Application of Real Options in the Governance of Innovation

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Abstract: This presentation starts from the analysis of real option to that of the game options and analyzes how strategic interactions are taking into account in corporate governance. Focusing on strategic investment decision, this presentation demonstrates, firstly, the relevance to use key lessons and implications of real options in the process of decision making and, secondly, how the use of option games hypothesis allows us to propose a combination of real option and game theory in competitive environment with unpredictable events. Consequently, real options game models bring together real options and game theory.

INTRODUCTION

Basically, real options analyses the options applied to real assets while game options introduces strategic interactions between firms by combining analysis tools of real options and game theory. Investment decisions are taken by considering that the market structure and investment strategies will determine the firm's position. In a dynamic analysis, the production of innovation depends on firm's competences (Danneels, 2002). Investment strategies and innovation are often analyzed through the concept of timing of innovation interpreted as the consideration of all relevant factors interacting in a competitive industry (Reinganum, 1989). Beyond these analyses, other more relevant issues were introduced with a view to extend economic theory. This paper aims at elaborating theoretical arguments from some empirical data and/or conceptual discussion of two literatures: real options and game theory in the governance of innovation. The connection of these literatures starts with the demonstration of how the limits of net present value (NPV) approach offer a new analytical framework incorporating the dynamic in the firms' strategies. Thus, the goal of the present research is twofold.

Firstly, firm's position (first or second) depends on strategic decisions. For example first mover position involves the introduction of a new product and this firm, theoretically, realizes monopoly profits by being the only player in the market. However, these first mover monopolistic advantages are temporary determined by the responses of rivals (followers). In a competitive industry, the strategy of the firm determines the profit obtained. In such situation, there are two questions: when and how the firm enters the market? The first answer of this question determines the firm's

position (Dixit, 1989; Lee and *al.*, 2000). Gaba and *al.* (2002) propose a relevant analysis of positioning strategies in a competitive industry. With this type of industry, the timing of market entry decisions is central in business strategists (Miller and Folta, 2002). On this point, the firm makes a choice according to the strategy of rival firms. Many analyses were made by decision theory and real options theory. The opportunity to invest can be seen as a *call option*, involving the right to acquire an asset for a specified price at some future time. In this perspective, game theory, separately, provides parallel answers highlighting the behavior of the firm on the market. Thus, the second answer is linked to the first by the interactions between economic agents (Schoenecker and Cooper, 1998).

Secondly, the strategy of the firm is used to determine the date of launch of an investment project which is estimated from traditional evaluation criteria such as the net present value (NPV). The decision of the firm to enter the market affects directly the development of an innovation. With the two previous questions or dilemmas, respectively related to technological uncertainty and market uncertainty, two approaches provide answers to the arbitration on investment decision. The first approach, called the dynamic net present value is defined as an extension of the traditional NPV to which is added the possibility to have options on the investment of real assets (Kort, 1990 ; Trigeorgis, 1996; Oriani and Sobrero, 2008). In this case, time plays a fundamental role in the investment decision. The second approach, called "option game" combines real options and game theory (Smit, Trigeorgis, 2006). These approaches are used to quantify the flexibility of an investment.

The rest of the presentation is organized as follows: The next section provides the relation between corporate governance and the analysis of NPV. Key lessons we have learned about this analysis in terms of main insights and implications are then discussed. An analysis of the "option games" is given next, while the final section presents theoretical results and the challenges that future research must focus on.

1. The NPV in the governance of innovation
1.1. The standard NPV

During the recent decades, the academic contributions about corporate governance have increased exponentially. The first reason is that this field of research is highly multidisciplinary, since it deals with important issues in economics, management, accountability, law, sociology, etc (Krafft and Ravix, 2008). In this paper, we only adopt a purely economist vision of the problem in the sense that investment decision and strategic interactions are taking into account. Even if, in the theoretical vision of corporate governance, the stakeholder perspective is considered as the major alternative to the shareholder value perspective, the second one is more important when the analysis deal with the economic performance and value of the firm. In this context,R&D is complex because once launched, firm cannot guaranty here success. So this complexity impacts on shareholder value.

