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Technology licensing decisions: a real options perspective

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Abstract

As part of the growing trend toward Open Innovation, the market for technology licenses has seen an unprecedented growth over the last decades. Yet, empirical studies in this area remain underdeveloped, and the decisions made by firms regarding technology licensing are not well known and understood. The goal of this paper is to explore whether real options (RO), a valuation approach derived from market finance, may constitute a useful framework to analyze licensing decisions made by firms.

The literature highlights numerous benefits of open innovation, for in-bound as well as for out-bound processes. On the other hand, open innovation approaches like technology licensing can be risky. For the innovator, there are significant risks involved in sharing innovation with current or potential competitors. Conversely, the licensee – who is the less informed party – faces the risk of overpaying for the technology. In order to be successful, the transactions of technology licenses must therefore be carefully managed, to come up with an appropriate price and deal structure. This is a difficult task, because the parties are facing considerable uncertainty, both from a technical and commercial point of view.

Current valuation tools used by firms to negotiate technology licensing agreements are not adequate: the multiples approach is too simplified to reflect the specificities of the deal, and discounted-cash flows (DCF) based methods are not adapted to contexts of high uncertainty. By contrast real options, which is a dynamic approach adapted to uncertain environments, appears as a promising framework to analyze technology licensing decisions. There is some anecdotal evidence of the use of real option by firms in the pharmaceutical industry for their licensing decisions, and academics have developed theoretical models to value licenses as real options.

In this paper, we investigate to what extent the RO approach can be used to analyze licensing decisions, and what are the potential barriers to its use. We successively review in-licensing, out-licensing and cross-licensing decisions. We find that depending on the context – in terms of type of technology, firm size, timing, etc. – licensing decisions may not necessarily give rise to a real option. When this is the case, the characteristics of the real option vary significantly depending on the context. Therefore, there is no "one size fits all" way of applying the RO framework to licensing decisions.

Our research suggests that RO theory may be useful for scholars to analyze issues such as the optimal governance mode to exploit an innovation. From a managerial perspective, RO will be useful only for those licensing decisions which follow an optional logic. When this condition is met, we believe that this approach can be a powerful framework: it enables managers to translate their intuitions into clear decisions rules to determine whether the firm should license-in or license-out a technology, and under what conditions. In so doing, real options serve both as an internal and external communication tool. Finally, we find that the real options contained in technology licensing decisions have "exotic" characteristics, which implies that we need to develop user-friendly and flexible models to estimate their value.

Keywords *: real options ; patent licensing ; technology markets; open innovation ; management of innovation*

INTRODUCTION

Although the exact size of the market for patent licenses is not known, various sources indicate that it has recorded a significant growth since the beginning of the 1990s (Athreye and Cantwell 2007). Degnan (1998) finds that in 1996, US corporations received $66 billion in royalty income from unaffiliated entities. According to other sources, the market for patent licensing has grown from $3 billion in 1980 (Rigby and Zook 2002) to $15 billion in 1990 (Rivette and Kline 2000) and further to $110 billion at the beginning of the years 2000 (Rivette and Kline 2000; Rigby and Zook 2002; Kline 2003; Chesbrough 2007). In some industries, such as telecommunications equipment, the importance of technology licenses is such, that it is estimated that smartphone makers have to pay for royalties that make up about 15-20% of the device selling price (Economist 2010, p.70).

Despite its success, the market for technology licenses is not well known. Many articles cite anecdotal evidence of the development of this market, whereby firms like IBM, Xerox, Texas Instrument or Hewlett Packard have significantly increased their revenues from the licensing of patents (e.g. Gu and Lev 2004; Economist 2005). But overall the empirical researches on technology licenses remain underdeveloped, especially compared to the wide literature on the management of patents. This can be due to two main reasons: technology licensing is a recent phenomenon, and it is a "sensitive" area on which firms do not like to communicate (Fosfuri 2006). According to Gu and Lev (2004), about 50% of companies engaged in patent licensing do not disclose royalties income in financial reports. There have been more studies examining the technology licenses practices of universities, where data are more accessible (e.g. Ziedonis 2007; Markman, Gianiodis et al. 2009). Although such studies improve our understanding of the management of licenses, they do not address a number of issues faced by firms. In all, there is a large research potential on technology licensing, both through conceptual works and empirical studies (Lichtenthaler and Ernst 2007).

