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JUSTIFYING THE ORIGIN OF REAL OPTIONS AND THEIR DIFFICULT EVALUATION IN STRATEGIC MANAGEMENT

ABSTRACT

I explore and review the introduction of real options in strategic management studies. My aim is to contribute to a better understanding of the origin of the real options. By distinguishing between shadow and real options and implementing entrepreneurship in the traditional option valuation framework, I obtain a more exhaustive representation of the strategic decision processes in the firm. I explain the creation of a real option as an entrepreneurial process, one which transforms inventive ideas into profitable innovation. This constitutes a step toward an option-based theory of the firm by describing the emergence of a firm's options and the strategic building of new competencies for exercising these options. In addition, this approach offers a parallel understanding of why the real options theory is less often used in practice than in theory.

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1 INTRODUCTION

The success of a firm depends on its capability to create and exploit new projects. Projects are competitive opportunities that firms must recognize and evaluate. They must be able to apply operating capabilities if they are to take advantage of such opportunities. The general management responsible for the firm's strategic direction frequently fails to manage the organization's technological innovation process that creates these opportunities (Hayes et al. (2005)).

To help managers in their decision-making process in uncertain environments, new techniques and theories have been developed, one of which is the real options theory. This conceptual decision-making framework is about to become a standard. The formal approach, originating from financial models, introduces future uncertainty

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and the opportunities a firm can seize, and thus is appealing for managers. However, the use of this approach raises many questions linked to the theory of the firm and strategic management (Grundy (2004); Warner, Fairbank, and Steensma (2006)).

A major issue, almost ignored in other studies, is the question of the origin of real options. In this paper I try to explain the origin of the option and provide some elements for a better evaluation of the option in theory and practice. I use the word *entrepreneur* as the resource that recognizes and creates options. The lack of consideration devoted to entrepreneurship by most real options research studies¹ explains why real options theory focuses mainly – if not exclusively – on the valuation of existing options and not on their creation. The insights gained from considering real options and entrepreneurship are directional. On the one hand, in a resource based framework, entrepreneurship can explain the origin of real options theory and contribute to a better evaluation of its value. On the other hand, real options can explain the direction a decision maker takes in the development of the new capabilities and resources, as an entrepreneurial activity, by suggesting another use of the resources. Combining entrepreneurship and real options explains the heterogeneity of the firm and its resources collection and capabilities building.

The paper is structured as follows. I first give a brief presentation of the requisites for real options and highlight the important elements and variables that create and influence their values. I develop the notion of real options in the specific field of strategic management. This leads me to consider the successive developments and criticisms of an options chain. In the following I introduce the distinctive roles of entrepreneurs and managers in order to obtain a richer representation of real options chain. Then, I analyze the components of the option values in the light of the new notions introduced. In a final section I discuss the difficulties of implementing these determinants in practice.

2 REQUISITES FOR AN OPTIONS-BASED APPROACH OF THE FIRM

In the strategic theory of the firm, the most obvious of the long-term goals is the survival of the firm. Survival is achieved by seizing profitable opportunities when these opportunities arise or are encouraged to arise. In the long run, the profitability, survival, and growth of a firm do not depend so much on the general efficiency with which the firm is able to organize the production as it does on the ability of the firm to establish one or more wide and relatively impregnable competence bases from which it can adapt and extend its operations in an uncertain, changing, and competitive world (Teece, Pisano, and Shuen (1997)). In this approach the value of a firm is directly linked to the resources of the firm. These resources are tied together in a firm-specific way, giving a firm the capability of achieving some tasks better than others.

The heterogeneity in resources is the main reason why firms exhibit different profits and survival rates (Barney (1991)). Because human resources are the repository of productive

¹ For a notable exception see McGrath (1999).

knowledge (including tacit and explicit knowledge), their development highly influences the modification of productive capabilities. Creating new knowledge, the most important task of the firm, enables the firm to produce new goods, create a new organization, or upgrade its efficiency. The learning mechanisms are at the base of these capabilities and allow the firm to grasp new opportunities (Prahalad and Hamel (1990)). Making good use of an opportunity that brings value to the firm is nowadays called the “real option,” so holding and being able to exercise this real option depends fundamentally on the competencies and learning activity of the firm.

An option gives the right, but not the obligation, to take a specific decision (invest, defer, alter) on an underlying asset, for a predetermined price at or before a certain time. For example, a firm can possess a production plant, and choose, depending on customer demand or competition, to construct a larger-capacity plant to obtain economies of scale (a growth option) or, on the contrary, to temporarily shut down the plant (option to defer production). The firm has the right, but not the obligation, to change its production capacity. This option, depending on the information at hand at the moment of exercise, allows the firm to develop new revenues flows or to reduce costs.

Table 1 shows the conceptual analogy between real and financial options.