Generally, the economics of innovation show that the model of shareholder value increased the ups and downs that innovative firms and innovative industries faced during and after the financial crash, leading to the conclusion that adopting this model is not neutral and even detrimental in some cases to the evolution of innovative firms and industries (Lazonick, 2007; Fransman, 2004; Krafft and Ravix, 2005, 2008).

By introducing options in the corporate governance analysis, questions is, here, connections between different stages of investment decisions and what real options is, and how, during the process of decision-making, firm may revise its initial decisions.

The static NPV approach is the traditional method to evaluate the economic viability of an investment project. From this point of view, investment and innovation are not differentiated. The standard NPV, defined as the difference between the discounted cash flows and the capital invested, remains a tool to estimate the economic viability of the project (Dixit and Pindyck, 1994). This traditional method

for assessing the profitability of an investment is a static analysis in the sense that the estimated useful life of the investment and cash flows are known in advance. Faced with lot of potential investments, the choice of the decision maker will focus on (i) the comparison between the costs of each project, (ii) the comparison of the benefits, (iii) the profitability of the projects, (iv) the payback period and (v) the discount rate. The economic definition of NPV is therefore a static approach of investment decision.

From the standpoint of the criteria taken into account when determining the NPV, the literature offers many definitions, but all of them are in the context of research and development (R&D). One part of the literature does not make a distinction between the terminology "timing of innovation" and the "timing of investment" (Barzel, 1968; Cripps, 1997). This analogy is due to the fact that the success of innovation is directly related to the investment strategy, which is estimated from the NPV and that the competitive environment is often overlooked. Thus, one of the main rules of decision-making in finance is to invest when the NPV is positive and to reject the project when it is negative (Lander and Pinches, 1998). Barzel (1968, p. 349) considers that the NPV is based on the timing of innovation from which it is possible to determine the optimal date of the introduction of innovation. If the NPV is positive, investment leads automatically to an innovation in the market.

However, the irreversibility of investment affects the decision-making in an uncertain world because it is costly or impossible for the decision maker to return to the initial investment. In other words, a decision is considered irreversible if it significantly reduces for a long time the variety of choices that would be possible in the future (Henry, 1974). Taking into account the uncertainty and the irreversibility of investment, a dilemma will emerge when the investment is undertaken immediately or later. In this perspective, the NPV of the project has a limit due to the possibility of obtaining additional information during different stages of investment (Dixit and Pindyck, 1994, p. 10).

Thus, the introduction of the reversibility is important in order to give advantage along the different stages of decision-making. An example is given by Héraud and Ionescu (2011) in the context of nuclear waste. They consider that: " the reversibility implies that at each step of decision, different options are available: retrievethe radioactive waste if new information justify it, reevaluate

the disposal process, modify the systemparameters or continue on the same path". With this consideration, the reversibility of an investment is important in order to optimize the decision process. Consequently, the perspective of the dynamic analysis is to study and to compare the different options that the firm faces during the stages of the investment process.

Literature on the investment decision aims that the firm has the opportunity to acquire new information over time (Bernanke, 1983; Abel (1983); Abel and Eberly (1994); Mittendorf, 2004). This opportunity offers the decision maker the possibility to postpone investment because of the existence of additional information (Brennan and Schwartz, 1985; Abel and al. 1996)[1]. Consequently, uncertainty and flexibility of the investment must be taken into account in investment decisions (McDonald and Siegel, 1986; Ingersol and Ross, 1992; Odening et al., 2007). All these criteria can guide the timing of innovation in a dynamic setting. Consequently, the perspective of the dynamic investment is to analyze the different options.

1.2 The dynamic NPV

In the presence of an uncertainty and dynamic of the path of investment, the decision maker learns, adapts and revises its decisions over time in response to the developments of the market. This dynamic is more relevant than the static NPV because it has an influence on the different stages of the timing of innovation. In this case, firms use criteria like internal rate of return, payback period, and profitability index more often than they use the standard NPV criterion in selecting projects. An analysis of investment projects in a dynamic framework is more complex but more relevant because of the inclusion of real options (Weitzman et al. 1981, McGrath and Nerkar, 2004). This dynamic approach allows to integrate the value of flexibility, the opportunities for growth and the competitive strategies in an uncertain environment (Burger-Helmchen, 2007, 2008). Thus, the entrepreneur takes a decision as if the traditional NPV has increased the firm's options (Trigeorgis, 1996). As the entrepreneur influences the uncertainty, the project becomes more expensive in the long term due to the inclusion of the option value. The option value is defined as the price that the decision maker is willing to pay in order to reconsider

