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## COMMITMENT PROCEDURES IN R&D INVESTMENTS : AN EXAMINATION OF DIFFERENT VARIETIES

### 1 Introduction

In his latest book, J.R. Hicks (1989) proposes a straightforward classification of the investments a firm can engage in. Within this classification, investments are clearly divided into two categories. The first one, defined as "defensive investments", encompasses three specific commitments : the first one is dedicated to the replacement of equipment, which is part of a much wider production capacity, the second one is aimed at reinforcing a productive system confronted to effective or potential competition, and the third one is made in order to improve internal relationships. Therefore, such types of commitments emerge from a risk of market shares losses, or a contest of global productive capabilities.

The second category, that of "offensive investments", is not only oriented towards the development of new equipment which either decreases utilization costs, or improves the production process of an existing good, but also towards the implementation of new capacity developed for the production of a new product. The latter is a typical example of an innovative choice (M. Amendola and J.L. Gaffard, 1988), within which uncertainty (F. Knight, 1921) can be defined as high or radical. A commitment to such investments implies the willingness to qualitatively transform the firm's environment, by creating new specific resources including organizational ones. The firm proceeds along this path without any reference to future market characteristics, because probability distributions of future events are not reliable.

In this article, our aim is first to provide a clear understanding of how, and under what conditions, the *ex ante* commitment procedure occurs in these different cases of investment. We shall focus more specifically on R&D expenses as presented in the literature, which may

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be at stake for both of the categories of investments described above. For this purpose, Option Value models applicable to irreversible investment choices under probabilizable uncertainty (that is Knightian risk) are presented. Such models appear as the most complex ones in the literature, because they take into account the context of increasing information. Option Value models address simultaneously the two following problems : the profitability calculation of each project defined in a given production possibilities set, and their comparison two by two in order to exhibit the optimal solution, which is then immediately adopted. Then, it signifies that an evaluation problem is clearly at stake. Therefore, R&D expenses appear as means of information acquisition on vertically-related future investments. They also will have to comply with the principle according to which any investment estimated as optimal will not reduce future possible acts.

Next the commitment procedure is identified as an evaluation and comparison of future possible investments. Such a procedure refers to a large scope of investments as classified by J.R. Hicks (1989), except those qualified as the consequence of innovative choices. Indeed, applying such standard procedures to the analysis of an innovative choice seems quite difficult, insofar as their very characteristics are denied. These characteristics are for instance, the difficulty or impossibility of measuring its results *ex ante*, and the willingness to widen future strategies. If standard models do not provide a satisfactory solution for innovative choice, a different analysis becomes of great interest, and a new analytical framework is required, grounded on a fundamentally different investment theory as well as on a different concept of rationality.

In this case, which is closer to the concrete problem of investment commitment, the firm no longer faces an evaluation problem. It has to specify, using conjectures whose contents will be defined later on, the minimal conditions for R&D investment success. In fact, these conditions depend on the capacity, be it technical or organizational, of the firm to carry on its innovative choice, while the financial constraints may become critical. Following our analysis, we will essentially focus on organizational capabilities. For instance, explicit agreements or more informal consensual organizational practices enable the firm to increase the set of its future strategies, with the creation of new market segments to operate on. "Good" conjectures should protect the firm along its productive path, preventing it from significant shake outs the occurrence of which would question its viability.

Thus the purpose of this article is to present R&D commitment procedures which are the most relevant to the Hicksian classification. Sections 2 and 3 develop standard evaluation procedures used in order to commit the first variety of R&D investments. Then we prove in section 4, that this kind of evaluation procedure is no longer valid when innovative choices are concerned. Consequently section 5 proposes a new commitment procedure in terms of

identifying minimal conditions of R&D investment feasibility. Some concluding remarks are given in section 6.

## **2 Option Value models as standard commitment procedures**

Standard procedures developed in economic theory are based on possible evaluation and comparison methods. They refer to the case of R&D investments dedicated to the implementation of new equipment.