One of the reasons for this strong growth of technology markets is that the nature of licensing has profoundly changed over the last twenty years. In the past, external technology exploitation by the mean of out-licensing was primarily conducted when the innovator was in a less favorable position to market a technology than potential licensee. In particular, this occurs in the case of foreign market entry or for technologies developed by the innovator that do not fit with its core business (Chesbrough 2007). Now licensing goes far beyond a marginal activity of commercializing residual technologies, and firms also license out their technology to potential or direct competitors (e.g. Lichtenthaler 2008).

This phenomenon reflects the trend towards open innovation. The term, coined by Chesbrough (2003), refers to the fact that because of increased product complexity, specialization, and shorter product life cycles, firms should use external markets instead of relying exclusively on their own R&D to release new products. Conversely, they may in some instances better find external paths to market a technology developed in house, rather than exploit it internally of keep it unused. Open innovation can thus take place through *in-bound* as well as trough *out-bound* processes, and one major way of achieving them is through technology licensing agreements (TLAs), on which this paper concentrates.

The implication of open innovation is that firms' strategy space has increased, as they now have the choice between internal R&D or internal exploitation on the one hand, and external markets on the other hand (Arora, Fosfuri et al. 2001). In this context, they must carefully balance the risks and benefits of licensing. For the potential licensee, external markets enable the acceleration of product development. On the other hand, technology transactions are fraught with information asymmetries and as the less informed party, the licensee faces the risk of overpaying for the technology (e.g. Gallini and Wright 1990). For the potential licensor, external markets create the opportunity to extract more value from technologies developed in-house. However, there is the risk of underestimating the value of the technology. For instance, Xerox virtually gave away a stream of innovations (computer mouse, graphical user interface, laser printer), and TRW undervalued some of its biggest breakthroughs, which were exploited by others, in particular Qualcomm, Broadcom and Texas Instrument (Rigby and Zook 2002). In addition, sharing innovation with current or potential competitors entails the risk of deteriorating the firm's long term competitive position (Kline 2003; Lichtenthaler 2008).

Licensing decisions are particularly difficult to make because they take place in a context of high uncertainty. First, the combination of technological and commercial uncertainty makes the value of a technology license very difficult to assess. In the context of open innovation, the level of commercial uncertainty maybe particularly high if firms are dealing with potential markets that they do not know well, whereas they were up to now used to evaluating technologies within their current markets and customers (Chesbrough 2004). Second, licensing decisions are exposed to the risk of opportunistic behavior from the partner, and it is very difficult to foresee how a licensee will exploit, and potentially improve, the licensed technology. This can trigger significant changes in the dynamics of competition.

In order to be successful, technology licensing therefore requires highly proficient management. Firms need appropriate decision tools to assist them (1) in the negotiations so that the patent is priced and structured properly and (2) in assessing the strategic impact of licensing-out their technology.
To date, firms probably rely too much on traditional financial measures based on Discounted Cash Flows (DCF) like the Net Present Value (NPV) for their licensing decisions (Kline 2003). Unfortunately, these methods are static, and therefore not well adapted to highly uncertain environments. Chesbrough (2004) argues that the transitions from a closed to an open innovation necessitate for firms to change their metrics for managing innovation; they need to use evaluation tools that encourage R&D managers to stage their investments in projects upon the receipt of new information.

In this regard, one major innovation in the field of finance has been the study of real options (RO). Real options, which are derived from financial options, are a dynamic approach adapted to uncertain environments. The main contribution of real options is to recognize that investment projects can evolve over time, and that this flexibility has value. Under uncertainty, real options may thus come up with more appropriate investment project values than DCF methods, and offer the possibility to reconcile strategic and financial analysis (Myers 1984).

There is a fairly robust literature that analogizes patents to real options (*see section I*). This implies that real options can be used for the management of patents, e.g. in patent licensing decisions, as suggested by Pitkethly (1997): *"Option based valuation approaches are thus proposed as a useful and potentially powerful framework in which to consider management of a company's patent portfolio and other IPR assets, and the difficulties of a rigorous application of the method form a fruitful field for future research."* As a matter of fact, we have anecdotal evidence of the use of real options by pharmaceutical firms in the negotiation of licensing agreements (Nichols 1994; Hoe and Diltz 2012). Therefore, real options appear as a promising framework to assist firms in making their licensing decisions. In addition, RO could contribute to understand why patent licenses may have a strategic value beyond the revenues generated by royalties, and therefore help academics better understand firms' governance decisions in terms of technology exploitation.