his choices and maintain analways optimal decision. This value is due to the fact that the decision maker can take into account the result of investment instead of being irreversibly bound by an earlier decision to the result of random occurrence. Thus, the R & D can generate other projects that are often not directly related to the initial innovation (Philips, 2004). From this point of view, the choice to have an option becomes a source of competitive strategy at different stages of the timing of innovation.

According to Trigeorgis (2005), the dynamic NPV can be written as follows: Dynamic (or Strategic) NPV = direct (passive) NPV + Option Premium (ROV) (Flexibility value) + Strategic value. Based on the dynamic NPV, it can be seen that it may now be justified to accept projects with negative (passive) NPV of expected cash flows. Thus, the decision maker can delay investment with positive NPV until a later time when expanded NPV would be maximized under uncertainty. Managerial flexibility or real option value (ROV) may be higher for firms or industries facing higher uncertainty. In competitive industry, early investment may have strategic value by influencing the equilibrium actions of competitors in a way beneficial to the investing firm or even by preempting competitive entry altogether in some cases.

The advantage of using the NPV in dynamic investment decisions is also linked to the strategy of waiting. "Wait and see" flexibility is clearly important in the evaluation of many investment opportunities under uncertainty. By delaying an investment decision, new information can be revealed that might affect the desirability of the investment along the way. These examples show the importance of real options theory in investment decisions. All of these elements give a complex analysis, but also the dynamic nature of the options (Perez and Berard, 2009).

Irreversibility, indispensable to the existence of an option value, is such that once the state of nature is realized in the future, if it is unfavorable, it will be impossible to reverse its decision. Thus, to facilitate the identification of different degrees of irreversibility, the concept of flexibility is used. The comparison between traditional NPV and dynamic NPV shows that the second one analyzes the evolution of the profitability of a project over time. In a competitive environment, a competitive firm should, over time, maximize the present value of all its future cash flows. Therefore, the introduction of adjustment costs in the analysis of the impact of the NPV dynamics on the different stages of the timing of innovation is important.

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[1]By using a large sample of U.K. manufacturing industries, Driver and *al.* (2006) provide a confirmation of the empirical relevance of real options.

The impact of the NPV dynamics on the timing of innovation is important in terms of flexibility of the investment project. With the inclusion of the option value, it is necessary to include the function of adjustment cost of the firm.

ANALYSIS OF OPTION GAMES

1.2. A tool for strategic analysis

The new valuation methodology of option games, based on the combined insights from real options and game theory, aims to capture the additional flexibility and strategic value beyond the direct expected cash flow benefits that have been the focus of traditional NPV analysis. It considers a firm's growth opportunities as a package of corporate real options that can be actively managed by the firm and that may be affected by competitive interaction. The combination of real options and game theory can be a valuable tool of analysis supporting the overall corporate strategy (Smit and Trigoergis, 2006). Faced with an investment, the decision maker must face two dilemmas. The first is related to the optimal date of introduction of innovation and the second is related to the investment strategy of rival firms. According to the situation, firm's position depends on its strategic position. For example, eBay was the first online auction firm and went on todominate its industry. However, Google was not the first search engine companybut went on also to dominate its own industry (first mover/second mover advantage).

Option games approach combines real options and game theory to measure respectively the value of flexibility and commitment allowing the investor to make a rational choice in an investment. Indeed, the integration of competitive strategies can be used to introduce decision-making process in order to rationalize the actions of each firm.

