence. The latest "*changes the technology of process or product in a way that imposes requirements that existing resources, skills and knowledge satisfy poorly or not at all*" (Abernathy and Clark, 1985). Therefore, the value of existing routines is reduced. As Schumpeter said, the "creative destruction" is the vehicle of growth.

But we focus on the first kind of innovation for which the changes don't need to be destructive. "*Innovation in process technology may require new procedures in handling information, but utilize existing labour skills in a more effective way. Such changes conserve the established competence of the firm*" (Abernathy and Clark, 1985). Thus, the question of internal coherence of the firm described in particular by Dosi, Teece and Winter (1990) emerges. New routines created or discovered by the exploration process have to be consistent with the firm global activity. The firm should be able to manage all its routines, new and old, if it wants to survive in the long run. The compatibility between routines is fundamental for the firm durability[4]. The firm diversification strategy is not randomly determined; at the opposite, it enforces some implicit rules such as those concerning its core activity.

✓ *Exploitation strategy*

As March (1991) describes, "*exploitation includes such things as refinement, choice, production, efficiency, selection, implementation, execution*". Exploitation consists in a refinement of existing technology, requiring individual coordination (Nooteboom, 1999). Indeed, the internal working of the firm refers to the coordination between members but also to the coherence among individual and collective knowledge. However, exploitation needs also fixed rules and routinization for an efficient management of the activities. The firm organizational structure should be sufficiently integrated to allow a large volume production, the emergence of economies of scale and the distribution of products in wider markets. This structure permits the emergence of a dominant design and a novel techno-economic paradigm

---

[4] Chakir, Jacoby (1999) proposes two case studies of cooperation agreements highlighting, in particular, the problem of internal coherence.

(Freeman and Perez, 1988). The firm sustains a price competition; with an high level profit objective.

Compared to the returns from exploration and the high uncertainty degree associated, exploitation is safer for the firm. Returns from exploitation are less remote in time, less distant from the initial position. The exploitation results are more certain than those of exploration, there are quicker and more precise. Exploitation constitutes the main source of benefits for the firm; it allows expenses for exploration necessary for market competition. As March (1991) remarks, "*basic research has less certain outcomes, longer time horizons, and more diffuse effects than does product development*".

2°) Exploration, exploitation dilemma: a theoretical overview

Exploration as exploitation competes for scarce resources and the firm makes choices between them. So, the firm faces the dilemma between exploration and exploitation while knowing that it is necessary to make a trade-off between cognitive distance and proximity. The paradox the firm faces with, relies on the necessity to mix exploration and exploitation in a specific way, which guarantees its survival. The search horizon have to be sufficiently close to maintain exploitation and at the same time sufficiently distant to discover significant novelty. In evolutionary models, the discussion around exploration and exploitation is framed in terms of balancing variation and selection processes. In this theoretical perspective, the firm is a set of routines and core competencies evolving under the influence of variation and selection mechanisms. The evolutionary model of the firm is constructed at the intersection of the Darwinian triptych of "heredity, variety, selection" and the Lamarckian concept of "inheritability of acquired characteristics".

During the evolution process, the firm mutates, changes and those changes need to be selected in order to preserve the internal coherence. New routines emerging from the variation process are not necessarily consistent with the other routines of the firm. It is therefore essential those routines would be selected in order to preserve the internal coherence and then the firm durability.

Variation process applies to firm's exploration behavior whereas internal selection process refers to its exploitation behavior. The dilemma March wants to solve is reduced to the question of firm's internal equilibrium between variation and selection. What is the appropriate trade-off between changes and stability? What is the share of mutation the firm needs compared to the share of stability? In an evolutionary model, the firm exploratory behavior can be measured by the practice and the rate of change in the environment (March, 1991). The higher the rate of change, the more the firm explores.

March (1991) proposes a simple model of adaptation whose objective consists in "elaborating the relation between exploration and exploitation, and exploring some implications of the relation for the accumulation and utilization of knowledge in organizations". In this mutual learning model, the dilemma between exploration and exploitation involves conflicts between short run and long run and between gains to individual knowledge and gains to collective knowledge. It's a simple model of the development and diffusion of organizational knowledge.

The environment or external reality has m dimensions taking the value 1 or −1 with the independent probability of 0.5. The organization is composed by n individuals and is represented by the organizational code. Individuals and organizational code have m dimensions taking the value −1, 0 or 1, which can change over time according to the adaptation process. The individual beliefs change continuously as a consequence of learning from the code. P_1 represents the effectiveness of socialization, the learning from the code and then the exploitation behavior. Therefore, 1-p_1 reflects the exploration behavior, that is the development by individuals of visions different from those of the organization. Adaptation process acts according to the suitability to the reality. "*The organizational code adapts to the beliefs of those individuals whose beliefs correspond with reality on more dimensions than does the code*" (March, 1991). The model measures the knowledge state at the individual and organizational levels. Individual beliefs and organizational code converge up to the stable equilibrium at which they share the same belief with respect to each dimension.

