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Alliance Dynamics through Real Options: The Case of an Alliance between Competing Pharmaceutical Companies

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Abstract:

This paper aims to better understand the dynamic aspects of strategic alliances between competitors, by relying on both the real options approach and the system dynamics approach. It raises the following question: what are the behavioral dynamics of real options in alliances? The systemic qualitative model we built from the study of an alliance formed by two competing firms around an R&D project revealed three sets of feedback structures (the “expected flexibility”, “uncertainty” and “collaborative skills and knowledge” dynamics), in which are embedded three types of real growth options (that is, unexpected discovery, relational reputation and interactive options). While previous studies have often focused on how partners unilaterally manage real options to reduce uncertainty, our study allowed us to identify the real options created by the alliance, which can be exploited collectively, independently by each partner or not at all, and to capture their dynamic aspects.

Key words: Alliances, Real options, System dynamics, Influence diagram, Pharmaceutical project.

1. INTRODUCTION

The drug development process is a long and strongly regulated process, of which the outputs remain uncertain. It involves drug discovery and screening, laboratory testing, animal studies, clinical trials, regulatory registration, and post-submission activity (Chen and Hung, 2010). This process is very costly and the total R&D cost per new drug was estimated at US\$ 802 million (Talay *et al.*, 2009; DiMasi *et al.*, 2003). Because developing a new drug requires high investments and a broad range of innovative resources (Ohba and Figueiredo, 2007), a significant number of alliances focuses on drug discovery and commercialization (Santoro and McGill, 2005), including knowledge intensive alliances such as joint pharmaceutical R&D projects. In fact, interfirm collaborations have become the “norm” in the pharmaceutical industry (Talay *et al.*, 2009).

According to the literature on alliances, many strategic alliances fail to yield the expected benefits or even lead to failure (Ariño and Doz, 2000; Hoang and Rothaermel, 2005; Park and Ungson, 2001), “because of the difficulties in coordinating two independent firms and in aligning operations at the alliance level with parent firms’ long-term goals” and “because of

the opportunistic hazards as each partner tries to maximize its own individual interest” (Park and Ungson, 2001, p. 37). In particular, while an increasing number of alliances are among direct competitors (Mitchell *et al.*, 2002; Park and Zhou, 2005), as more and more rivals share resources (Ybarra and Turk, 2011; Mitchell *et al.*, 2002), previous empirical studies have shown that such alliances are most likely to fail (Park and Ungson, 2001; Park and Russo, 1996). Direct competitors are certainly more likely to engage in future competitive behavior (Park and Ungson, 2001), and blur the distinction between competition and cooperation in alliances (Dussauge and Garrette, 1995). For instance, in R&D intensive industries such as the pharmaceutical industry, cooperation between competitors is seen as particularly risky (Miotti and Sachwald, 2003). Notably, while alliances have become a popular vehicle for acquiring and leveraging technological capabilities in R&D projects, the hazards of knowledge sharing are especially salient for competing partners (Oxley and Sampson, 2004). Strategic alliances between competing firms are therefore intrinsically difficult to manage and are characterized by a high level of uncertainty (Park and Ungson, 2001), regarding future states of nature but also about the partner’s future behavior (Ariño and de la Torre, 1998).

Various theoretical perspectives were used to explain this phenomenon, including transaction cost theory, game theory, resource dependency theory, learning theory, agency theory, to name but a few (Park and Ungson, 2001). Among them, the real options approach can be found in numerous studies on alliances (*e.g.* Wang and Miao, 2006; Santoro and McGill, 2005; Vassolo *et al.*, 2004; McCarter *et al.*, 2011; Reuer and Tong, 2010). This approach is particularly interesting, as it is capable of incorporating not only the value of flexibility and growth opportunities but also of competitive strategies in an uncertain environment (Smit and Trigeorgis, 2006). The real options literature has mainly examined how partners individually use real options to reduce uncertainty in investment decisions (Folta and Miller, 2002). However, McCarter *et al.* (2011) introduced the concept of “collective real options”, which are created by the alliance and can be exploited collectively (Li *et al.*, 2007) or independently by each partner (Pape and Schmidt-Tank, 2004). While collective real options may impact the management of strategic alliances (McCarter *et al.*, 2011), they are not clearly defined in the literature. Most studies consider real options as exogenous data (Philippe, 2004; Myers, 1977). Moreover, the traditional approach often follows a linear approach, which leads to downplay the complexity of real options (McGrath and Boisot, 2005) and the importance of dynamic interactions between the factors involved in an alliance. As alliances develop and evolve under the influence of events and interactions between the partner organizations (Kumar and Nti, 1998), a more dynamic perspective is needed (Saxton, 1997; Ariño and de la

Torre, 1998; Dussauge *et al.*, 2000). The fact remains that the alliance literature tends to favor static representations and still suffers from a lack of dynamic perspectives (Park and Ungson, 2001). To address this gap, some authors suggested that the principles of systemic modeling could be applied to alliances in order to better understand the behavioral dynamics they imply (*e.g.* Kumar and Nti, 1998; Kumar and Nti, 2004). For instance, the system dynamics approach was used by Kumar and Nti (2004) to examine how international strategic alliances evolve. Besides, the same approach was used to explore real options regarding contractual relationships between clients and suppliers (Marquez and Blanchar, 2004), and decision making in new product development projects (Ford and Sobek, 2005).

In line with these studies, this paper aims to better understand the dynamic aspects of strategic alliances between competitors, by relying on both the real options approach and the system dynamics approach. It raises the following questions: What are the types of real options created by the alliance? And what are the behavioral dynamics in which they are embedded? In this perspective, a systemic qualitative model was developed from the study of an alliance formed between competitors around an R&D project. This model, which is an influence diagram, allowed us to explore the behavioral dynamics of real options in this alliance.