Option games area aims to include the dynamic in the process of decision-making, and proposes a new interpretation of investment strategies in a situation of strategic interaction (Dasgupta, 1988; Beath et *al.* 1989; Weibull, 1995). The types of strategic interactions are conceivable in different situations. Firstly, when the actions of firms are sequential and, secondly, when the actions are simultaneous with the type of available information. Baumol (2002, p.199) considers that innovation as a routine process of optimization mechanism represented by a continuous decision-making. Thus, the decision concerns the choice between the race to be the first to get innovation (first mover) or to postpone the introduction date of innovation

(follower). The introduction date of an innovation in the marketplace is a deliberate choice. On the one hand, when this date is early ("preemption"), the firm can obtain significant profits. The literature focusing on option games shows that competitive forces and potential market may provide an incentive to invest earlier (Kulatilaka and Perotti, 1998). To give an example, just consider what happened in the market of the Internet bubble. In the 90s, many start-up which had no idea of the potential market size, were created to provide services in the Internet field. With the need to make a decision quickly in a situation of uncertainty, firms were ready to invest in order to take the leader position. On the other hand, the standard literature on real options emphasizes the importance of the option value of waiting. When the introduction date of innovation is delayed, firm can obtain significant profits through improvement process of innovation (Gal-or, 1985, Teece, 1996, Katz and Shapiro, 1987; Cannor, 1988). In this perspective, Baumol (2002) explains the fact that establishing its competitive position on innovation is not always guaranteed. For example, by imitating quickly the new products or process, rival firms can adversely affect the durability of the first mover advantages by sharing and/or reducing their potential profits. Thus, the firm's reaction function concept became a tool for strategic analysis (Bowman and Moskowitz, 2001).

However, the most efficient position of the firm depends on the literature we focus on. On the one hand, the firm can introduce an innovation in first place in order to obtain a dominant position (Lieberman and Montgomery, 1988), while on the other hand, the firm which introduces an innovation in second position can also obtain a dominant position (Geroski, 2003). With these two opposite literatures, the firm's strategy is to find the optimal introduction date of innovation (Mariotti, 1992). Smit and Trigeorgis (2006) use an option game theory to develop strategies for business investment. In this situation, the extension on the NPV is determined by a strategic variable which is the value of flexibility (Smit and Ankum, 1993; Aguerrevere, 2003; Grenadier, 2002 and Lambrecht, 2004). For example, Dixit and Pindyck (1994, pp. 309-316) analyze the strategies of two firms competing to obtain an innovation. In this analysis, it is irrational to enter the market earlier than the expected optimal date of innovation ("grap the Dollar").

The reality is more evident in the sense that a firm has not only to choose the optimal timing of investment, but she also has to determine the optimal production in the market. In this spirit, the combination of real options theory and

game theory finds its importance in the consideration of competitive strategies.

1.3. From option games to evolutionary games

Traditionally, option games analyze the combination between real options and static game theory. This paragraph proposes an extension of static games to dynamic games by considering the usual framework of real options. The notion of Nash equilibrium is central in reasoning about the outcome of a static game. In a Nash equilibrium for a two-player game, neither player has an incentive to deviate from the strategy. In a dynamic analysis, the analogous notion of Nash equilibrium is an *evolutionarily stable strategy* (ESS). ESS tends to persist once it is prevalent in a population. Using a general way of characterizing EES, we can now understand how the players or firms can take place in an evolutionary game. According to the objectives of traditional game theory (TGT), evolutionary games attempt to determine the ESS (Maynard Smith and Price, 1973, Maynard Smith, 1982). Evolutionary games are applicable to a large number of models with at least two players (Nelson and Winter, 1982, p. 161; Dosi and Winter, 2003). Considered as an extension of the Nash equilibrium, the ESS is the central reference of evolutionary games because the concepts used are in the dynamic analysis (Taylor and Junker, 1978).

The rationality assumptions underlying EGT are, in many cases, more appropriate for the modeling of social systems than those assumptions underlying the TGT. Thus, EGT provides an important element missing from the traditional theory (Friedman, 1991, 1996, Fernando, 1996). Considering strategic interactions, the model of Wen (2002) aims that Pareto optimal equilibrium is generally more advantageous for the firm which adopts the strategy of waiting. However, when the game is repeated in an infinite horizon, the backward induction method is no longer valid because the tools of analysis do not allow the identification of the equilibrium. With the evolutionary game, the main assumptions (bounded rationality of agents, repeated game and learning by imitation) encourage to resolve failures (high rationality, multiple equilibrium) of TGT. The goal is then to determine the process selected by rational players to be in an optimal position without coordinating their actions. With the anticipation process, there is an adjustment of equilibrium, since each player acts as if each step of the game is the last.