In the standard paradigm, forecasts are perfect, the investment decision is considered as myopic : the choice procedure, established in terms of evaluation and comparison of two projects, only takes into account variables representing current or near future dates. The traditional choice criterion is the maximization of expected utility. When considering discontinuous time, this criterion is equivalent to the Net Present Value (NPV). In an R&D investment case, choice criteria must take into account the fact that expenses cannot be covered by proceeds because of sunk costs. Irreversibility<sup>1</sup> must therefore be introduced in the choice procedure previously defined. Hence, an irreversibility constraint is added to the standard optimization program. K.J.Arrow (1968) suggests the adoption of a shortsighted investment decision rule, adapted from reversible decision rules.

Should uncertainty, *i.e.* irreversibility and historical time, be introduced perfect flexibility of decision is then questioned. It must be redefined as the non-reduction of possible futures. Thus calculation of decision variables requires a deep look into the future. Investment decisions are implemented over several periods of time, thus imposing the integration of risk<sup>2</sup>. Such methods while addressing irreversibility, only add an opportunity cost to the standard criteria (R.S.Pindyck, 1991). This extra cost, defined as a random variable, which represents what the decision-maker is ready to pay at time 0 to keep the investment option alive is in the literature defined as the Option Value<sup>3</sup>.

It is the maximum value that a decision-maker is ready to pay to avoid the complete and definitive disappearance of an irreplaceable good<sup>4</sup>. The price of an asset, the total cost and the value of the project are to be compared through the decision rule : the Option Value is an opportunity cost, added to the total cost of the investment, thereby making a decision a reversible one. But these models do not take into account the specific characteristics of R&D investments (*i.e.* the irreversibility of the sequential decision under uncertainty). We shall

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<sup>1</sup> According to K.J.Arrow and A.C.Fisher (1974), "a technically irreversible development could be characterised as one that would be infinitely costly to reverse".

<sup>2</sup> This definition influences the adopted notion of sequentiality. This point will be examined in section 4.

<sup>3</sup> The Option Value was first mentioned in a non financial context by B.A.Weisbrod (1964). In the field of environmental economics, the Option Value is the expected value of perfect information.

<sup>4</sup> In C.J. Cichetti & A.M. Freeman (1971) such an approach is characterized by an exogenous and stable information structure and by risk adverse agents.

focus on a few Option Value models which best address the problems of the evaluation and comparison of R&D investment project. Such models include the following assumptions :

i) increasing information. Increasing information means that the uncertainty concerning the value of the decision variables decreases over time. R&D investment is sequential, which implies that as time goes on new information on the investment feasibility is provided. The assumption is made that increasing information is exogenous : the learning process is independent of the decision-maker's steps.

ii) agents are risk-neutral. This hypothesis is not required for the validity of the model, but it implies that the value of waiting has nothing to do with risk-aversion.

iii) irreversibility is understood as the reduction of the possible future acts.

When information acquisition occurs, the Option Value must be integrated in the decision rule<sup>5</sup>. The decision rule for R&D investment under uncertainty is now presented.

B.S.Bernanke (1983) proposes a model which offers a generalization of different models of Option Value<sup>6</sup>. The decision rule implies the following behavior, "Accept the most profitable irreversible investment if and only if its current return exceeds the value of the options thus forfeited"<sup>7</sup>. Bernanke's model is grounded on the idea that, in an uncertain environment, more information represents a value for the firm : the Return On Investment (ROI) is better appraised in long term projects when the decision-maker obtains extra information.

The Option Value concept has evolved, and offers henceforth a positive aspect ; departing from the notion of opportunity cost as in the standard models presented above, B.S.Bernanke (1983) replaces it by that of "waiting power". The Option Value, as defined by K.J.Arrow and A.C.Fisher or C.Henry (1974) becomes the expectation of a positive differential between the maximum return among non-retained projects, and the return of the retained one. It is the expected value of "bad news" : a worsening of bad news implies an increase of the Option Value and consequently a delay of the investment decision.

Information acquisition does not only offer the possibility of renewing one's choices in order to maintain the optimality of a decision, but it also becomes a means of optimizing the decision process. Extra information provides some indication on the future steps of the process, and allows the optimization of decision rule. Within this new framework of increasing information, the Option Value becomes the expected value of the awaited

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<sup>5</sup> Under such conditions, A.Cukierman (1980) defines a model of the typical investment behavior, in which the firm gathers information before making any decision. The decision-maker determines his actions by looking at his utility function, conditioned by the states of nature. The investment decisions are independent of financial conditions. In such a perspective, regarding the profitability of a given project, the evaluation method consists of comparing an immediate investment decision with a decision to delay it, the latter aiming at obtaining more information (see R.McDonald and D.Siegel, 1986, for an example).