We begin by first reviewing the opportunities and threats of strategic alliances, and essential elements of the real options approach. We then explain the research method used, which is based on a longitudinal case study of an alliance formed by two competing firms around a pharmaceutical project, and which leads to the development of an influence diagram according to the principles of system dynamics. We finally present and analyze this influence diagram, which enabled us to highlight three major feedback structures, before discussing the main modeling results, and the research limits and future perspectives.

2. ALLIANCES THROUGH THE OPTION LENS

After introducing the motives and threats of strategic alliances, this section legitimates the use of the real options approach in order to analyze alliances formed around an R&D project.

2.1. Opportunities and threats of strategic alliances between competing firms

Gulati (1998, p. 293) defines strategic alliances as “voluntary arrangements between firms involving exchange, sharing, or codevelopment of products, technologies, or services. They can occur as a result of a wide range of motives and goals, take a variety of forms, and occur across vertical and horizontal boundaries”. Firms form strategic alliances for different motives, and notably in order to gain production efficiencies and the resultant lower costs; to

expedite access to technology, markets, and/or customers; to promote organizational learning; to expand strategic competencies; and to launch a strategic response to a competitor (Bruner and Spekman, 1998). Strategic alliances enable partner organizations to access new technologies and reduce risks (Niosi, 2003). They are a good way to access, learn or share new knowledge, abilities, or assets (Kogut, 1988; Hamel, 1991; Kale *et al.*, 2000). For instance, one party can offer a technical skill and the other a new market for the product (Teece, 1986). Partners may also build components together to reduce production and transaction costs, but final products will be competing on the market (Williamson, 1985).

Whereas different partnership types exist, including links with competitors, customers, suppliers, universities or research institutes (Duysters and Lokshin, 2011; Miotti and Sachwald, 2003), this article focuses on strategic alliances between competitors, which refer to collaborative projects implemented by firms operating in the same industry (Dussauge and Garrette, 1995). Indeed, some authors argue that an increasing number of alliances are among direct competitors (Mitchell *et al.*, 2002; Park and Zhou, 2005), as more and more rivals share technology and other resources (Ybarra and Turk, 2011). In particular, there are several examples of alliances formed around R&D projects between rivals (Oxley and Sampson, 2004). Competitors are motivated to form strategic alliances with one another to expand into new activities or markets (the so-called “link alliances”, in which competing partners contribute complementary resources and capabilities) or to increase efficiency in their existing activities (the so-called “scale alliances”, in which competing partners contribute similar resources and capabilities, and which are the most common for alliances involving R&D resources) (Mitchell *et al.*, 2002). In R&D intensive industries (such as the pharmaceutical industry), there are many opportunities for inter-partner learning and major competitive consequences of such learning (Hamel, 1991; Mitchell *et al.*, 2002). However, R&D cooperation between competitors is particularly risky (Miotti and Sachwald, 2003). Alliances between rivals can “lead to the loss of critical proprietary knowledge, to increased dependence of one partner *vis-à-vis* the other, and even to the takeover of one partner by the other” (Dussauge *et al.*, 2000, p. 100), and direct competitors are certainly more likely to engage in future competitive behavior (Park and Ungson, 2001).

Indeed, while firms can benefit from alliances in many ways, strategic alliances are characterized by risks emerging from the conflict between competition and collaboration (Das and Teng, 2000), and this conflict especially prevails in alliances between potentially competing companies (Park and Russo, 1996). If one partner favors more common interest than its own interest (Axelrod, 1984), non-cooperation may originate from asymmetrical

information or balance of power. Information asymmetry occurs when one party has more information compared to another (Akerlof, 1970). The balance of power, closely linked to the concept of negotiation (Crozier and Friedberg, 1977), may lead one partner to abuse its dominant position for its own profit. In those cases, contributions may be seen as unbalanced and asymmetrical (Park and Ungson, 2001). More precisely, strategic alliances induce interpersonal risks (Das and Teng, 1996), which are specific to collaborative relationships. Some risks can be linked to opportunism and lead to skill drain (Lorange, 1997), unfair payment (Doz and Hamel, 1998), diverging goals (Hagedoorn and Sadowski, 1999; Hurry, 1993), a lack of transparency impeding learning (Hamel, 1991), or the defection of one partner (Nooteboom *et al.*, 1997). One example of opportunistic behaviors from one partner can be the breach of the agreed terms of the contract to exploit another partner and make a profit out of it (Parkhe, 1993a). While one of the benefits of alliances is meant to be creating and sharing knowledge (Kogut, 1988; Hamel, 1991; Das and Kumar, 2007), partners could act opportunistically by withholding important information or even providing false information to deceive the other (Park and Ungson, 2001). More generally, “examples of opportunistic behavior are withholding or distorting information, shirking or failing to fulfill promises or obligations, appropriation of the partner firm's technology or key personnel, late payments, and delivery of substandard products” (Parkhe, 1993a, p. 828). In addition, beyond risks linked to opportunism, other problems may arise: problems to control and coordinate the partners' behaviors, and diverging strategies (Park and Ungson, 2001).

Therefore, while alliances in R&D intensive industries offer a high potential for efficiency gains and few opportunities for limiting competition (Dussauge *et al.*, 2000), they are affected by several conditions and threats. In particular, alliances between competing organizations are extremely difficult to manage, as they bring together a priori opposing behavioral patterns: on one hand, collaboration, which is common goal-oriented and benefits to all partners; and on the other hand, competition, which creates a competitive spirit among one or several partners and favors individual interests before collaborative ones (Park and Ungson, 2001).