Table 1: Correspondence between Financial and Real Options

Variable	Financial Option	Real Option-Project
K	Exercise Price	Cost to acquire the asset
S	Stock Price	Present value of the future cash flows from the asset
T	Time to expiration	Length of time the option is viable
σ^2	Variance of the stock returns	Riskiness of the asset, variance of the best and worst case scenario
r	Risk-free rate of return	Risk-free rate of return

Table 1 lists the five fundamental variables that enter in the option calculation. Two of these variables are (K) and (S). The exercise price (K) represents the amount the firm must pay when the option is exercised. For instance, if the firm wishes to construct a new plant, (K) would represent the construction costs. (S) represents the value of the newly constructed plant and corresponds to the present value of the future cash flows that the firm earns by exploiting the plant.

Based on these variables I can calculate the cost of acquiring the real option. I distinguish between this cost (also known as premium) at the origin of the option and the value the option takes when the firm holds it for a certain length of time. This value is important for calculating the optimal moment of exercise of the option. Once the option is exercised, the firm loses the value of the option, but obtains the underlying asset of the option (S) minus the cost of investment (K). It may happen that the value of the option is higher than the gain expected from the exercise of the option. This excess value derives from the

presence of uncertainty that exists between the date of evaluation and the expiration date of the option. The longer the time to exercise, the higher the difference between the good and bad situation outcomes that the option allows to size as higher the option value. This property comes from the interplay of three conditions that shape the value of the option: uncertainty, flexibility, and irreversibility.

2.1 UNCERTAINTY

Real options share with financial options their main reason of existence: uncertainty. In the financial case, uncertainty is reduced to risk in the form of probabilities of good or bad outcomes. These probabilities are estimated, e.g., for a stock price, by the historical data of stock price. These probabilities are exogenous for the firm and are not influenced by its behavior. In the case of real options, uncertainty can take a much broader variety of forms, uncertainty about the demand for a good, uncertainty in the reaction of rival firms, uncertainty of the outcomes of a court decision.

2.2 FLEXIBILITY

The second condition required for the real option is flexibility. Flexibility represents the possibility for an investor to exercise a real option (invest in a project, etc.) or to abandon it. It is flexibility that gives an option its asymmetric payoff, and which adds a positive value to the project. In the case of a financial project, flexibility is identified as the possibility of transferring rights onto an underlying asset, as counterpart for a payment. In the case of real options, this flexibility has a variety of expressions. I define six broad categories of real options, which correspond to six expressions of the flexibility. I show these categories in *table 2*.

Table 2: Variety of Real Option and Corresponding Flexibility

Type of Real Option	Expression of the Flexibility
The option to defer	The option to defer, or to wait, derives its value from reducing uncertainty granted by the ability to wait until more information has arrived
The option to abandon	The possibility of shutting down an unprofitable project
The option to switch	The flexibility to change the nature of the input or output, or modus operandi (to use substitutes)
The option to contract /expand	The capability to alter the capacity depending on market conditions (low/high demand, intensity of competition)
The option to growth	To create infrastructure and opportunities for future expansion
The option to stage/ compound option	To break up investment into incremental conditional steps

2.3 IRREVERSIBILITY

The last condition for the existence of real options is the irreversibility of the investment. A decision can be considered irreversible if it significantly reduces, over a long time, the variety of choices that would be possible in the future. For financial options, irreversibility is evidenced by the payment of the premium. Whatever the buyer decides, this premium is definitely acquired by the seller. But the option can be sold again on the financial market, which is what makes the characteristics of irreversibility for a financial option relatively unconstraining.

In the real options case, the irreversibility is of major importance. To sell the project again, or the rights of a project, is only possible in the case of patents. The irreversibility is not only manifested in the financial part as a forgone financing capacity that limits the investment possibilities of the firm, but also in terms of capabilities and knowledge accumulated that locks the firm in some specific activities.