<sup>6</sup> For justifications see A. Cukierman (1980), B.S. Bernanke (1983), or R. McDonald and D. Siegel (1986)

<sup>7</sup> B.S. Bernanke, 1983, p.90

information between time  $t$  (irreversible decision) and time  $t+1$  (reversible decision). The evolution of the concept of Option Value towards "waiting power" corresponds to a transformation of the notion of irreversibility ; from an irreversibility in terms of reduction of future possible acts, to an irreversibility stemming from the impossibility of using extra available information. This new notion of irreversibility is connected with the definition of A.G.Hart's flexibility (1949). This kind of flexibility emanates from the chronology of the decision-making process using sequential information ; the decision is taken once the new information is obtained in order to improve the chances of making the correct one.

When reference is made to the standard concept of Option Value, the reversible decision is preferred<sup>8</sup>. But when it is assumed that the source of irreversibility is the impossible use of new information, the irreversible decision is selected (even if the expected profit is negative) instead of the reversible one. More information leads to an increase of irreversibility in terms of reduction of future possibilities (the first variety of flexibility), but also increases flexibility, as defined by A.G.Hart's theory (the second variety). Accordingly, the firm must gather information at the first stages of the whole project, to improve the evaluation of the R&D investment. Some extensions of Option Value models examine the earliest stages of the process, when R&D is implemented and numerous crucial information regarding the future is generated.

### **3 Extensions of Option Value models**

These models assume that the main motive to set up R&D investment is to provide information and to endogenize risk : each investment step gives the firm a new option to initiate the next one. Thus the third assumption of previous Option Value models becomes irreversibility, which is understood as being the impossibility of using any new information. Some extended Option Value models are proposed to analyze this dynamic investment behavior.

The model of K.Roberts and M.L.Weitzman (1981) focuses on a series of sequentially related investments over time : the problem is then to define an optimal plan to co-ordinate these activities. The principal hypothesis of these authors is that the early stages of the sequence of investments provides crucial information about future returns and costs of the completed project. This model exhibits an optimal decision rule, which is a sophisticated expression of a cost-benefit arbitrage. The authors admit that the spread of total benefits becomes narrower as the project is sequentially completed. At the beginning of the project,

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<sup>8</sup> Comparing the rules we have defined for the standard evaluation and for the irreversible investment, it is noteworthy that irreversible investment evaluation criteria are stricter than reversible ones.(B.S. Bernanke, 1983, p.90).

the standard deviation of estimated benefits is very high, but decreases after the effective implementation of the successive production stages. Formally, it is assumed that the deviation is proportional to the expected cost to complete the project. In contrast to the benefits, which are terminal payouts, costs in a sequential project are running payments, added across stages. The cost of proceeding from one stage to the next is typically uncertain, but once paid it is a sunk cost. So the main reasons to engage the first stages which appear as "test-stages" are, first, to receive final benefits generated from the R&D stage, and second, to obtain more information about potential benefits from continuing to pay running costs. If the firm embarks on these "test-stages", it can greatly decrease the degree of uncertainty as concerning future results by gaining this available extra-information. Even a project rejected by standard evaluation criteria (Net Present Value) can prove to be profitable as time goes on (as information arrives), and the only way to observe this fact is to get in motion R&D test-stage. Hence, in this model, the Option Value coincides with a kind of "shadow value" that would hold during the first steps of the project. When the environment is uncertain, the evaluation of an R&D investment should not be made without bearing in mind the following stages, but on the contrary should take them into consideration.

The setting of K.Roberts and M.L.Weitzman (1981) can be extended to include Bernanke's bad news principle (1983) (even though formal definitions of option value are quite different for these authors). R&D investments can be perceived as a means of transferring or endogenizing risk, so as to alleviate part of uncertainty. The concept of R&D investment as "risk-endogenization" provides new elements to clarify, not only the importance of the project process'following stages, but also the interaction between the firm's and its competitor's strategies. Originally the bad news principle was defined by B.S.Bernanke (1983), to explain and simplify the notion of option value.