At the same time, one should be cautious about the potential benefits of the RO framework. From a managerial perspective, the potential use of RO is limited by its complexity: generally speaking, RO are not easy for managers to understand and implement (e.g. Lander and Pinches 1998). In the specific case of licensing, it appears that each transaction is unique, and it is difficult to adapt RO valuation models to the specificities of the technology licensing agreement that is negotiated (Amram 2005).
More fundamentally, one should be aware of the fact that not all strategic decisions can be analyzed as real options, even if they take place in uncertain environments (Adner and Levinthal 2004). For example, although Kogut (1991) has shown that Joint Ventures (JVs) can be interpreted as an option to expand, Cuypers and Martin (2010) later found out that, depending on the type of uncertainty involved, the RO logic does not necessarily apply to international JVs. Consequently, the intuition that patents can be analyzed as options does not necessarily mean that RO will be useful to support and understand all patent licensing decisions.

In this paper, we explore to what extent licensing decisions can be analyzed as options, and under what conditions the RO framework can be of any use to academics and practitioners alike.
The literature on Open Innovation can be structured along two main processes: out-bound and in-bound (Dahlander and Gann 2010). Similarly, we can consider that the literature on technology licensing addresses two main strategic issues: (1) In-bound: under what conditions should a firm purchase a license? (2) Out-bound: what is the best governance to exploit an invention, in other words: should the firm out-license a technology or exploit the invention in-house? Thirdly, we can distinguish the special case of cross-licensing, which mixes in-bound and out-bound processes.

The remainder of this paper is organized as follows: In section 1, we present the real options approach, and its potential benefits for licensing decisions. In section 2, we review licensing-in decisions. Section 3 and 4 are successively dealing with licensing-out and cross-licensing decisions. In the conclusion, we summarize our main findings and provide suggestions for future research.

I. THE PROMISE OF THE REAL OPTIONS APPROACH

I.1. Traditional patent valuation methods used in licensing negotiations

In order to quickly evaluate large patent portfolios, e.g. as part of due diligence processes in mergers and acquisitions (M&A) transactions, sophisticated algorithms have been developed. These algorithms enable the parties to quickly filter for example a group of 400 relevant patents to 40. What remains difficult to perform, however, is the valuation of the subset of the most valuable patents. It appears that intellectual property specialists are lacking a systematic method, and that the valuation of patents is more art than science (Meeks and Eldering 2010).

For firms negotiating a technology licensing agreement, the objective is to agree on a “fair” royalty rate for the two parties. The methods most commonly used to establish the royalty rate are: (i) comparison with previous similar deals done by others, (ii) alignment with industry or internal practice, and (iii) DCF calculation (Salauze 2011).

Comparison with previous deals and industry practices

Alignment with industry or internal practice is generally frustrating when the parties belong to different industries, or when one of the parties has limited bargaining power (Salauze 2011, p.210). The use of generalized rules of thumbs is also problematic because they fail to capture the specificities of the technology that is negotiated. Salauze (2011) indicates that comparison with previous similar deals is always questionable because, even if data are extracted from a reliable database, negotiators have the feeling that no deal is really similar to the deal they are currently discussing.

Among the rules of thumb most often quoted in the context of licensing royalty rates is the "25 per cent rule". This rule suggests that the infringer of a patent should pay a royalty equal to 25 percent of profits (usually defined as operating profits). However, use of a one size fits all model such as the 25 per cent rule does not take into account investment risk and the required return on investment on intellectual property that is appropriate for specific situations (Shapiro 2010).

In the pharmaceutical industry, an in-depth analysis of historic market data from going back over 10 years has shown that the 25 per cent rule is not commonly used nor appropriate (Borshell and Dawkes 2010). This is all the more true as license contracts within the drug development industry have become extremely complex, including sublicensing, co-development, or profit sharing (Villiger and Bogdan 2009). Generally speaking, as a result of a recent federal appellate court decision (*Uniloc v. Microsoft 2011*), the 25 per cent rule can no longer be used to derive reasonable royalty rates in patent infringement cases (Shapiro 2011).