2.2. Towards a real options approach to strategic alliances

As earlier mentioned, the real options approach was used in numerous previous studies on strategic alliances (*e.g.* Wang and Miao, 2006; Santoro and McGill, 2005; Vassolo *et al.*, 2004; McCarter *et al.*, 2011; Reuer and Tong, 2010). Strictly and financially speaking, options are contracts which give the holder the right, but not the obligation, to buy (or sell) a share at an agreed time for an agreed price called the strike price (Trigeorgis, 1995). A real

option “applies financial options theory (with some modifications) to the case of real, i.e., non-financial, assets” (McGrath and Boisot, 2005, p. 2).

It may be broadly defined as the right, but not the obligation, to take an action in the future (Amram and Kulatilaka, 1999), and is particularly valuable in uncertain and highly unpredictable environments (McGrath and Boisot, 2005). What makes real options valuable and distinct from other organizational resources is that real options confer preferential access to investment choices (Bowman and Hurry, 1993). Real options are intrinsically viewed as the flexibility a manager has for making decisions about real assets (Sick, 1995).

Options are not mere financial tools; they help to better formalize and understand companies and their growth. Myers (1977) was the first to use the term “real options” to refer to a firm’s growth opportunities. These growth opportunities can indeed be viewed as real options because their value depends on the firm’s discretion to invest in the future. According to Kester (1984), such growth options can increase the value of productive capacity, new product development or other firm acquisition, advertising budget, research expenditures, and marketing plans. In addition, they can partly protect firms from possible threats (McGrath and Boisot, 2005).

In R&D projects, which are characterized by irreversibility, uncertainty and long-term investment decisions (Weitzman *et al.*, 1981), real options play a major part. According to Bowman and Hurry (1993), when a company makes R&D investments, it implicitly benefits from unforeseen opportunities. Under uncertainty, using the options approach seems to be particularly relevant (Courtney *et al.*, 1997). Micalizzi (1999) showed that the more uncertain a project is, the more the real options approach increases its value. For instance, the skills gathered by the researchers of a team throughout different projects can develop, reinvent, and explore unforeseen opportunities in the long run.

Real options can belong to one company or be shared among several partner organizations (Kester, 1984). Thus, several authors used the real options approach to study strategic alliances (*e.g.* Wang and Miao, 2006; Santoro and McGill, 2005; Vassolo *et al.*, 2004; McCarter *et al.*, 2011; Reuer and Tong, 2010). Real options research often focuses on understanding how alliance partners use real options unilaterally to manage environmental uncertainty (Folta, 1998; Reuer and Tong, 2005). For instance, Folta and Miller (2002) and Dalziel (2009) examined when companies invest money in alliances and when these financial investments are considered as options. Smit and Trigeorgis (2006) combined the real options approach with game theory to assess investment opportunities under uncertainty, and more specifically to find the “best” choice between independent competition and collaboration

through a strategic alliance. However, as suggested by Li *et al.* (2007), real options can be created, acquired and exercised by collectives. Such collective real options provide not only environmental information, but also social information (Dixit and Pindyck, 1994; Li *et al.*, 2007). Concerning the latter, Van de Vrande *et al.* (2009) showed, for example, that partners may make small initial investments towards an alliance to uncover more information about each other's intentions before committing more resources to the alliance. Therefore, real options provide strategic alliances a mechanism to manage both environmental uncertainty (linked to factors exogenous to the alliance that influence the anticipated benefits of collective action) and social uncertainty (linked to factors endogenous to the alliance that influence the perceived trustworthiness of the partners) (McCarter *et al.*, 2011).

While strategic alliances can be studied through real options, which are capable of including the value of flexibility, growth opportunities, and competitive strategies in an uncertain environment (Smit and Trigeorgis, 2006), these real options are complex and not clearly defined in the literature. Moreover, as earlier mentioned, the latter unfortunately tends to consider them as exogenous data (Philippe, 2004; Myers, 1977), and to downplay the nonlinear relationships they follow (McGrath and Boisot, 2005). Following the studies applying system dynamics to option strategies (*e.g.* Marquez and Blanchar, 2004; Ford and Sobek, 2005; Cooke, 2004), this paper hence offers a dynamic approach of real options to better understand how collaborative and competitive behaviors interact in alliances.

3. THE STUDY OF AN ALLIANCE FORMED AROUND A PHARMACEUTICAL PROJECT

To be able to take into account both the phenomenon of growth options and the context in which they evolve, we chose to rely on a qualitative and interpretative approach (Eisenhardt, 1989). In accordance with others who call for qualitative research to understand the core issues of collaboration (Parkhe, 1993b) and in particular for “longitudinal case studies that are capable of capturing the complexity and dynamics of cooperation” (Smith *et al.*, 1995, p. 19), our method is based on a longitudinal case study and follows a single-case study design (Yin, 2009). After introducing this case, we will explain how data were collected and analyzed. We will finally present the principles of system dynamics and qualitative modeling.

3.1. The project LF16: A required alliance between competing organizations

This study is based on a new drug development project (project LF16) for treating cranial trauma within PGF group¹, one of the leading European pharmaceutical companies. We chose to study an R&D pharmaceutical project because the outcomes of alliances in this field are characterized by a higher uncertainty level (Santoro and McGill, 2005). The process of new drug development and commercialization is long, complex, and highly regulated. It consisted of one preclinical trial and four clinical trials: (1) the phase I trial involved healthy volunteers; (2) the phase II trial looked for the therapeutic properties and adverse side effects of the drug in patients; (3) the phase III trial, which was much more expensive than the previous one, was used to determine its efficacy and safety among a larger population of patients; and (4) the phase IV trial, conducted after the approval from the national drug regulatory agency and its marketing, was used to monitor patients under medication (Robbins-Roth, 2000).