Thus, Option Value could be detailed by an analysis of agents' investment behavior in front of favorable or unfavorable events, and at the same time the mathematical formalization would be relieved. Literally, the bad news principle suggests that of all possible events, only unfavorable ones (or "downside risk") have an impact on the current propensity to start an investment project. Option Value is now a conditional expectation : "The investor who declines to invest in project  $i$  today (but retains the right to do so tomorrow) gives up short-run returns. In exchange for this sacrifice, he enters period  $t+1$  with an "option" that entitles him to invest in some project other than  $i$  (or to wait longer) if he chooses" (B.S.Bernanke, 1983, p. 92). The Option Value could be defined as an *a priori* measure of regret, that the decision-maker could feel in the second period if ever he makes the wrong inflexible investment. Therefore, taking on some of the bad news entitles the firm to benefit from "waiting power" : the possibility of a downturn, and the ability to avoid an action that could thereby prove to be a mistake, is what makes waiting valuable.

Then the notion of Option Value evolves and tends to be less relevant (because the irreversibility effect tends to disappear). At the same time, the flexibility of the firm making the decision increases. As already stated, in K.Roberts and M.L.Weitzman's article, R&D investments can effectively take a part in the uncertainty faced by the firm, by simply exploiting the extra-information generated in the early stages. In such a way the decision-maker could manage the unfavorable events and, applying the bad news principle, could endogenize part of the risk, allowing active strategies, and an increasing aggressive investment capacity. Aggressive strategic behavior facing investment decision makers mainly signifies here the ability not to act according to market price signals, but to wait for new information, which can prevent wrong strategies<sup>9</sup>. This necessity to gather information in order to take an optimal decision, refers to A.G.Hart's flexibility (in terms of using extra information).

However, these models do not take into account the other notion of flexibility : keeping alive possible future acts. Extensions of option models that use this kind of flexibility are now discussed. In this perspective, R.A.Jones and J.M.Ostroy (1984) develop a model which presents dynamic flexibility in terms of switching costs. Adjustment between stages takes time and incurs some costs. There are two possible states for an action : either it belongs to the set of possible future acts or it does not. The nature of the action depends on the technological characteristics of prior decisions. The assumption<sup>10</sup> is that the conversion of an impossible future action into a possible one is prohibitive considering resources. This hypothesis is equivalent to introducing switching costs. R.A.Jones and J.M.Ostroy propose a model which builds an information structure : they formalize the notion of flexibility by considering different sequential decision sets, and propose a value of flexibility depending on the amount of information an agent expects to receive and on the switching costs. They study the effect of increasing expected information on the initial choices degrees of flexibility. These choices are made between alternatives that imply different degrees of future commitment, and the selection depends on their related probability distributions of payoffs over time. In a context of increasing information, the long term commitment becomes less attractive than the shorter term ones, because the former prevents new information from being acquired. The value of flexibility is the difference between profits gained by extra-information and by prior decisions, net of switching costs.

R.A.Jones and J.M.Ostroy (1984) do not use the Option Value concept and prefer to describe the connection between the comparison of beliefs based on variability, and the comparison of actions based on flexibility in order to explain flexibility behavior. This sequential decision model suggests that it is the decision-maker's beliefs that must be the most variable, and the position he will choose that is the most flexible. They add that the amount to

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<sup>9</sup> This phenomenon is-known as "hysteresis cases" in Option Value models.

<sup>10</sup> cf.P. Cohendet and P. Llerena (1989)



be learned in the future has no effect on the initial choice (which is determined by prior beliefs alone).

But to reach a complete understanding of these evaluation methods, some further remarks must be considered.