DCF calculations

Taking into account information and data specific to the technology being negotiated is much more likely to lead to financial terms that are fair for both parties. Technically, this is performed by establishing a provisional profit and loss statement, in which the following cash-flows are estimated: revenues generated following the market introduction of the product covered by the technology minus variable costs (e.g. marketing and production costs); investment necessary to launch the product (pre-marketing costs, construction of a plant, etc.). When all these cash-flows are summed up and discounted, one comes up with the expected "profit" generated by the product. The parties agree on a "profit split" ratio (PSR) to determine which share of the profit is left to the licensee. They can then derive the royalty that is owed by the licensee to the licensor, and which is usually expressed as a percentage of sales, which are later easier to control than profit (Salauze 2011).

This NPV calculation can then be made more sophisticated in different ways. In particular, parties can include the development cost supported by the licensee in order to adapt the licensed technology to the product marketed by the licensee. In the pharmaceutical sector, firms also typically calculate an "expanded NPV" or "augmented NPV", which results from the combination of decision trees and NPV calculation (Bode-Greuel and Greuel 2005; Cartwright and Borshell 2012). Decision trees are used to reflect the risk of failure at each step of the process from the pre-clinical stage to the approval by the health authorities (Federal Drug Association in the US).

Whether uncertainty is accounted for through the discount rate in a simple NPV or in a more sophisticated manner by weighted probabilities in decision trees, there is a relative consensus in the literature to say that DCF methods tend to produce suboptimal decisions under uncertainty because they fail to take into account the managerial flexibility that can be exercised as the level of uncertainty get reduced (among numerous references, see e.g. Dixit and Pindyck 1995; Trigeorgis 1996).

By contrast, the real options framework incorporates from the outset the possibility for managers to change the course of action as they get more information on the profitability of the investment project.

In the specific context of technology licensing, researches in the pharmaceutical industry (Bowman and Moskowitz 2001; Hoe and Diltz 2012) show that real options produce more appropriate decisions for the licensee than NPV calculations because real options take into account managerial flexibility (see *section II* for more details).

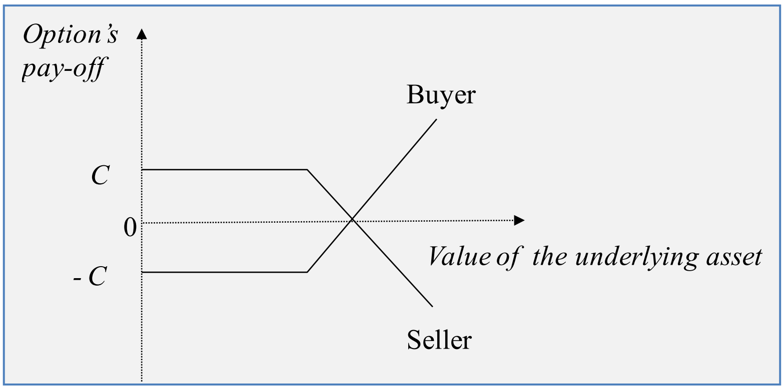
I.2. Real options

The real option concept

The real options concept rests on the analogy between investments made by firms in uncertain contexts and options that are exchanged on financial markets. A financial option gives the right, but not the obligation, to purchase (or sell) a financial asset (called the underlying asset) at a given price (called the exercise price) at (or before) a given date (maturity). To be given this right, the option's holder has to pay for an option's premium. He will exercise the option only if the evolution of the underlying asset is favorable, e.g. if the underlying asset's price is above the exercise price in the case of a call option. Otherwise, the option will not be exercised, and the loss incurred by the option's holder will be limited to the option's premium.

Similarly, when investment projects take place in particularly uncertain environments, firms may undertake a limited initial investment (e.g. elaborate a prototype, perform a market test, form a joint-venture), and perform a larger investment (e.g. move from prototype to industrial phase, commercialize a new product, purchase the remaining capital of the joint-venture) only if the circumstances are favorable.
Such investment projects can be analogized to options, in the sense that they enable managers to exploit the upside risk, while keeping the potential loss limited to the initial investment. In other words, the specificity of the option's logic is the asymmetry of the pay-offs: if the value of the underlying asset is below the exercise price when the option expires, the option's holder will not exercise the option, and will limit his loss to the payment of the option's premium *C*. On the upside, the potential gain is theoretically unlimited. The option's seller (the bank) is in the opposite situation: he receives for sure the option's premium, but is exposed to unlimited risk (Figure 1).