To fund the project and perform large-scale drug testing, PGF group considered forming an alliance with PI, a competing company. PGF chose this partner because PI has the phase III skill that PGF misses. PI group, which is also one of the leading European pharmaceutical companies, has expertise in allergy and immunology whereas PGF group in central nervous system. Their alliance offers two interesting characteristics. First, their partnership should be sought for phase III funding. PGF decision was, however, somewhat flexible as PGF was faced with two opportunities: either forming an alliance with PI from phase II, or appealing to a venture-capital firm in phase II and then only after forming an alliance with PI. Secondly, as both pharmaceutical companies are competitors in central nervous system, collaboration and competition may conflict.

Finally, it must be noted that PGF has largely developed through strategic alliances, such as international alliances, and therefore has extensive experience in partnerships.

3.2. Data collection and analysis method

When we started our research, PGF had already started the first steps of project LF16, and had to choose between collaborating right away with PI to carry on the project and postponing this alliance. We had in a way to understand why PGF would choose or not to form this alliance by taking into account the opportunities and threats of this partnership, as perceived by PGF top management.

¹ For privacy reasons, the names of the companies and some technical data have been modified.

Data were collected through two sources. On the one hand, secondary data was used, including annual reports, internal project reviews, internal newsletter, confidential internal studies, press releases, etc. On the other hand, semi-structured interviews were conducted within PGF at the managerial level (over a 19-months period). Indeed, literature has pointed out that managers' dominant reality and interpretations of events may frame meaning and viewpoints for other organizational participants (Isabella, 1990). Thus, 21 interviews were conducted with the LF16 project manager (lasting between 1 and 3 hours). This respondent was considered as a "key informant" (Yin, 2009) throughout the study. We relied on a key informant, because a kind of "*fil rouge*" was necessary to track the evolution of real options and negotiations with the industrial partner. Because of his strong involvement in the alliance, the LF16 project manager was able to play this role. He was responsible for coordinating activities and tasks, facilitating the team, steering the project, representing it before internal governance committees, and negotiating with the partner. Moreover, he reasoned about the overall duration of the R&D project and then had a macroscopic view of this project. For data triangulation, we also interviewed three other key actors of the project: the associate director, the management controller, and the technology watch manager (see Table 1). As pointed out by Yin (2009, p. 107), we had to "be cautious about becoming overly dependent on a key informant, especially because of the interpersonal influence that the informant may have over [the researcher]". Thus, we ensured that the collected events and facts had been supported by more than a single key informant: we sought to corroborate any insight by such a key informant, rather than analyze each additional interview separately.

Table 1 – Interviews conducted within PGF

Number of interviews	Position	Duration
21 (from 1 to 2 interviews per month)	LF16 project manager	Average of 3 hours
1	Technology watch manager	2 hours
1	Management controller	3 hours
1	Associate director	2 hours
Total: 24 interviews		

Given our research objective, the main goal of our data collection was not to capture the value itself of real options but rather the process leading to them (McGrath, 1999). As growth options encompass environmental uncertainty, intuition, and the unique nature of the company (Kester, 1984), our interview guide mainly focused on the project's history and context, and the opportunities created by the project for PGF (the initial opportunities and their evolution). In addition, as there are collective real options in alliances (Li *et al.*, 2007), a second part in our interview guide concerned the opportunities and threats for each partner as

perceived and anticipated by PGF (and which could therefore be generated by the alliance), the possible outcomes and consequences of the collaboration, and the possible outcomes and consequences of the non-collaboration. We deliberately chose not to use the term of "real option" during interviews, in order to avoid inducing the respondents in error and avoid encouraging them to give an interpretation of real options.

All the interviews were recorded, transcribed and coded using NVivo software. A content analysis was performed, based on open coding of the interview transcripts. The two researchers independently developed codes for broad themes based on the data content and completed coding of the interviews, before confronting their analysis. This coding process allowed us to consider multiple points of view for each interview and, consequently, reduce researcher bias in the qualitative data analysis (Kreiner *et al.*, 2006). Then, we had recourse to two analysis techniques. First, we used event listing, which consists in organizing a series of events in chronological order by sorting them into multiple categories (Miles and Huberman, 1994). To enhance descriptive validity, both the interview transcripts and the secondary data were used to track the major events of the history of the LF16 project. Secondly, we relied on the approach for developing a causal diagram described by Miles and Huberman (1994). Following an inductive approach, we discovered phenomena in the flow of events and sought to identify recurring relations between them. From the thematic codes we developed, we made assumptions about directions of influence among sets of variables, and maintained a list of events, factors, results and processes. If this analysis process consisted mainly of a series of intuitions at the beginning, we were then able to adjust our assumptions and refine our list during the repeated interviews with the project manager. As recommended by Miles and Huberman (1994), data reduction, data display and conclusion drawing were interwoven before, during and after data collection. Finally, this list was used to build our qualitative system dynamics model.

3.3. Creating a qualitative system dynamics model

System dynamics is a well-known systemic modeling approach. It is based on non-linear dynamics theory and focuses on the dynamic nature of complex systems. A system can be defined as an organized and ordered set of interrelated elements (Forrester, 1975). Its complexity is due to the multiplicity of its components (natural, technical, economic and social) and of their interactions (Sterman, 2000). A complex system is deemed dynamic due to its internal causal structure and, fundamentally, because of the presence of feedback loops that impact the whole system (Meadows and Robinson, 1985). There are two types of

feedback loops in systems: (1) positive loops generate reinforcing, exponential growth behaviors; (2) negative loops generate balancing, equilibrating behaviors (Sterman, 2000). Positive and negative feedback loops do not act separately, and their interactions generate complex system behaviors (Senge, 1990). System dynamics helps to understand such dynamic, highly unpredictable behaviors and has been hence applied to complex managerial problems such as the management of multi-project R&D systems (Repenning, 2000), the development of inter-organizational networks (Akkermans, 2001), and the process of innovation management (Milling, 2002), to name but a few.