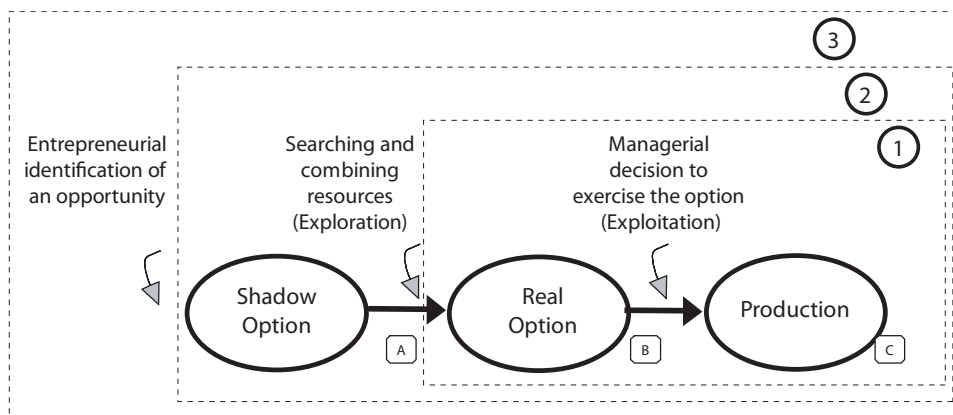
3 THE OPTIONS CHAIN

The existence and development of the real options requires the fulfillment of some conditions (uncertainty, flexibility, irreversibility). These conditions, sufficient in a financial approach, are only necessary in a managerial approach, in which the origin of the option, conditional on the behavior of individuals, needs to be explained. Who creates real options?

To answer this question I analyze the different contributions made to the real options theory by the strategic management approach. The development I propose is related to the understanding of the label *real* options. Too often, the adjective “real” is explained by making exclusive reference to the financial theory that argues that financial options refer to a financial traded underlying asset. In contrast, the term “real options” refers to a nonfinancial (real world) asset, e.g., a production facility or an R&D patent. This definition is correct according to the origin of option calculation formulas, but incomplete in terms of the problematic underlying nonfinancial assets. Carr (2002), and Kogut and Kulatilaka (2004) note that many firms, even when they are aware of the existence of an opportunity of profit, either do not possess the option to exploit the opportunity or cannot exercise the option correctly. This limitation sometimes arises from the lack of knowledge and competencies needed to exploit the opportunity. Knowing that an opportunity exists and being able to exploit that opportunity are two different things. I define real options as options that the firm is aware of and for the exploitation of which it has constructed the necessary resources and knowledge. So a real option is an option that the firm can *really* exercise.

Figure 1 represents the successive developments of the real options chain in strategic management studies. The following discussion and presentation of the options chain and the introduction of the entrepreneur/manager rely on that figure.

Figure 1: The Revisited Option Chain (initial work by Bowman and Hurry (1993), 764)



3.1 STANDARD OPTION EXPLOITATION

The area labeled 1 represents the initial step of the real options theory as it appears in today's major textbooks on the topic (Trigeorgis (1996)). These textbooks focus mainly on the calculation of the value of the real option and the determination of the optimal timing for exercising this option.

This short options chain is constructed as follows. The option is supposed to exist, to be in the hand of the decision maker. The decision maker (always referred to as the manager in these books) evaluates the option contingent on the future possible states, and decides to exercise it or not. The value thresholds that determine the manager's decision are generally different from those determined by standard net present value techniques. For example, in the presence of an option to wait, this hurdle is much higher. An opposite example would be the growth option, which justifies investing in projects that have as stand-alones a negative present value. Only future development possibilities can justify the investment.

When this hurdle is hit or exceeded, the option is exercised, which means that the project enters, for instance, a phase of building and exploitation. Once the firm enters the market, new options can arise, such as expanding the size of the plant, diversifying the product line, or in the worst case, stopping the production and shutting down the factory.

3.2 EXPLORATION OF THE IDENTIFICATION OF OPPORTUNITIES, THE EMERGENCE OF THE SHADOW OPTION

This development, as noted by academics in the strategic management field, makes the important assumption that the option exists and that the decision maker is informed of its existence. Obviously, this is not always the case. Bowman and Hurry (1993), struck by

that implicit hypothesis, introduce the notion of shadow option, the option that a firm can exploit, or at least consider in its portfolio of choices, if it is aware of the choice. This approach is appealing for the introduction of information systems in the firm, the use of consultants and technological watch agencies. The options that a firm has depend on resource and knowledge available inside the firm, but that the decision maker ignores.

Opportunities (that are not yet options) come into being when individuals have different beliefs that the available or potential resources might be able to transform some inputs into some outputs that can be sold and raise a profit. An opportunity is a favorable, momentary circumstance or situation that has been recognized after a manager has either sought it out or it has spontaneously appeared.

Schumpeter (1934) distinguishes between the notions of invention and of innovation; I draw a parallel between these notions and the notion of option. An invention is the discovery of an opportunity, what Bowman and Hurry (1993) describe as a *shadow option*. An innovation is an invention that has been transformed and updated, one which originates through an opportunity, into an exploitable and hopefully profitable option. When the opportunity becomes exploitable, the firm possesses a real option. The transformation of the invention into a profitable innovation depends on whether the firm has the appropriate resources at the right moment.

Once the shadow option is taken into account (area 2 *figure 1*) the rest of the options chain can be considered in the same way as described above. When the shadow option is recognized, it moves from a shadow option into a real option. The option must then be evaluated, and compared to the other options. The managers must also take into account the probable interactions between *them* in the portfolio of option decisions of the firm.