Figure 1: Pay-off diagram at option expiration (case of a call option)



Typology of real options

The literature (e.g. Dixit and Pindyck 1994; Trigeorgis 1996) traditionally distinguishes between two main categories of options: " investment options", which refer to the possibility of modifying the perimeter of an investment project (e.g. postpone, grow, downsize, sequence, etc.), and "operating options", which refer to the flexibility offered in the management of some assets: e.g. dual-fuel steam boiler (Kulatilaka 1993), gaz turbines that can be easily shut down and restarted (Copeland and Antikarov 2001). Amram and Kulatilaka (1999) add a third category of real options, called "contractual options". These refer to contract provisions that present the characteristics of an option. For example, aircraft manufacturers often give airline companies the opportunity to cancel or modify an order once it has been placed. This flexibility offered to airline companies has value, and Airbus used the RO approach to estimate it (Coy 1999).

We can also distinguish *simple* from *compound* options. Compound options correspond to a sequence of options, whereby the exercise of an option leads to the creation of a new option, and only the last option of the chain generates cash-flows when it is exercised. Compound options can be observed for example in oil exploration projects: if they produce a positive result, geological analyses of a potential oil field will be followed by drilling tests. In turn, if oil reserves revealed by the drilling tests appear sufficient, the oil company will then apply for a license to exploit the field. Compound options are particularly frequent in R&D projects, which typically give rise to a succession of decisions, embedded into three main phases: research, development and deployment (Jensen and Warren 2001).

Patents as real options

A patent is the right to exclude competitors from manufacturing and selling products covered by the patented "claims". In practice, this right gives the patent holder the possibility to operate in a monopoly position, and hence to generate a higher profit than in a competitive market. However, the patent holder has no obligation to exploit the technology covered by the patent. In this sense, a patent can be considered as a real option, as has been early recognized in the literature. In his seminal articles on real options, Myers (1977) identified patents, along as certain trademarks, franchises and operating licenses as real options.

For the patent holder, the "premium" to be paid to obtain this option is the cost of inventing, of filing and renewing the patent and of enforcing monopoly against infringers. The underlying value corresponds to the present value of cash-flows generated by the commercialization of the invention. The exercise price is the investment cost necessary for the market entry of the product, which includes further development costs, as well as production and marketing costs. The time left to expiration is the time until the patent expires, and will be lower if the patented technology becomes obsolete following the apparition of a superior technology or if competitors manage to "invent around".

Instead of commercializing the invention, another way of "exercising" the option for the patent holder is to assert it by engaging licensing discussions or starting litigation process against infringer (Cotropia 2009). We do not discuss this case, which goes beyond the scope of this article.

At an industry level, this reasoning has been used by economists to understand the relationship between patenting on the one hand, and firm-level productivity and market value on the other hand (Bloom and Van Reenen 2002). In a similar vein, Wu and Tseng (2006) study the link between patent value on the one hand, and value of the underlying asset, time to maturity and risk-free rate on the other hand. Other economists have used the options analogy to analyze firms' decision to renew patent fees (Pakes 1986) and to produce some recommendations on the structure of patent renewal fees

(Baudry and Dumont 2006). The patent application process itself has also been studied as a real option (Laxman and Aggarwal 2003).

However, little can be found in the literature on the implications of analyzing patents as real options on firms' licensing practices. Therefore, it appears necessary to explore whether patents that are licensed can be typically considered as (valuable) real options, and hence whether the real options framework can be useful in analyzing firms' licensing decisions.

Determinants of a real option's value

Not all strategic decisions can be analyzed as options. We discuss below three conditions that have to be met for the creation of a real option: (1) uncertainty (2) information revelation and (3) managerial flexibility.

One of the main insights drawn from the financial theory is that the higher the uncertainty – measured by the volatility of the underlying asset's stock price – the higher the option value. Therefore, if the considered investment decision takes place in a context of low uncertainty, the real option value will be low, and the extra insight brought by the RO framework will be marginal.
In the case of patent licenses we can expect wide differences in the level of uncertainty regarding the commercial value of an invention, and the rent that the two parties can extract from this technology. The level of uncertainty will notably depend on the type of technology: it may be higher for product than for process technologies, and for general-purpose than for specialized technology. Also, the position of the technology in the development cycle has a strong impact on the level of uncertainty: it will be the highest for *ex-ante* licensing agreements dealing with a technology for which the patent has not been granted yet, and the lowest for licensing agreements dealing with a technology that is used by a product already commercialized.
Conversely, the level of uncertainty should not be too high. As pointed out by Adner and Levinthal (2004), the investment opportunity under study can be analyzed as a real option only if the opportunities on one is taking an option can be clearly specified at the inception of the option. By contrast, if the technical agenda or the target market of the investment opportunity are too flexible, then we are in the case of a path-dependent investment, which cannot be considered as a real option.