The model can be a closed system with neither entry nor exit, or an open system. In the closed system, March analyzes the effect of learning rates and of learning rates heterogeneity. When p_1 is high, we can observe a positive effect on the individual knowledge but an adverse effect on the improvement of organizational knowledge and then on the improvement on individual knowledge in the long run. Therefore, the organizational population has to be composed of slow learners and fast learners. In this case, the model shows that the heterogeneous population has always-higher knowledge equilibrium than the homogeneous population. Finally, the higher knowledge equilibrium can be obtained thanks to the mixed organizational population, that is with exploiters and explorers.

In the open system, March is interested in the effect of environmental turbulence and personnel turnover, which is another way to introduce variability in the model. The first-order effect of turnover on individual knowledge is negative, but we observe there is a positive relation between the length of service and the individual knowledge level. On the whole, the turnover effect on individual knowledge is strong and slightly more complicated on the organizational knowledge where it reflects a trade-off between the learning and the turnover rates. Firstly, when the exploitation level is moderate (p_1=0.1, for example) and the turnover relatively high,

organizational knowledge level decreases. However, when exploitation is high (p_1=0.9, for example), organizational knowledge increases till turnover achieves a particular threshold and then decreases. The environmental turbulence effect on the level of knowledge is negative. But this effect can be made up for the existence of turnover, even if it is moderate, especially on the organizational knowledge. However, the closer the new entrants to the current organizational code, the less efficient the turnover as source of exploration.

Finally, we observe that diversity increases level of knowledge. New entrants know less on average than incumbents but what they know is less redundant with the organizational code. In probability, they certainly contribute more to improve organizational knowledge.

II – Model

Interdependency models allow representing the relationship between members of organization. Adaptation processes are complex; variation and selection mechanisms, which refer to the exploration, exploitation dilemma in the evolutionary approach of the firm, are interdependent. As Levinthal (1997) remarks, their complexity and interrelationship encourage the use of simulation models.

1°) Interdependency models

A useful starting point to analyze these processes is to consider a mapping representation of the population. The concept of *"fitness landscape"* developed by Wright (1931) is a multidimensional space in which each attribute is represented by a dimension of the space according to its fitness value. The genotype represents different possible configurations of the population. Each genotype has fitness and the distribution of fitness values over the space of genotypes constitutes the *"fitness landscape"*[5]. Each individual of the population is represented by a dimension of the space associated to a fitness value, which depends on how well that individual solves the problem at hand. As described above, the overall distribution of the individual's fitness values over the population constitutes the fitness landscape. For simplicity, we consider that each population is a bit string of length *l* and that the distance between two populations is called *"hamming distance"*. It represents the number of locations at which corresponding bits differ. So the fitness landscape can be represented in a (*l*+1)-dimensional plot. But the main interest of this kind of representation is to show how individuals can move all over the landscape, i.e. how to represent evolution process.

---

[5] Kauffman (1993) notes that "often, Wright (1931) thought of the fitness of a given gene or genotype as a function of its frequency in the population". Like Kauffman in his book (1993), we consider, here, the simpler idea that each genotype can be assigned fitness.

According to Wright, evolution causes populations to move along landscapes in particular ways, especially local search processes. Each population component searches a better position on the landscape, i.e. a position that gives it a higher fitness value. However as the economic rationality of agents is bounded and because they cannot observe all the possible position over the landscape, an accurate representation has to consider a limited space within which components can move. That is the reason why the search process is local. In this context, the concept of *"neighborhood search"*, developed by March and Simon (1958) can be compared to the *"local hill climbing"* Holland's (1975) notion. Adaptation can be seen as a moving of population towards local peaks (Wright, 1931).

The ultimate goal for the population is to enhance the global fitness value through the increase of the component fitness value. So the population shape will be modified.

2°) NK model

"*NK* model" is a simple formal model of rugged fitness landscape that demonstrates the topology of the fitness landscape is determined by the degree of interdependence of the fitness contribution of various attributes of the organism. *N* represents the number of parts of the system, i.e. the number of genes of the genotype. An entity is composed of *N* attributes where each one can take on two possible values, 0 or 1[6]. Thus, the fitness space consists of 2^N possible configurations. Furthermore, the contribution of each element to the fitness landscape depends upon its own fitness level and upon *K* other elements among *N*. Thus, each attribute can take on 2^{K+1} different values depending on the value of the attribute itself and on the value of the *K* other attributes with which it interacts. *K* measures the richness of epistatic interactions[7] among the components of the system and influences the relative smoothness or ruggedness of the landscape. *K* is necessarily inferior to *N* but can assume all the values between 0 and *N*-1[8].