More specifically, this approach offers a set of qualitative and quantitative modeling tools. Influence diagrams are a qualitative system dynamics tool which is used to model the causal structure and the feedback loops of a system. Such diagrams highlight all the variables of a system, the links between these variables, the polarity associated with causal links, and the feedback loops assumed important (Sterman, 2000).

In our study, we developed an influence diagram mapping the causal structure and dynamic behaviors of the option strategies available to PGF, in the case of an alliance with its competitor PI for project LF16. From the list of events, factors, results and processes, created directly from the interview transcripts (and refined during repeated interviews with the project manager), we built a qualitative model following Diffenbach's (1982) guidelines: (1) identifying key variables; (2) suppressing redundant variables; (3) identifying causal links between the variables and the polarity² of each link. First, if the list created from the interview transcripts should be exhaustive, the list of variables used here had to be more selective. Second, we ensured that no duplicate or redundant variable remained, given that a same factor could be expressed in different ways. Third, concerning the identification and the polarity of the interrelationships among the variables (following from the assumptions of causality refined during the repeated interviews), the two researchers performed this step independently, before aggregating the individual input and reconciling differences. Finally, we closely studied the influence diagram to identify feedback loops³ and map their dynamic behaviors.

² A positive causal link between two variables A and B indicates that, if A increases (decreases), B increases (decreases), while a negative link indicates that if A increases (decreases), B decreases (increases).

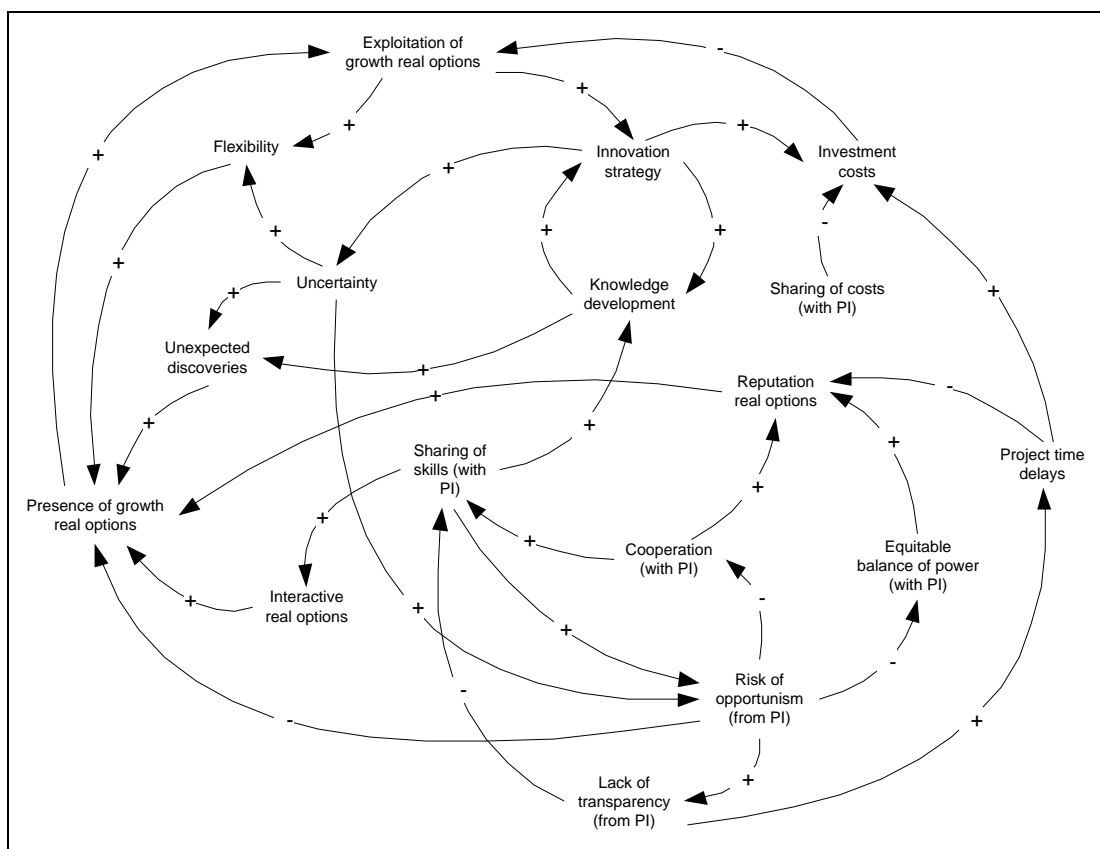
³ Reinforcing and balancing loops can be distinguished from the number of negative links involved: Reinforcing loops have an even number of negative links, and balancing loops an odd number.

4. REAL OPTIONS DYNAMICS IN AN ALLIANCE

The influence diagram, mapping the behavioral dynamics of an alliance formed around an R&D project and of its real growth options, involves 17 variables and 31 causal links (see Figure 1). It includes three types of real growth options that were identified in project LF16: unexpected discovery options, interactive options, and relational reputation options.

From the analysis of this qualitative model, we identified five reinforcing and eight balancing feedback loops, which can be grouped into three sets of feedback structures: expected flexibility dynamics, uncertainty dynamics, and skills and knowledge dynamics in the collaboration.