All the models discussed above associate uncertainty to a market failure origin (O.Favereau, 1989). In such cases, failure is overcome by the introduction of the Option Value as a supplementary element of the list of cost-benefits specific to flexible decisions. At each point of time, the decision-maker is assumed to dispose of a complete probability distribution of unknown events and he has the opportunity on this basis to take the corresponding optimal decision. The analysis in terms of Option Value is then a sophisticated extension of the cost-benefit approach. Within this framework, it must be noted that uncertainty questions the stability of the criterion proper to this type of analysis : the criterion of maximization of expected utility. M.Allais (1953) demonstrates that the use of such a criterion in probabilizable uncertainty does not take into account the rational behavior of a decision-maker<sup>11</sup>. The relationships between Option Value models and the kind of underlying rationality in these models must be outlined. O.Favereau (1989) in his study of the linkages between Option Value and substantial rationality - as part of standard choice theory - concludes that Option Value is not compatible with the notion of substantial rationality. These results are presented in the Henry paradox (or the Option Value paradox).

C.Henry (1974) defines the option value as the maximal medium surplus that can be obtained from an initial reversible decision. This surplus exists because flexibility enables one to take advantage of future information gains. In this case the Option Value takes a paradoxical form (O.Favereau, 1989), for it is associated with the mistake made with standard calculation. According to standard calculation, the agent makes a decision using the presently available information without any perspective of obtaining more information in the future. In the case of acquisition of supplementary information, backward induction solving shows that this standard criterion is mistaken. The Option Value is the difference between these two strategies. This is summarized in what Favereau calls the Henry paradox: if Option Value is needed, then one cannot calculate it, but if it is possible to calculate it, then it implies that it is unnecessary. The standard choice criterion proceeds from an aggregation of discounted expected effects. Then, it cannot refer to the entire period of forecast, which is essential to inter-temporal decisions. Accordingly, O.Favereau advocates the use of a procedural type of rationality, in order to take into account the importance of the learning processes between two periods. As it is, H.A.Simon (1976) defines procedural rationality as enlarged to the methods which enable decision making.

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<sup>11</sup> See Allais's paradox and the controversy Allais-Machina.

Finally in standard evaluation methods, the purpose is to obtain simple and reliable evaluation and comparison criteria. But determining the value of a project is quite a difficult task, especially in the extended Option Value models : for instance, the decision rule in the K.Roberts and M.L.Weitzman model relies on the calculation of the conditional expectation of a random variable. Moreover, choice procedures for projects consist of comparing two by two the opportunities, in a given and finished set, which limit the possible options. Last, the selected criterion is not always the most relevant once the project is implemented (O.Favereau, 1989).

#### **4 R&D as an element of an innovative choice**

The proposed different types of evaluation and comparison of investment projects assume that agents are able to communicate their preferences, to benefit from reliable calculations (*i.e.* without any distortion), and to improve their preferential structures over time. In this setting, the expectations needed in this evaluation problem clearly correspond to the case where R&D investments are aimed at purchasing new equipment.

In all the traditional models presented above, the decision-maker is confronted with a complex choice between a finite number of probabilizable projects. Their profitability evolves over time (as information becomes available) and is perfectly anticipated sequentially. More precisely, the decision-maker is able to define an *ex ante* set of possible choices which includes the optimal one. As the information is acquired, it gradually reduces the uncertainty regarding profitability, and the firm refines its set to exhibit the better investment choice. This implies that at each point of time, the firm has the capability to reach this "target" quickly, despite the disturbances it faces (uncertainty and irreversibility). The firm must keep as flexible a position as possible, so as to minimize the relationships between irreversibility and the costs of moving from one position to another. When the future is "well known", *i.e.* events are probabilizable, the sequentiality is considered as a decisional one : successive periods improve the knowledge of decision optimality. In an extreme sense in this literature, R&D expenses committed by the firm in order to prevent itself from external perturbations, are considered as a defensive strategy (product differentiation, marketing expenses).

However, some R&D investment projects do not exhibit the initial conditions of evaluation methods : these projects are those defined by J.R. Hicks (1989) as taking place in a context of radical uncertainty (as G.L.S. Shackle, 1972, puts it), the purpose of which is to create a new productive capacity. In this "concrete" case, the choice procedures described above are no longer valid : the new productive capacity is determined simultaneously with the production level, while the necessary information to apply the decision rule is yet to come.