Here the question is to discover an attractive peak on the rugged fitness landscape i.e. a peak with a higher fitness value. The search should be sensitive to the fitness value of alternative locations in the space of possible solutions. It is a local search process which examines alternatives in the immediate neighborhood of the current position. Search is a step-by-step process, which implies a moving only if the new fitness value is higher. At the end, the search mechanism stops when the local optimum is reached i.e. when there is no more possible position with a higher fitness value. During the search process and after a few iterations, the number of solutions, yet in touch, declines radically (Kauffman, 1993; Levinthal, 1997). It clearly reflects

---

[6] Describing this kind of model, Levinthal (1997) notes, "the model can be extended to an arbitrary finite number of possible values of an attribute".
[7] Epistatic effects refer to the action of a specific gene on another one non-allele.
[8] For a precise description of NK model, refer to Jacoby (2001).

the fact that many initial starting points share the same local optimum. The more rugged the landscape, the higher the number of local optima. The local search process results in a ″walk″ to the optimum from all the starting points. However, search efforts can be ″trapped″ on a sub-optimal local peak. Indeed, search process is path-dependent and reveals here its limited nature.

However we can also identify another kind of search process focused on the adoption of alternatives far removed from the organization's current mode of operation. Kauffman (1993) calls, these kind of radical changes, *″long jump″*. In practical terms, the "long jump" corresponds to the random specification of each of the *N* attributes of the organization. Consequently, the organization adopts this new alternative if its fitness value is higher. Thus the likelihood of a radical organizational change is sensitive to the organization's current performance. The more efficient the organization, the less the likelihood for a radical change.

Local search and adaptation processes modeled in *NK* represent exploration behavior whereas selection refers to exploitation. We are interested in the impact exploration and exploitation have on the global performance, so we focus on their influence on individual fitness values. The results presented here, take into account the following initialization. The number of organizations is kept constant over time and, it is set at 100. We set *N*=10, number of organizations=100, number of runs=100 and runs the simulation for *K*=0, *K*=1, *K*=5. The results reflect the average behavior.

The first set of runs rests only on local adaptation - without ″long jump″ or selection - and is characterized by a high diversity degree. Organizations have only an exploration strategy.

Quite rapidly, the number of organizational forms decreases whatever the value of *K*. The search process continues till all the organizations reach a local optimum. While the organizations are initially randomly distributed on the fitness landscape, these results show that many of them share the same local optimum.

In a second set of simulation, there is no diversity and all the organizations are assigned to the same organizational form. It is assumed that organizations are engaged in local and distant search processes. The organizations' strategy is always only based on exploration. In the first few periods, roughly half of the organizations can identify attractive forms and adopt them. But quite rapidly, local search process leads to the decline in the number of distinct organizational forms in the population.

A third set of simulation postulates a pure selection process without adaptation; the strategy adopted by firms is only exploitation. Changes occur only by birth and death of organizational forms, which are not sensitive to the value of *K*. The landscape is driven towards the fittest organizational form. Contrary to adaptation processes, the rate of organizational forms

differentiation is slower. However, selection process drives the population towards the existence of a unique form while adaptation leads to a set of organizational forms over which selection occurs.

But what happens if, now, we consider changing environments[9]. What is the challenge for incumbents in a Schumpeterian environment? How do adaptation and selection interact in a changing external environment?

To explore these issues, after 25 periods of time, the simulation process specifies a new the fitness landscape by changing one dimension in the fitness contribution. When the degree of epistatic interaction equals zero, all the incumbents survive. But the higher the value of *K*, the less the share of surviving incumbents. With high levels of interaction, the local adaptation is not an efficient response to changes in the fitness landscape. As a result, in a changing environment, survivals are more dependent of a long-jump process result.

The diversity of organizational forms seems to be explained thanks to the diversity of environments in which organizations act. But this kind of argumentation requires the existence of a well-defined scheme of interrelationship between environment and organizations. The degree of epistatic interactions appears as an interesting factor to explain both organizational diversity and persistence of organizations in changing environment, (Levinthal, 1997).

Conclusion

Volberda (1998) suggests possible solutions to solve the paradox of exploration/exploitation.

First, the firm can be engaged in both exploration and exploitation mechanisms because one part of the organization is devoted to exploration while another part deals with exploitation. Thus, there is horizontal or vertical separation within the firm. In the first case, some divisions are engaged in exploration, typically R&D department, while others are engaged in exploitation, typically production department. But, in this case, the interface problem persists. Conversely, the vertical separation can go two ways. Either the management delegates the exploration activity and controls the upholding of internal coherence; or he determines the search direction and coordinates the staff.

In the horizontal separation, all the department interacting with the market and sources of technology can grip new opportunities they meet. There is no path pre-determined by the management. If the firm is vertically separated, the management claims specific paths the divisions have to respect in their exploration activity. Advantages and drawbacks are more or less the same Aoki (1986) identifies for the horizontal structure of firms J and the vertical one of firms A.