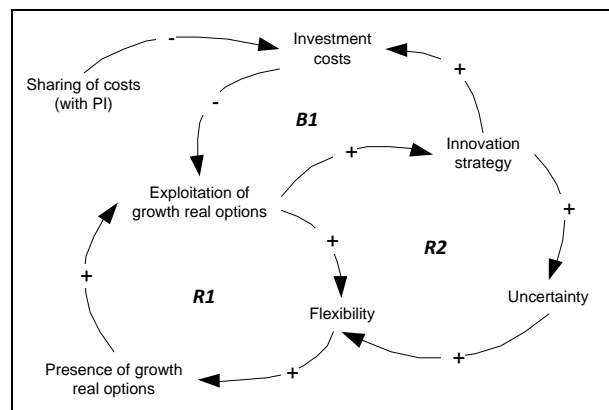
Figure 1 – Real options dynamics of an alliance formed around an R&D project



4.1. Expected flexibility dynamics

Flexibility dynamic behaviors are represented by three interacting feedback loops: two reinforcing loops (R1 and R2) and one balancing loop (B1) (see Figure 2).

Figure 2 – Expected flexibility dynamics



Project LF16 is an innovating project with uncertain outcomes, as in most new drug development projects. As the greater the uncertainty, the higher the flexibility (Trigeorgis, 1993), the flexibility of the project is largely due to the uncertainty PGF is faced with. And yet, flexibility can lead to a virtuous cycle where option strategies are reinforcing (R1). For instance, it can increase the amount of new information, skills and knowledge that might be used to identify and seize opportunities not directly foreseeable at the beginning of the project (Kester, 1984). In fact, flexibility both leads and aims to achieve growth (Kester, 1984). The dynamics of flexibility was hence triggered by the uncertainty perceived, stemming from the innovative nature of project LF16 and, more generally, from PGF innovation strategy. In other words, innovation and real growth options are mutually reinforcing (R2).

However, as innovation strategies are expensive, they tend to be limited to the investment required (B1). Thus, while flexibility can trigger a positive loop where innovation and real growth options are successfully reinforcing, dynamic behaviors are closer to the archetype called “growth and underinvestment”: when growth approaches a limit, it can be pushed into the future if a company makes rapid and aggressive investments (Senge, 1990). In our case, forming an alliance with its competitor PI was one of the ways PGF had to eliminate this limit by sharing investment costs.

4.2. Uncertainty dynamics

Uncertainty dynamics involve one reinforcing loop (R3) and five balancing loops (from B2 to B6) (see Figure 3).

delay drug development, but also imply extra costs. On a broader scale, the lack of cooperation tends to reduce alliance partners' involvement and indirectly increase costs (e.g. coordination costs) (Das and Kumar, 2007). On the other hand, the balance of power is in favor of PI because of its financial upper hand. The LF16 project manager explains that: *“PI has the right to say: we pay, we decide, you [PGF] can give your opinion, we've listened to you, you've been heard, but that's what we want to do, that's our management's call.”*. For PGF, and according to Ariño and de la Torre (1998), when this occurs, the challenge is to restore balance in the relationship.

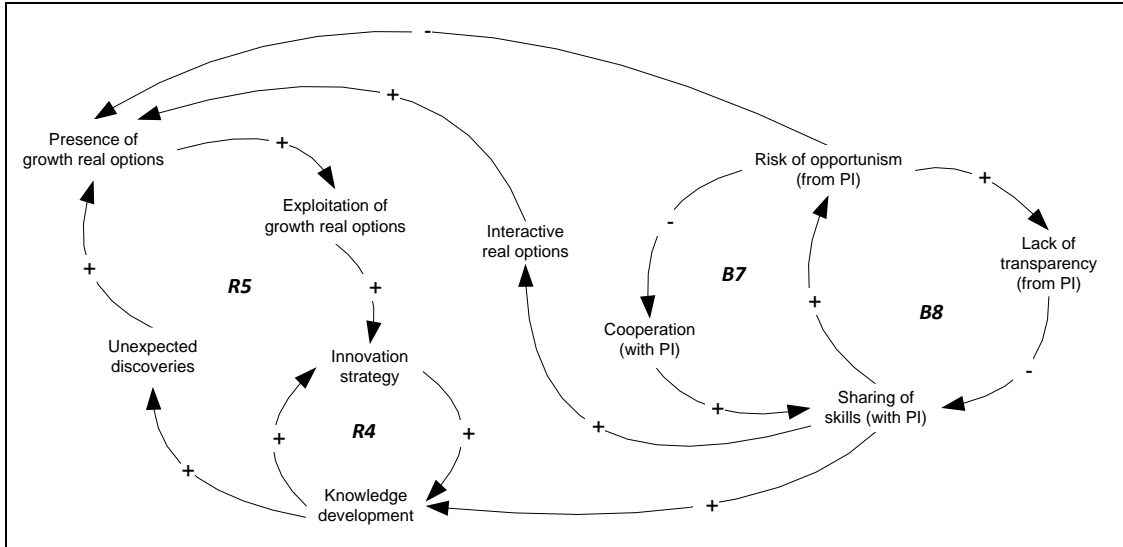
Moreover, such behaviors from PI ultimately deteriorate relational reputation options (B4, B5 and B6). Alliance success or failure can indeed affect the partners' reputation (Das and Kumar, 2007). This option, mainly concerning PGF, allowed the firm to exploit its good reputation based on previous collaborations (Shane and Cable, 2002). This relational reputation option is essential for PGF, as strategic alliances are one of their main development axes. Through the collaboration with PI, PGF thus seeks to consolidate its image of successfully managing alliances. Conversely, a non-collaborative behavior from PI and/or PGF could negatively affect the reputation (for example, if a legal dispute arises).