The second necessary condition for the existence of the real option is the possibility of information revelation, so that the option holder can make a conscious decision at exercise time. In the case of financial options, the option's holder can observe the evolution of the underlying asset's price on the stock exchange, and decide on this basis whether or not he should exercise the option when it expires. In the case of real options, the reduction of uncertainty may similarly take place through observation, for example if the main source of uncertainty is the price of a commodity or of raw material. The revelation of information can also be obtained in a pro-active way. For example, the uncertainty regarding the size of the reserves of an oil field can be reduced by performing drilling tests; consumer acceptance of a new product can be better evaluated thanks to market test; the technical feasibility of a new product can be assessed thanks to the realization of a prototype.
In other cases however, the level of uncertainty cannot be reduced below a reasonable level *before* the investment decision is made. In this case, the investment opportunity cannot be analyzed as an option. For instance, Huchzermeier und Loch (2001) developed a model in which they analyze five types of uncertainty in R&D projects: uncertainty in market payoffs, project budgets, product performance, market requirements, and project schedules. In this model, the reduction of uncertainty regarding

product performance and market requirements cannot occur before the investment decision takes place. Therefore, the option logic cannot be used to take into account these two sources of uncertainty.

The third condition is managerial flexibility, i.e. the possibility for management to alter the course of action upon reception of new information. If the scope for flexibility is reduced, e.g. in case there is no alternative technology, or in case of an "all-or-nothing" type of investment, then the investment opportunity is a bet, not an option.

Obviously, there is no strict answer on whether an investment opportunity may be analyzed as an option. For example, the reduction of uncertainty is rarely complete before the investment decision is made. But if we relax too much the conditions cited above, and move away from the option logic, the risk is to come up with wrong conclusions (e.g. believing that increased uncertainty will raise the project value) or at best to obtain a very low option value and *in fine* the same recommendation as the one produced by a simple NPV analysis.

Application of real options to technology licensing decisions

Empirical analyses have pointed out that there are strong differences in the management of technology licenses across industries. In particular, Anand and Khanna (2000) revealed robust cross-industry differences in the incidence of licensing activity, the proportion of *ex-ante* contracts, the importance of exclusive contracts, etc. The existence of these differences suggests that, depending on the context, the strategic issues that firms face in the management of licenses, and the solutions found, may differ. The analysis of the literature reveals that at least five factors have an impact in the framing of technology licensing decisions.

(1) *Type of technology*: in industries where technology has a cumulative nature – i.e. innovations build up on each other – actors need to cooperate and to have a quite open management of their technology. Other technological features that may affect licensing decisions are: (i) process V. product innovation. For example, in the chemical industry, licensing was primarily used as a mean of generating revenues from process technologies (Arora 1997) ; (ii) general-purpose (Gambardella and McGahan 2010) V. "specialized" technology.
(2) *Timing*: the decision to license depends on whether we are dealing with an emerging or a mature technology. For example, in his "Profiting From Innovation" (PFI) framework, Teece (1986) indicates that one of the key parameters in firms' licensing decision is the timing, as the success of an innovation depends to a large extent on whether the dominant design has already emerged when it is launched.
(3) *Size of actors and presence of complementary assets*: firms that lack complementary assets (e.g. production and marketing capabilities) are usually better of selling their technology through a license, rather than exploiting their inventions internally (Teece 1986). According to the survey by Gambardella et al. (2007), firm size and complementary assets are the main determinant in the willingness to license.
(4) *Industry structure*: in the chemical industry, Arora (1997) shows that the strategies of rent appropriation and industry structure are inter-dependent. Similarly, Fosfuri (2006) finds out that there is an inverted U-shaped relationship between the number of potential technology holders and the propensity to out-license a technology.
(5) *Motivation for licensing*: the empirical study conducted by Lichtenthaler and Ernst (2007) shows that generating revenues is just one out of a series of possible motivations for firms to out-license a technology. Lichtenthaler (2010) also indicates that the strategic issues firms are facing depends significantly on whether they are following a "pro-active" or a "reactive" licensing strategy.