To highlight the different stages of the timing of innovation with evolutionary game, we propose an analysis called Smit-

Trigeorgis' approach. The approach, described in Smit-Trigeorgis (2006), is developed from the perspective of the relationship between firms. We considered that competition takes place between firms whose competitive positions are not always identical. By analyzing a symmetric and asymmetric innovation race, a game with incomplete information and competition vs. cooperation, the Smit-Trigeorgis' approach can be extended in the dynamic analysis: this is to consider the stages of the timing of innovation. From this, three situations can be highlighted:

In the first situation, the innovation race is symmetric. This is to suppose that the investment strategies of firms are identical. Each firm has a strong incentive to invest immediately in order to avoid being ahead of its rival. In this case, the resulting game is such that the profit of the firm may be lower than that it could obtain if the strategies are not coordinated. This situation is identical to the game of "prisoner's dilemma".

In the second situation, the innovation race is asymmetrical. This is to suppose that there is an incumbent firm and a potential entrant. In this case, direct competition is not profitable for firms in the dynamic competition. Indeed, a firm can use the "threat of a battle" strategy if it has an advantage of leadership firm. Thus, the commitment to invest in first position provides an important market size. Of course, instead of adopting a strategy of direct competition, firms can sometimes have an incentive to adapt their strategies according to market evolution. This situation is identical to the game of "Burning Bridges" because information is complete. Thus, the type of innovation, the amount of R&D and the identity of each firm are determined at each stage of the timing of innovation.

In the third situation, the race for innovation is simultaneous. This is due to the fact that the strategies of rival firms are not known in advance and information is either imperfect or incomplete. In the first case, a firm makes a decision ignoring the action or the strategy of its rival. In the second case, a firm makes a decision ignoring the characteristics of its rival. In this case, the stage of the timing of innovation cannot be identified by a Smit-Trigeorgis' approach.

SUMMARY AND CONCLUSION

Following a comprehensive thematic of the evolution of real options, this paper has illustrated, through some simple examples, how real options and game options are tools of strategic analysis in corporate governance. Thus, the

decision maker will be easily changed according to the occurrence or non-random phenomenon. We first demonstrate that the dynamic NPV is relevant insofar as the inclusion of real options for considering the option the firm has on its investment choices. This point justifies the development of real options. Then, game theory has given more consideration to the elements of competition.

From static to dynamic NPV, literature on real options evolves according to the tools of dynamic analysis. This analysis highlights two important results. The first one was to keep the dynamic analysis of strategic interactions and proposed a new area of analytical theory taking into account the foundations of static game theory. Considering the failures of this theory, option games are renewed in a dynamic analysis by integrating the theoretical analysis tools of EGT. When the periods are considered, the dynamic NPV and evolutionary game have something in common: the consideration of time. The dynamic nature of decision making during the different stages of innovation allows us to analyze jointly both approaches.

The second result is that by using the characteristic of the replicator dynamic, a decision is made by considering that real options and game theory complement each other. The aims and interests of practicing the option value resulting from the dynamic NPV are identical to those of the replicator dynamics of evolutionary game. Specifically, the firm chooses to invest on profitable investment, but also in terms of potential strategic advantage. The combination of real options and evolutionary game presents the characteristics of the investment strategy of each firm. Many models focus solely on criteria of return on investment by neglecting the competitive environment. Dynamic analysis on the NPV is an approach that differs from standard analysis. Moreover, taking into account the assumptions of game theory can solve the environmental constraints of the firm. In this perspective, the relationship between firms with Reinganum's approach is identical to that of Smit-Trigeorgis. In other words, the criteria used to determine the different stages in the timing of innovation are identifiable from the factors used to determine the relationship of symmetry or asymmetry between firms. This "gap" in the literature on innovation related decision-making processes is of interest for scholars and/or managers.

However, it is sometimes difficult to identify the complementarity between options and EGT through a reliable model incorporating the rationality of economic agents. Is it reasonable to consider the behavior of an agent as that of the population to which it belongs? This question,

considered as a challenge, deserves some attention and structures our further research.

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