In sum, in project LF16 which is characterized by uncertainty, there are risks of opportunism that could negatively affect growth options, such as reputation or unexpected discovery options: they tend to limit option strategies. When firms are faced with risks and do not benefit from uncertainty, it hinders the innovation process and deteriorate option strategies. A compromise must therefore be found between the positive and negative effects of uncertainty, so that the system could be balanced and regulate itself. Delaying the entrance of competitors in R&D projects can be a way to get closer to balance. That is the strategy ultimately chosen by PGF.

4.3. Skills and knowledge dynamics in the collaboration

Skills and knowledge dynamics in the collaboration involved two reinforcing loops (R4 and R5) and two balancing loops (B7 and B8) (see Figure 4).

Figure 4 – Skills and knowledge dynamics in the collaboration



In R&D projects, innovation and knowledge are mutually reinforcing (R4). In such dynamics of innovation, some skills can then generate unexpected discoveries. In project LF16, a treatment for hereditary angioedema was discovered while this genetic disease was not targeted in this project aiming to treat cranial trauma. This growth option (the so-called “unexpected discoveries”) highlights how important human capital is, and how researchers are able to use their knowledge to identify new options. If such real growth options were used, they could lead to “new” innovation strategies. In our case, a new indication for the drug studied in the project could be found. Thus, knowledge is a key to success: it can lead to a virtuous cycle where real growth options and innovation are mutually reinforcing (R5).

In project LF16, this unexpected discovery on hereditary angioedema was, however, not exploited. PGF top management thought that exploiting this option would conflict with their refocusing strategy, as explained by the project manager: *“We made this choice because top management see it as non-strategic and difficult to develop. [...] It’s not compatible. And also, we’ve discussed it and some people said it’s impossible. Our first idea was: let’s study angioedema. We focus on cranial trauma, but we also develop angioedema. So, we could get money a bit earlier. Studying angioedema at the same time would be much less risky. But, they [top management] don’t see the point. In the end, they said no and I respect their decision. It makes sense, we can’t dissipate our efforts and resources in different areas, and we can only partly sell angioedema.”* The project manager and top management had different views on the subject: top management wanted to follow a refocusing strategy while the project manager was more tempted to develop a new option considering what he knew about the situation. Accordingly, if the project manager had used an options approach, he could

have convinced top management. It would have helped him to partly explain and conceptualize his intuition (McGrath *et al.*, 2004).

Besides, alliances can help to develop knowledge if partners truly collaborate and share their skills (Dyer and Singh, 1998). In project LF16, sharing skills enabled one partner to generate a real option called interactive, i.e. an option combining several complementing drugs in a single offer. For instance, PI portfolio encompasses an antiepileptic drug. If the survival rate after cranial trauma increases, it will also increase the number of patients treated for epilepsy, as epilepsy is one of its post-traumatic effects. In other words, as explained by the LF16 project manager, people suffering from trauma are more likely to have epileptic seizures. Thus, the initial project planned to enlarge the competitor's portfolio with a complementing drug and, accordingly, the interactive option contributed to the partner's virtuous cycle, reinforcing their innovation and real options.

However, the collaboration from PGF and the sharing of knowledge with PI increase the risk of opportunism from PI. While this behavior ultimately decreases cooperation (B7), it also increases the lack of transparency (B8). According to Teece (1986), when the skills shared by each company are heterogeneous, one of the partners may be tempted to capture the other company's knowledge. In those potentially threatening situations, the partners are less likely to share their skills. In other words, the positive effects of the collaboration (i.e. skills and knowledge development, and ultimately real growth options exploitation) are limited by the risk of opportunism this sharing of information may generate: "the collective knowledge development and mutual learning in the competitive alliance are limited by the (natural) opportunistic behavior of organizations. In turn, the co-operation as such can even be destroyed" (Soekijad and Andriessen, 2003, p. 578). The dynamics of skills and knowledge in collaborations can sometimes lead to a situation where the short-term solution chosen (here, cooperation) is likely to have unexpected long-term effects and deteriorate the situation (here, consequences created by an opportunistic behavior). This situation is similar to what Senge (1990) calls "the failing solution".

5. DISCUSSION AND CONCLUSION

In this article, we relied on a modeling approach by combining both the system dynamics principles and the real options approach, in order to capture the complexity and the dynamics surrounding the opportunities and threats of strategic alliances between competitors around an R&D project. Focusing on uncertainty (Santoro and McGill, 2005), a real options approach is especially relevant to address R&D projects in alliances as they imply long-term investment

decisions whose outcomes are uncertain (Weitzman *et al.*, 1981; Smit and Trigeorgis, 2006). However, the traditional approach, which considers real options as exogenous data (Philippe, 2004; Myers, 1977) and tends to downplay their complexity and dynamic aspects (McGrath and Boisot, 2005), may be not suitable for analyzing strategic alliances between competitors that create both growth options and opportunism risks. As growth options and success in such alliances are subject to behavioral dynamics, they work as a complex and dynamic “system” and have to be treated as such. System dynamics modeling is such an appropriate methodological approach that it allowed us not to minimize the complexity of real options and their nonlinear relationships in strategic alliances. In this perspective, we built a qualitative system dynamics model from a longitudinal case study, in order to map and analyze the causal structure and the behavioral dynamics in which real growth options are embedded when two competing pharmaceutical companies form an alliance.

This study allowed us to refine the concept of real growth options as defined by Trigeorgis (1993), by pointing out three types of options: unexpected discovery options, relational reputation options, and interactive options. We found three sets of feedback structures in which they are embedded: the “expected flexibility dynamics” emphasizing the virtuous cycle in which innovation and real growth options are mutually reinforcing; the “uncertainty dynamics” which clearly indicate why firms should exploit the uncertainty value and find a compromise between positive and negative risks; and the “collaborative skills and knowledge dynamics” where the positive and negative effects of knowledge sharing between competitors are conflicting.