---

[9] This option corresponds to the environmental turbulence proposed by March (1991).

The second Volberda's proposition concerns the separation between different specialized firms. One firm focuses on a specific stage of exploration while another one offers complementary stages in exploitation. In the pharmaceutical industry, "*large companies provide efficient production, marketing and distribution whereas biotechnological firms explore novel product forms*", (Nooteboom, 1999).

Finally, the last proposition explains that separation can occur in time. The firm can explore during a certain period of time and then exploit during another one. Nooteboom refers to Burns and Stalker's (1961) "oscillating" concept, specifying it's very difficult to achieve. Indeed, it requires the constant job redefinition; people periodically change their function in the firm, which changes itself its activity, oscillating between exploration and exploitation.

But, NK models are above all used to illustrate the temporal separation. So, the two first propositions remain research paths to explore, in particular thanks to those analytical models.

REFERENCES

Abernathy W.J., K.B. Clark: "Innovation: Mapping the winds of creative destruction", *Research Policy*, 14, pp. 3-22, (1985).

Aoki M.: "Horizontal vs. vertical information structure of the firm", *American Economic Review*, 76/5, pp. 971-983, (1986).

Burns T., G.M. Stalker: *The management of innovation*, London: Tavistock, (1961).

Chakir K., N. Jacoby: "How internal selection process leads to a cooperation agreement? An application to car industry", *European Meeting on Applied Evolutionary Economics*, Grenoble, June 7-9, (1999).

Dosi G., D.J. Teece, S.G. Winter: "Les frontières des entreprises: vers une théorie de la cohérence de la grande entreprise", *Revue d'économie industrielle*, n°51, (1990).

Freeman C., C.Perez: "Structural crises of adjustment, business cycles and investment behaviour", in Dosi (ed.), *Technical Change and Economic Theory*, London: Francis Pinter, (1988).

Frenken K., L. Marengo, M. Valente: "Interdependencies, nearly-decomposability and Adaptation" in Brenner T. (ed.) *Computational techniques to model learning in economics*, Kluwer Academics, (1999).

Henderson R.M., K.B. Clark: "Architectural innovation: The reconstruction of existing product technologies and the failure of established firms", *Administrative Science Quarterly*, 35, pp. 9-30, (1990)

Holland J.H.: *Adaptation in natural and artificial systems*, University of Michigan Press, Ann Arbor, MI, (1975).

Holland J.H., K.J. Holyoak, R.E. Nisbett, P.R. Thagard: *Induction; Processes of Inference, learning and discovery*, Cambridge CA: MIT Press, (1989).

Jacoby N.: "Evolution of Firms in Complex Worlds: Generalized NK models", in Mira J., A. Prieto (eds), *Connectionist Models of Neurons, Learning Processes, and Artificial Intelligence*, Lecture Notes on Computer Science 2084, Berlin, Springer Verlag, pp.602-611, (2001).

Kauffman S.A.: *The Origins of Order*, Oxford, Oxford University Press, (1993).

Langlois R.N., P.L. Robertson: *Firms, Markets and Economic Change*, Routledge, (1995).

Levinthal D.: "Adaptation on rugged landscapes", *Management Science*, vol. 43, pp. 934-950, (1997).

March J.G.: "Exploration and exploitation in organizational learning", *Organization Science*, vol.10, n°1, pp. 299-316, (1991).

March J.G., H. Simon: *Organizations*, John Wiley & Co., New York, (1958).

Marengo L., G. Dosi, P. Legrenzi, C. Pasquali: "The structure of problem-solving knowledge and the structure of organizations", *Industrial and Corporate Change*, vol. 9, n°4, special issue December, pp. 757-788, (2000).

Mitchell M.: *An introduction to genetic algorithm*, MIT Press (1998).

Nelson R.R., S.G. Winter: *An Evolutionary Theory of Economic Change*, Cambridge MA, Harvard University Press, (1982).

Nooteboom B.: "The Combination of Exploitation and Exploration: How does it work?", *EGOS Colloquium, Knowledge and Organization Track*, Warwick, 3-6 July, (1999).

Schumpeter J.A.: *The Theory of Economic Development*, Cambridge MA, Harvard University Press, (1934).

Smith J.M.: *Evolutionary Genetics*, Oxford University Press, New York, (1989).

Valente M.: Laboratory for simulation development–Lsd, www.business.auc.dk/~mv/, (1998).

Vernon R.: "International investment and international trade in the product cycle", *Quarterly Journal of Economics,* 80, 190-207, (1966).

Volberda H.W.: *Building the flexible firm*, Oxford University Press, (1998)

Wright S.: "Evolution in Mendelian populations", *Genetics*, 16 : 97-159, (1931).