This kind of R&D investment must be considered as an element of an innovative choice under uncertainty. An innovative choice is one which generates new opportunities and new technological developments, *i.e.* new economic means of exploiting scientific ideas and already existing results or learning revealed during the initiated process (M.Amendola and J.L.Gaffard, 1988). Then, the probability distribution of events is no longer available. That is, the *ex ante* choice criteria of investment are no longer available because continuous changes in competitors' behavior or in environment conditions may occur between the expectation and the implementation of the firm's investment. Moreover, even if information is generated as time goes by, one can be sure neither of its availability nor of its quantity or quality in order to overcome uncertainty. Hence, innovative choices are part of a process which implies structural change, *i.e.* a momentaneous loss of any probabilistic reference to the future market structure. Any process of evaluation or acquisition of knowledge may not eliminate the underlying uncertainty, it may only transform it (G.P. O'Driscoll and M.J. Rizzo, 1985). Thus, there seems to be a paradox, as innovative choices themselves create the instability that induces the loss of any reference. Anyway, this paradox is only apparent and disappears when we consider that innovative choices are the only way to deal with high uncertainty, as described below.

For these reasons, we must propose some other commitment procedures. No longer is our purpose to evaluate and compare some possibilities, but to identify the minimal conditions of feasibility of R&D investment.

R&D investments may be viewed in this context as the very first step of the innovative choice, as an initial decision that opens up "(...) a path which not only has many bifurcations, but in which any further decision opens, or simply makes it possible to perceive, further bifurcations". (S.Bruno, 1991, p 30). Hence, far from relying on a perfect decision-tree as in sophisticated models of decision theory (especially Option Value ones), the firm may use R&D expenses to scan future opportunities that reveal themselves not only over time, but also as a consequence of previous particular actions. R&D can still be interpreted as an element of flexibility, but in a very different way than in Option value models. As the environment is no more exogenous, but on the contrary modelled step by step by the firm and its active strategies, the corresponding flexibility is viewed as a process which can generate new alternatives of choice and may increase the scope of future choices. This notion could be called the "flexibility of initiative" as opposed to the flexibility of response described in option value models, where the main purpose is to make sure that choices will not decrease in the future. The flexibility of initiative derives from a behavior which tends to impulse changes over the environment and tries to reduce the gap between basic or fundamental knowledge and environment complexity (M.Amendola and J.L.Gaffard, 1988). In this new framework, the profitability evaluation of a project is of a very different kind. Hence, the problem of the firm is to elaborate the set of possible choices rather than to pick up an optimal investment in

a given set of possibilities, just because the firm has no access to a complete probability distribution, and a technical and isolated expression of its profitability is impossible. In this setting, any investment will necessarily have an irreversible nature, characterized by the temporal spread of its profitability, and the desynchronization between its costs and benefits, the costs being paid at once and the benefits remaining uncertain and only paid later.

Anyway, even if this innovative choice (materialized by irreversible expenses) seems necessary, it has also to be implementable. Then, during the entire strategy of action, the firm has to develop and to make easier the technical and temporal complementarities that are associated to these irreversible processes (N.Georgescu-Roegen, 1971 ; J.Hicks, 1973). In such a context, the rationality can be defined in a very different way : the behavior of a decision-maker is a rational one if he engages the investment that pursues correctly the strategy initiated by prior investments, according to its successive financial positions. The preferred decision will be very different from the optimal one in the traditional sense, because the environment is sequentially changing, and one cannot properly define or anticipate *ex ante* what the optimum will be. Hence, a normative reference may exist in this context, but remains of very little use as positive requirements of coherence and viability of the production process appear more fundamental.

## **5 Another commitment procedure for innovative choices**

The development of innovative choices is necessarily sequential. It is a step by step learning process, implemented by the firm when confronted with a complex and unstable environment. It implies that the firm is "out of equilibrium"<sup>12</sup>, *i.e.* the systematic balance between costs and benefits over a long period is no longer valid. However innovative choices are not necessarily viable, particularly because of the financial constraints the firm faces. When the characteristics of future R&D market games are no more available, the commitment procedure no longer refers to technical evaluation criteria. Conjectures are therefore made in order to conduct the investments, and to guide the firm through an industrial path. By definition, these conjectures are an identification of some minimal conditions for successful investments : conjectures are a function of the learning a firm accumulates over time and they are aimed at defining the means of controlling innovative choices' viability conditions.