The addition made by Bowman and Hurry (1993) does not completely answer the question of the origin of the real option, it merely shifts the debate. Instead of explaining the origin of real options, the genesis of the shadow option must be elucidated.

3.3 STRATEGIC MANAGEMENT DEBATES

Before introducing the entrepreneur/manager I add to *figure 1* the outcomes of a recent debate in strategic management studies on real options that highlights other problems in the option chain. This debate focuses on the link between the different steps of the options chain. I refer to these steps by the letters A, B, and C, and explore these three cases below.

The debate starts at A, based on works by Adner and Levinthal (2004). These authors observe the growing interest in real options. At the same time, they notice that the phrase “real options” is very trendy, but encompasses different realities, including papers that talk about real options when they actually mean something else. In their work, these authors describe what is or is not a real option, and show the characteristics of a real option. They show that a real option is not something that the firm gets for free, but only by paying a

premium (but the payment can be not deliberate). This characteristic determines the real option, so it is natural to place this debate between the shadow and the real option.

Kogut and Kulatilaka (2001) discuss the difficulties of transferring concepts from one domain into another, in this case, from the financial world to strategic management. This “translation” can be particularly misleading if the reader does not take into account the specificities of each domain and performs too radical translation. The authors also consider the qualification and applicability of the option logic according to the ability that a firm has to influence the option. This is a fundamental difference from the financial option, where the firm’s action does not change the value of the underlying asset traded on financial markets.

The B on *figure 1* refers to two organizational forces that act to undermine the real options approach in strategic decision making.

(i) The fundamental distinction between an option and a standard evaluation technique comes from the nonsymmetric payoffs of the option. The real options models define the investment only if positive outcomes emerge (the good state of the world), and avoid negative outcomes by stopping investment in bad states of the world. Stopping investment is a key to limiting downside risk. Adner and Levinthal (2004) highlight the importance of abandoning a project when keeping the options alive requires active investment and involvement in individuals and capital to maintain the capabilities of the firm and to exploit the option if it becomes profitable. These authors note that the firm can change its capabilities (with time and money), and theoretically, it can also change the condition of use of the option, and so manipulate the outcome of that option. In that case, an option can be made profitable. If the firm decides to act this way, the involvement of the firm may be costly and lead to bankruptcy, because the firm is always a step closer to making the option interesting to exercise, but without reaching this exercise point. This means that the firm needs to have a clear agenda of action, and to undertake and follow it when the time comes to abandon an option. If the firm does not follow this abandonment schedule, then it avoids the downside risk of the real option but suffers a large downside risk of the shadow option.

(ii) Adner and Levinthal (2004) also note that the value of the option derives from the uncertainty of the outcome. Thus, the higher the uncertainty, the broader the set of possible outcomes. On the contrary, when the uncertainty is not resolved, another trap for decision makers appears. If uncertainty is stable or increases, the variety of choices of the firm increases. Exploring this broader spectrum of uncertainty has an impact. The exploration of this variety of option increases the possibilities of choice, creating “options on options,” instead of reducing uncertainty. Thus, the more the firm invests in its real options portfolio, the more the size (number of options) and value of the portfolio increase, but the less the firm is able to exercise a significant part of its option. In that case, the firm never exercises the option, because the more it searches, the more the option value, and the potential value of her investment if exercised increase.

This leads to some kind of hysteria. The firm increases its capabilities without building the capacities for production, and lacks the possibility to enter the exploitation phases (Kogut and Kulatilaka (2001)).

The letter C on *figure 1* refers to the exploitation of the real option and conception of further development phases.

Kogut and Kulatilaka (2001) give a numerical example of status quo biases. They discuss the fact that new options will change the organizational structure of the firm, and individuals will see their positions in the organization chart modified. These employees can be reluctant to accept these modifications and slow down the schedule of application. Numerical simulation shows that missing the optimal timing significantly decreases the value of the option, and so eliminates the potential gains coming from its introduction.

McGrath (1999) analyzes the bias that can affect decisions at this stage, in particular, if one or several of the previous steps have not been a complete success. Some of the biases modify the smoothness of the options chain during the different steps. These errors and biases can leave marks on the firm and the decision-makers.

At the end of the options chain, the firm can enter another chain, depending on the resources available. The biases can lead to overreaction and seriously alter the value of the future shadow and real options. If there is success in the production phase, then the firm has a strong incentive to explore the future in the same way it took before. This can be a poor guide for action, since the routines that proved effective in exploitation are probably not the most appropriate for the creation of new opportunities. They merely imitate creativity and are devoid of innovation.

Moreover, when a routine is a success, it is difficult for a management to abandon it. Resting too long on existing routines reduces the dynamic capabilities of the firm and its ability to build new resources and obtain rents.