First, unexpected discovery options are embedded in both the “uncertainty” and “collaborative skills and knowledge” dynamics. Both knowledge development (through sharing of skills) and uncertainty can directly favor unexpected discoveries. However, the well-known issues of striking a balance between “too much” and “not enough” sharing are also highlighted in the specific context of such a real option. In the same way, due to the negative effects of uncertainty, risks of opportunism can in turn negatively affect unexpected discovery options. Managing these negative loops is here essential, given that serendipitous discoveries play a key role in the pharmaceutical industry (Tarabusi, 1993). Definitely, not only environmental uncertainty (Reuer and Tong, 2005; Folta, 1998) but also risks related to partners’ behaviors must be considered to take full advantage of such a real option. Secondly, as relational reputation options are also embedded in the “uncertainty” dynamics, the same observation is made. Reputation options, however, share some specific characteristics. For instance, given that alliance partners can develop alliance management skills (Crossan *et al.*,

1999), both past and current experiences of the two partners can participate in the construction of the relational reputation options. In addition, as the success or failure of the previous alliances formed can affect reputation (Das and Kumar, 2007), other partners' reputations should influence an alliance partner's willingness to acquire real options (McCarter *et al.*, 2011). Our study then represents an interesting case, given that PGF has extensive experience in partnerships. One may suggest that its expectations about the partner's future behavior have been strongly conditioned by its prior experiences (Ariño and de la Torre, 1998). Moreover, while relational reputation options are simultaneously involved in different feedback loops in our influence diagram, one may ask if such options would be less anchored in the "system" for firms with less extensive experience. Thirdly, concerning interactive options, which are embedded in the "collaborative skills and knowledge" dynamics, it should be noted that they are involved in no feedback loops. This does not mean that they do not experience the dynamics of the system, but they are certainly less exposed and less complex.

To sum up, our study confirms that both environmental and social uncertainties influence option strategies and alliance success (McCarter *et al.*, 2011), while real options research often focuses on understanding how alliance partners use real options to manage environmental uncertainty (Folta, 1998; Reuer and Tong, 2005). Indeed, it appears that real growth options (especially unexpected discovery and relational reputation options) are strongly and dynamically linked to partners' behavior. Although human capital is essential in research projects (Johnson *et al.*, 2006), the influence diagram built in this research highlights the fact that partners' behavior and intentions are key determinants in the process leading to the creation or deterioration of real growth options, and ultimately to their exploitation. In fact, the level of cooperation (current and past, perceived and expected) is at the heart of the behavioral dynamics of an alliance and its growth options. For instance, Jones and George (1998) suggested that reputation is closely linked to cooperation in alliances initiatives. This notion of cooperation can be opposed to the notion of non-cooperation, which occurs when an alliance partner fails to contribute private resources towards alliances initiatives (Dawes, 1980).

Moreover, whereas traditional research on real options typically examined how individual partners acquire real options (Folta and Miller, 2002), our research reveals that the three types of real growth options identified were created by the collective, that is, the alliance. Such collective real options can be exploited collectively (Li *et al.*, 2007), but they can also be exploited later and independently by each partner (Pape and Schmidt-Tank, 2004) or not at all. For example, although an interactive option in favor of PI was collectively created in

project LF16, PI finally decided not to exploit this one. Conversely, the unexpected discovery option collectively created could be later exercised by both alliance partners. If there are collective options, they are also created, developed or suppressed because of specific decisions and opportunism risks.

Furthermore, this study could be useful to practitioners. Our research suggests that cooperation can be seen as the expression of optional behaviors. While intuition plays a major role in a real options approach, which is primarily a “way of thinking” rather than a range of tools (Mauboussin, 1999), managers should ask themselves if they adequately consider the value of their firm’s cooperation and the potential for alliance development. Appreciating the value of real options is, however, highly complex. This article then offers a system dynamics model that can help managers to think about all interacting factors that contribute to this value, rather than relying only on their intuition. This model represents a dynamic hypothesis of the feedback structure of the “system” of real options in strategic alliances, but it can also serve as a “platform” to the creation of a shared mental model amongst members of an organization (Sterman, 2000). As the development of a shared understanding of complex problems is difficult to achieve using unstructured representations, an influence diagram can help to develop a shared comprehensive and common understanding about a complex phenomenon. This is a real issue, as shown in our case: the top management team and the project manager had different views on the unexpected discovery option that has emerged during cooperation, and the latter was not able to convince the merits of his intuition when he saw the strategic potential to seize this opportunity.

Some limitations can, however, restrict the scope of this study and inspire avenues for future research. Firstly, our study only takes into account the viewpoint of one of the two partners involved in the alliance. Integrating the story of the other partner was impossible because this research project was strictly confidential and we were contractually unauthorized to contact the partner competitor. Given that alliance dynamics is caused by joint interactions and decisions between the involved partners, analyzing both sides would allow us to confront the two partners’ opinions, notably in order to identify the concurring and diverging opinions on the options found. Secondly, it would have been worth considering the alliances between more than two partners and taking into account the dynamics driven by several partners. Indeed, the higher the number of partners is, the less profitable the exploitation of shared options is (Kester, 1984), as the benefits from the cooperation are shared. Thirdly, our study neglected the processes of learning through past and present interactions between firms. As both uncertainties about future states of nature and about the partner’s future behavior can

resolve through processes of learning (Ariño and de la Torre, 1998), taking into consideration “learning options” would be especially interesting. Finally, beyond qualitative modeling, the system dynamics approach is a simulation technique: an influence diagram is often a first step to build a quantitative model which helps to simulate different decision choices (Sterman, 2000). Expanding our study using this numerical method could help to anticipate and quantify the outcomes of an alliance between competitors in an R&D project.

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