As R.Nelson and S.Winter (1982) put it, learning is the repetition of operating tasks, implemented in order to improve and accelerate them, and to discover new productive opportunities by experience. Learning is cumulative and local<sup>13</sup> : it is a test, retroaction and

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<sup>12</sup> cf. M.Amendola and J.L.Gaffard (1988).

<sup>13</sup> What is learned today refers to information accumulated the day before, within highly specific transactions and productions, cf. K.Pavitt (1986) et D.Teece (1988).

evaluation process, which depends more on organizational than individual<sup>14</sup> conditions. Accordingly, conjectures are defined as such a test, retroaction and evaluation process, which is conditional upon the firm's organizational structures and history (*i.e.* its routines<sup>15</sup> and previous investment set).

At this point, two remarks must be outlined. First, as a "try and error" process, conjectures need some degree of effective commitment in order to identify the profitability of an investment. It appears that possible future acts are no more chosen in a given set, but have to be constructed step by step while experiencing some mistakes and successes. Second, technical evaluation (defined as a punctual measure) must be clearly differentiated from conjectures (defined as a learning process). As Bruno (1991, p.21) stresses it : "Evaluation is nothing else than a quantitative specification of certain conjectural aspects of the process of constructing and analyzing the choice-set". For this author, technical evaluation may play the role of punctual focusing for the firm's decision-makers. It may also clearly and precisely stress the importance of such investments for the firm fronting external contacts (financial lenders or potential cooperative firms). In either case, it may improve the quality of the choice process. From this perspective, technical evaluation seems to be only an element of the decision process which is mainly governed by organizational requirements, especially learning capacities elaborated to preserve both coherence and viability of the firm, in order to develop an *ex ante* or initiative flexibility. The purpose is no longer to evaluate and compare two by two projects, but to determine the feasibility conditions of investments, that is the necessary conditions to make investments implementable.

As mentioned above, if innovative action necessary occurs in high uncertainty situations, it also has to be implementable. In particular, technical and temporal complementarities have to be protected. As G.B.Richardson (1960) puts it, these minimal conditions can only be organizational ones. Firms have to build "market connexions" in order to coordinate investments in time, and to derive the necessary information creation and expectation set up, so as to ensure the viability of the production process<sup>16</sup>. More precisely, the volume of competitive investments has to remain under a maximal limit by some elements of constraint and inertia initiated by the active firm's strategy. Moreover, the volume of complimentary investments will be kept over a maximal limit so as the active firm develops

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<sup>14</sup> Even though learning processes are initially individual ones, their very significance only appears within information sharing and creation, which are collective ones, by definition. It must be noted that such an idea is present in the writings of different authors : cf. for instance K.Arrow (1974), G.Dosi, D.Teece and S.Winter (1987), or even M.Aoki (1988).

<sup>15</sup> "Organizational routines" are complex models (where collective and interacted relations appear) which provide efficient solutions to particular problems. They are defined as "static", when they refer to repetition of existing tasks, and as "dynamic", when related to learning and development of new products and processes. R&D efforts are a significant example of dynamic routines.

<sup>16</sup> The author shows that standard mechanisms of adjustment can only drive the economic system until equilibrium at the price of strict assumptions over information creation and expectation building. Moreover, standard analysis cannot proceed further than the explanation of how equilibrium is maintained once reached, but does not provide any demonstration of the possibility of reaching an equilibrium.

elements of continuity to ensure its own action, or its combined action with other firms within the framework of cooperation agreements. These arguments can be added to the ones developed in the evolutionary literature<sup>17</sup> or in Austrian-subjectivist economics<sup>18</sup>, by the advocacy of a "routine" or "pattern coordination", rather than by an exact (neoclassical) equilibrium.

Some significant consequences emerge from such an approach. The first one is that the prevalent commitment criterion will be the one which permit the coherence among all activities (the previous and the new ones)<sup>19</sup>. Indeed, the firm focuses its competencies on specific activities, and its success fully depends on these opportunities in the market. According to previous investments and organizational routines, any imitation effect or adoption of radically different activities will be hazardous<sup>20</sup>. Rather than such complete differentiation, R.Caves and M.E.Porter (1977) advocate intra-industry mobility, from one segment or subgroup to another, the proximity degree being dependent upon technical and organizational similarities. For instance, if a, b, c, and d are increasingly profitable investment projects, it seems to be more interesting to choose at first the a-project, because it requires to control a well-known activity (*i.e.* entry barriers are quite low), then to proceed step by step towards d-project, if financial positions allow it.