In *table 2* I list some real option categories. Many of them are dependent on market conditions. If market conditions are more favorable than expected, then the firm can expand the scale of production or accelerate resource utilization. Conversely, if conditions are less favorable than expected, the scale of operation can be reduced. Adapting production to product demand is part of the options logic. This logic also includes the option to adapt production gradually to market conditions, including qualitative adaptation, skills, and routines adaptation through staged options. Cohen (1991) analyzes the speed of executing routines, of changing their contents and of switching between them. For this author, the foundations of dynamic capabilities are the skills and routines of the individual members. The building, modifying, and refinement of that repertoire of routines constitute much of the performance that can be found in learning-curve research. If a firm, because of the market or for manager entrenchment reasons, decides not to change the production, then the ability of the firm to adapt or change its routines will vanish and so will its dynamic capabilities and options creation capacities. The stability of the environment, the clinging to habits, is unfavorable for the development of the necessary entrepreneurial spirit. However, this debate does not alter the firm's short-term profitability, which can be strongly increased by sticking with existing routines.

Many psychological phenomena or cognitive biases can alter the development of future options, for example, the confirmation bias. During the decision phase, individuals may see information with negative connotations as less plausible, but on the other hand, they promptly take into account information with positive connotations. This makes the numerical part of the evaluation false (costs, revenues, opportunities, profits). Another bias is the overconfidence bias, when individuals attribute success to their own actions and failure to bad luck (Barney (1986)). For example, a “technology guru”, whose advice influences the market. If firms or investors follow his advice, they may make massive investments in an option that has little or no value. Entrants see new markets as profitable and full of growth options, and so enter the market. If other firms make the same observation, all of them entering the market together lead to a reduction of profits.

The mirror effect of this bias is to assign everything that once led to a failure to a negative path that must not be followed again. This eliminates all attempts to build similar new shadow options in the future.

All those biases do not mean that a manager should reconsider the advantage of using real options in comparison to other techniques. The option represents the flexibility inherent in the project. Using techniques that do not reflect the flexibility clearly impairs the judgment of the decision makers, and, following our discussion, does not imply that the managers use better timing, relying on one or the other technique.

The important point on the origin of the shadow option, my addition to this chain, is represented in the area 3 on *figure 1*.

4 INTRODUCTION OF THE ENTREPRENEURIAL RESOURCE

In microeconomic theory, when authors need to introduce novelties or special variations into a theory of the firm, they often refer to the figure of the entrepreneur (Barreto (1989)). In this paper I consider entrepreneurship as one of the firm’s resources and an employee who exploits opportunity (Cohendet, Llerena, and Marengo (2000)). In economics, the characteristics given to entrepreneurs are widely influenced by the work of Schumpeter (1931) and Kirzner (1979). Kirzner introduced the concept of “entrepreneurial alertness” as the special ability of the entrepreneur to see where products (or services) do not exist and can be profitably exploited. Alertness exists when one individual has an insight into the value of a given resource while others do not. From this perspective, entrepreneurial alertness refers to “flashes of superior insight” that enable an individual to recognize an opportunity when it presents itself.

As mentioned, the starting point of the shadow option is the identification of an opportunity. This identification is often a vision resulting from the *imagination* of the entrepreneur of something that could be an opportunity. This imagination, as described by Witt (1998), leads to action. The identification of a shadow option consists of the entrepreneur’s representation of the world. The entrepreneur acts in accordance with his/her newly created state of the world. As a consequence, the entrepreneurial resource will begin to

disseminate information about his/her findings. After that discovery the search begins for resources and the creation of knowledge for transforming this shadow option into a real option. The search process that follows is greatly influenced by the vision of the entrepreneurial resource.

4.1 ENTREPRENEURS, OPTIONS AND HEURISTICS

The entrepreneur's representation of the world and behavior for searching how to move from the shadow to a real option is a special kind of heuristics. Kogut and Kulatilaka (2001) give an insightful approach of real options, capabilities, and heuristics. The authors split heuristics into two parts, a cognitive frame and rules of search. A cognitive (or heuristic) frame refers to the representation of the problem and the expected solution space. The heuristic rules of search are the algorithms by which solutions are found in the solution space. These authors identify four qualities of a good heuristic: it is easy to use, easy to communicate, provides a better direction than the ones currently employed, and motivates the people who have to implement the strategy. The matrix for portfolio analysis of the Boston Consulting Group is a perfect example of a heuristic. The vision span in this matrix is a child's play, the pictures of cow, dog, star, and question mark are understood and remembered by everybody, from a first-year management student to the executive (Macmillan and Tampoe (2001)). The BCG matrix example is only one part of a heuristic, and represents the cognitive frame. Nelson and Winter (1982) use the notion of routines, which is an organizational enactment of heuristic problem-solving, representing the second part of a heuristic, the rules of search.

The definition of vision and imagination that I developed previously implies a special cognitive frame. For Busenitz and Barney (1997), entrepreneurs use heuristics more extensively than do managers in larger organizations. In using heuristics, entrepreneurs make simplifications that allow the development of ideas, and enable them to continue without answering all possible problems that may arise. Especially in complex situations where less complete or uncertain information is available, such behaviors ease the evolution of the organization. The differences in the use of heuristics between entrepreneurial and managerial firms lie in the fact that entrepreneurial firms are more responsive to opportunities. The differences in their appraisal of the future suggest a difference in the options identification. Also the heuristic-based logic enables entrepreneurs to make sense of uncertain and complex situations more quickly than does hierarchic management. Gavetti and Levinthal (2000) pinpoint that decision making in such a context is forward looking, as opposed to backward-looking procedures that do not develop options but instead focus on resources already in use.

4.2 COMBINING RESOURCES, THE EMERGENCE OF THE REAL OPTION

Once the opportunity is identified, I note that the entrepreneur certainly does not have the specific knowledge and expertise in every area necessary to fulfill his goal. This lets him be in charge of finding and combining the adequate resources for his endeavor. Acquiring

a new production capability by building a new competence is not instantaneous. The building process is mainly path dependent and involves tacit knowledge acquired by learning by experience and experimentation. This implies that firms that create knowledge are also options-creating firms. By creating new knowledge, these firms expand their cognitive frames, part of the real options heuristic. The value of the entrepreneurial resource appears here as having the ability to combine different kinds of expert knowledge in way to exploit opportunities. The individual we call an entrepreneur is not necessarily outside of the firm; rather, he is more likely to be a member of the firm that is becoming entrepreneurial. Neither is it necessary that this is brought about by one individual. A group of individuals, in what is called “diffused entrepreneurship,” could perform this action. As the diffusion of the entrepreneurial mind becomes broader, we move from a Schumpeter Mark I to a Schumpeter Mark II framework.

4.3 CREATION OF NEW CAPABILITIES AND PRODUCTIVE KNOWLEDGE

Once the entrepreneurial resource obtains a commitment for discovering resources and creating new knowledge, the shaping of the real options begins. The search for appropriate resources can be carried out inside or outside the firm. An intuitive solution for this search is to rely on communities. Communities, according to the knowledge-based theory of the firm, are the intangible places where knowledge is shared and created. Each community has its own specificities concerning the modes of learning, the type of knowledge created, autonomy, and hierarchical architecture. Thus, the organizational and knowledge environment of communities has important consequences for our understanding of how coordination, motivation, and the sharing of visions works, and how these factors structure the firm’s enabling options. The nature of the activities concerned (production, research development, finance, etc.), and the goals and motivations of the potential users and developers of the innovative idea contribute to the speed, the inflexibilities, and the different dimensions of the new routines used to give consistency to the emerging real options. Two major types of communities are usually discussed in the literature, communities of practice and epistemic communities. The way to distinguish them is that epistemic communities are truly oriented toward new knowledge creation, and communities of practice are oriented toward the achievement of the activity (Cohendet and Llerena (2003)).

Creating the underlying knowledge necessary to transform a shadow option into a real option is a task that corresponds to the attributes of an epistemic community. Using the real options and enhancing the practical implementation of a productive process are tasks that correspond to a community of practice. Thus, the passage from a shadow to a real option reflects the transformation of the epistemic community into a community of practice. The type of management must also change from entrepreneurial to managerial. Nootboom (2000), building on a different representation of exploitation and exploration than the shadow and real option concept I use, comes to the same utilization timing between entrepreneur and manager.

The point of view I take in the major part of this paper is that a firm must invest in knowledge assets. Unlike physical or financial assets, knowledge can be transferred throughout

the firm and applied to various projects and processes. That is the essence of a core competence as the basis for strategy. The options logic seems particularly compelling for evaluating such knowledge assets. If a knowledge asset created by an option combines with existing knowledge, then the firm may be more likely to exercise the option than if the asset were isolated. This is because the value of the knowledge is contingent on its transfer, combination and recombination with other knowledge-based assets in a firm.

Another point of view would be that when establishing an option on knowledge assets, the firm may have the choice of combining new assets or keeping them isolated. In some cases, an incompatible culture, routine, or technology must be kept isolated from other assets in order to thrive. Isolation also serves to limit the development of social networks that may lead to the escalation of commitment (Andrikopoulos (2005); Coff and Laverty (2001)). The importance of knowledge assets in the strategic approach of real options is unquestionable. Nonetheless, the influence of the individuals responsible for the management of this specific asset must not be overlooked. These individuals include the entrepreneur and manager whose roles have been discussed previously, but also the communities.