Thus, coherence of productive and organizational capacities has some effects on the adopted time-path. These effects are called, in the evolutionary theory, "lock in" or "technological determinism" phenomena. According to this theory, the firm proceeds on a given path (trajectory), without being able to "cross the borders", and such an inability is systematically understood as a constraint the firm cannot overcome. This conclusion seems to be quite doubtful, because it signifies that future possible acts sequentially decrease, despite the firm's efforts. Moreover, as shown below, this is a restrictive conception of innovative choices.

The second consequence of our analysis is that this conclusion is only a particular case of the chosen approach. When innovative choices are examined, the creation of specific resources and the construction of organizational conditions must be studied. This assertion is not only derived from G.B. Richardson (1960), but also from N. Kaldor (1985), even though innovative choices are not their main concern. For both of these authors, when steady states are no more valid, market imperfections (*i.e.* "market connexions") are understood as means of coordinating strategies, but at the same time they appear essentially as means of enlarging a possible set of acts. Some R&D commitments are conducted in order to benefit from cost sharing, while some others are engaged in to obtain reliable information on real

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<sup>17</sup> cf R.Nelson and S.Winter (1982), and also K.Pavitt (1991).

<sup>18</sup> This literature is derived from F.A.Hayek, L.Von Mises, G.L.S.Shackle, and more recently G.P.O'Driscoll and M.J.Rizzo (1985).

<sup>19</sup> Firms have to "stick to their knitting", G.Dosi, D.Teece, and S.Winter (1987).

<sup>20</sup> Routines are effectively highly specific to a firm, especially because of the prevalence of their tacit character.

competitors' capacities (J.L.Gaffard, 1993). These commitments allow the firm to create new market segments, to "cross the borders", and to improve future strategies while lessening technical path constraints. Consequently, "good" conjectures depend not only on technical opportunities but also on organizational ones. The firm will integrate all these elements in its commitment procedure, in order to protect its productive path from significant alterations.

## 6 Concluding remarks

Traditional decision theory has recently grown in sophistication, especially by the formalization of investment behaviors in an increasing information context. Anyway, the relationship of simultaneity and automatism between the determination of the decision rule and the decision by itself fundamentally remains. As such, the investment behavior of the decision-maker is purely guided by reference to a signal, which is a simple scalar : the evaluation criterion. In this article, we submit that such a mechanism is only possible when the firm faces a "globally stable" environment, that is when the firm knows perfectly the future events, or at least their evolution in time. Actually, in such a framework, the underlying idea is that any desire or incentive of the firm is feasible (F.Fisher, 1989).

We propose then to study a more radical situation, that of an innovative choice. Under high uncertainty, investment behaviors are mainly guided by organizational pattern - and not much significantly by traditional decision theory principles - the objective being now to benefit from and control existing and future learning processes. We intend to focus on the conditions the firm has to develop in order to transform the desired investment into a feasible one. Of course, this process may result in a complex time path, *i.e.*, different from the standard one, and guided by (apparently) "simplistic" behaviors, *i.e.*, not maximization ones. Anyway, it seems that the more complex the environment, the simplest will be the agents' behavior (cf R.Nelson and S.Winter, 1982 ; R.A.Heiner, 1988 ; K.Pavitt, 1991).

It should be pointed out that such a framework is not entirely established as yet, in particular mathematical formalizations remain still weak. Nevertheless, the structuring of existing insights within the understanding of "out of equilibrium" strategies becomes quite significant.

Although the proposed approach is less developed than the standard one, it cannot be understood only as a special case. If so, routine behavior and step by step path would become sub-optimal. The new proposed approach is specific to an analytical field, that standard paradigm cannot take into consideration in a satisfactory and complete way. Indeed, in standard theory, analyzed problems are reduced to known traditional formalizations, which do not encompass the real significance of these difficulties.

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