4.4 FROM ENTREPRENEUR TO MANAGER

A recurrent, if not fundamental, problem in real options valuation is the definition of the value of the option. The determination of the value of the option is a critical aspect because it determines whether the option is used or not, and if it is, then when it is appropriate to use it. Troubles arise when trying to identify numbers for the different variables used in real options formulas, as Luehrman (1998) suggests, practitioners often have to “take an educated guess”.

The decision to exercise the option and to turn to a production phase is part of the managerial decision-making process. A reason why the manager does not enter the option chain earlier comes from the nature of the output of the shadow option. The output of the knowledge-building process (what is done during the shadow option) is difficult to evaluate, the knowledge is diverse and the manager is not aware of all pieces before the entrepreneur ends his action. The managerial decision depends on the balance between entering the market with the actual resources and knowledge, or waiting for absorbing more capacities. As shown by Lane et al. (1998), managerial capabilities are developed by training, repetition in decision-making, rules of thumb implementation, and day-to-day management. This approach to managerial decision-making is in fact the situation most often described by real options valuation problems (area 1 *figure 1*), where I use basic managerial economic inputs such as cost or existing demand (including some standard deviation). These data are made by entrepreneurial action for convincing management of the accuracy of their first vision. If managers take this data into account, the entrepreneurial part of the option chain is a success. At this point, I catch up with other studies of real options concerned with evaluation based on some informative inputs. This leads to a description of value determination of the options based on theories of the firm considerations.

5 EVALUATION ALONG THE OPTIONS CHAIN

Here, I present an original approach to assessing the value of the real options, based on the difference between shadow and real option. I do not pretend to give a unique and exact value, rather, an interval where the “*real*” real options value should be.

I determine boundaries for four variables that intervene in the real options analysis: the premium needed to acquire the option, the strike price for exercising the option, the gain if the option is exercised, and the value of the option. I omit two parameters usually found in real option, the interest rate (assumed constant) and the time to expiration. I discuss the variables for both shadow and real options. However, it is difficult to assign costs directly to an innovative activity as needed by the formulas, in particular for the shadow option. Also, these costs can be incurred by the firm without obtaining an option. On the contrary, the costs supported by the firm can generate more than one shadow option. These costs can be taken in two different ways. If the firm deliberately tries to create a favorable environment for new ideas the costs are accountable and justifiable. If the firm does not support these costs deliberately, then the occurrence of the shadow option is just an unintended event that the inefficient organization produces by chance. *Table 3* summarizes the following discussion.

Table 3: Cost and Value of the Shadow and Real Options

	Shadow option (SO)	Real option (RO)
Premium (P)	P_{SO} - The cost of the entrepreneurial resource that launches the process. - Organizational Slack - Cost of additional training, without a direct link to productivity.	P_{RO} - If follows the exercise of the shadow option, the exercise price and the premium of the shadow option ($PSO + KSO$). - If the firm does not have the previous shadow option, at least S , given through dynamic transaction costs.
Exercise price (K)	K_{SO} - Cost of convincing decision maker to spend financial resources to search and obtain raw resources. - Cost of monitoring the employee.	K_{RO} Cost to acquire the necessary assets to enter production (plant, workers...).
Gain if exercised (S)	S_{SO} The value of best use of the new combination of resources.	S_{RO} Present value of future cash flows.
Value of the option (V)	V_{SO} The value of the shadow option is greater than the gain S because it incorporates the future strategic possibilities.	V_{RO} As calculated by traditional real option evaluation models (uncertainty on demand, further development etc...).

5.1 THE SHADOW OPTION

- The premium of the shadow option includes the cost supported by the firm for being aware of the existence of an opportunity. At the individual level, it includes the cost of the entrepreneurial resources that launch the process. These costs are expressed in wages and training cost of the employee, but are not directly linked to the actual production. At the organization level, it necessitates some weak ties between the task of an individual and his productive behavior. Here, the creation of an option should be linked to organizational slack. For March (1979), organizational slack is the spare resources and unexploited opportunities that act as a buffer against bad times. These spare resources and unexploited opportunities come from the fact that the firm does not always optimize. The slack smoothes the firm's performance, reducing performance during good times and improving it during bad times. Organizational slack costs are the costs of the resources that a firm acquires and that are not committed to a direct use or/and necessary expenditure (see Bourgeois (1981) for an interesting discussion of how to measure slack). The kind of innovative idea arising from an employee such as a manager or a product line agent creates a different type of option at different costs, e.g., product innovation, process innovation...
- The exercise price of the shadow option includes the costs that are necessary to transform the shadow option into a real option. They are the costs of negotiation (in time) that the entrepreneur spends explaining the idea and convincing the decision makers in the firm to spend financial resources on the competence building process. If the firm decides to build the competencies (eventually, after some market analysis costs) the costs come from the activity of search and combination of different types of resources in such a way as to produce new knowledge needed to practically implement the new idea. Good proxies for such costs are R&D expenses or start-up creation outlays (in the sense that start-ups are legally different entities that are created to try to transform an idea into something profitable).
- If the shadow option is exercised, the gain depends on the best use of the new combination of resources the firm has realized. The best use determines the highest gain the firm can obtain by combining resources, either through internal use of the resources or by selling them on a market. The combination can have a value of zero if there can be no productive use following the investment, or, on the contrary, the uniqueness of the combination can be highly valuable if the opportunity it contributes to seizing is considerable.
- The value of the shadow option is generally divided in two parts, the intrinsic value and the speculative value. For a shadow option, the value, built on the market price (which can be zero), is at least the gain of selling the resources, and a maximum value incorporating all future strategic options that can be built on the basis of these resources. In this analysis, the boundaries of the shadow option are zero and infinite. This approximation cannot provide help for someone who needs to identify the exact value of the firm's option. However, I note that this value is constantly varying, so this framework shows clearly that real options are only useful as a tool if decision

makers agree to monitor them often, to specify boundaries of acceptance in advance (e.g., rules of thumb), and to stick to these boundaries. Also, the value of the shadow option is mainly influenced by its speculative value. Many over-optimistic analyses that are performed confuse the value of the shadow option with the value of the real options they try to emulate. From my point of view, the value of the shadow option is only a transition point to guide an effective real option evaluation.

5.2 THE REAL OPTION

- The premium of the real option depends on the previous initiatives of the firm, whether the firm has already invested in the shadow option or not. If the state of the firm follows the exercise of the shadow option, then the sum of the exercise price and the premium of the shadow option form the premium of the real option. If the firm has not previously invested in the shadow option, then the costs are at least equivalent to the gain of the shadow option. This means that the firms that want a certain bundle of competences have a choice between building these resources within the firm, which can be extremely time consuming, or buying them on the market, which can be expensive. If many firms are interested in a rare resource, the price on the market increases. Langlois (1992) gives an example of costs that influence the ranking of activities (and competencies) a firm can acquire. If the firm does not support the shadow option costs, then the ranking of the profitable activities a firm can expect to enter is different from the ranking of a firm that has not incurred these costs.
- The cost of exercising the real option. If I assume that the firm has the necessary competencies to exploit an opportunity, e.g., to enter the production stage, then the firm must hire employees; build a production facility, etc. The firm can also switch employees from one production plant to another, abandoning an older product for the sake of launching a new one (as depicted in the BCG matrix). These costs are usually the only ones taken into account in standard real options evaluation.
- The remaining two points, gain when the option is exercised and value of the real options, are consistent with the definition most often found in corporate finance books. The gain obtained when the real option is exercised is the present value of the cash flow generated by the option. The value of the real option is given by adequate formulas and depends on the market structure, the demand of the consumer's variation, and other factors.

6 DISCUSSION

The aim of this article is to show the "translation" of the option concept from the financial to the strategic management field. In addition to the financial characteristics needed to obtain an option value, the management perspective needs to specify the roles of indi-

viduals. I use the concept introduced by Bowman and Hurry (1993) of shadow options and options chain in my presentation, and I enhance my presentation with entrepreneurship. I suggest that entrepreneurship in a new firm, or an existing one, is at the origin of real options.

I show that a firm with an entrepreneurial heuristic will assign a different value to resources and to options than other firms. The value of the competence is a major part of the real option value, and conversely, future options partly determine the competence value.

In theoretical approaches, real options show a greater effectiveness than do standard evaluation techniques. However, it is puzzling to see how few firms use real options. This can be explained by several facts. First, that the mathematical background needed to use option techniques can be too demanding. Second, in addition to the biases listed in this paper, a manager can encounter problems to represent option cognitively. Miller and Shapira (2004) explore this point in a study on option evaluation that they conducted on a sample of finance trained students and practitioners. They note that the options are systematically misevaluated, especially because people take into account facts that actually have no impact on the option value. In a study of five different industries, Howell and Jäggle (1997) note that the values attributed to options are systemically over- or underevaluated, depending on the industrial sector of the interviewed manager.

In my paper I propose an explication of the difficulty of using the real options theory in practice. Not only are the whole costs that should be taken into account in option evaluation difficult – if not impossible – to account for (the cost of shadow and real option), but also the creation and utilization of this option requires the input of different individuals (entrepreneurs and managers) who have different points of view and different value representations. This can lead a firm to not consider options that might otherwise result in the profitable exploitation of an opportunity.

Future developments of real options should increase the integration in the real options theory with behavioral finance and the theory of the firm considerations. This would be a way to obtain a strategic theory of the firm that explains the difficult tasks of capabilities building and capacities exploitation.

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