(6) Other factors notably include the s*trength of IPRs* (e.g. Arora and Ceccagnoli 2006) and the *role played by standards*, especially in industries showing strong network externalities.

In the following sections, we explore whether licensing decisions may lead to the creation of a real option, depending on the factors listed above. We successfully review the decision to license-in, to license-out and to cross-license. We describe the characteristics of the real options identified, and discuss the benefits of using a RO approach to analyze licensing decisions, both from an academic and a managerial point of view.

II. THE DECISION TO LICENSE IN

In this section, we analyze the licensee's point of view and determine in which cases the real options framework may guide the management in their licensing-in decisions.

II.1. OPTIONS IN THE DECISION TO LICENSE IN

The option to develop and exploit an innovation

The type of technology licensing agreement that has been cited in the literature as the example of a real option corresponds to the licensing of an ex-ante patent license in the pharmaceutical industry.

There are two sorts of patent licensing agreements: *ex-post* and *ex-ante*. In the later case, the parties sign a licensing agreement on a patent that has not been granted yet. This sort of contract can be typically observed in the pharmacy and biotechnology industries. An example is described in the "Gamma project", in which the pharmaceutical company Merck had signed an agreement with Biogen Inc. to develop and bring to the market an asthma drug (Nichols 1994; Bowman and Moskowitz 2001). The licensee (e.g. a large pharmaceutical firm) pays to the licensor (e.g. a biotech startup) an upfront fee, followed by milestone payments, which are conditioned on specific stages reached by the licensor in the development of the technology. Once the technology is developed, the licensee pays for a fee as a percentage of the sales realized thanks to the technology.

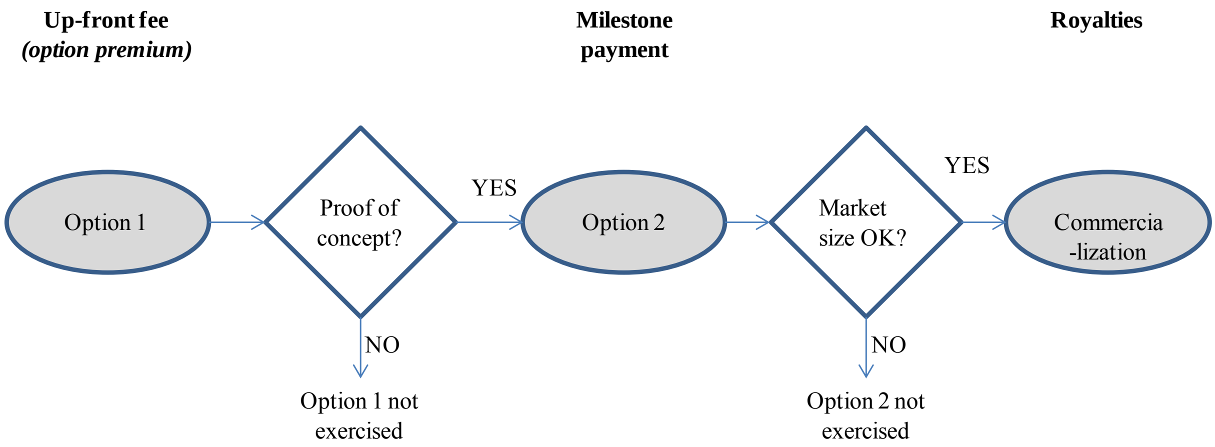
From the licensee's point of view, this type of licensing agreement can be analyzed as an option. The underlying asset of this option corresponds to the present value of the cash-flows S generated by the selling of the new product using the licensed technology. The exercise price corresponds to the investment (e.g. residual R&D costs, production facilities, marketing costs, distribution network) that is necessary to launch the new product.
Exercising the option means introducing the new drug on the market. The time to expiration of the option correspond to the timeframe during which the product can be launched before a competitive product may get clearly established (American type option). For example, in Merck's "Gamma project", it was estimated that the market introduction could take place in year 2, 3 or 4 (after the signature of the licensing agreement).

During this period, the technical and commercial uncertainty gets progressively reduced: As the technology is not developed yet when the licensing contract is signed, the final markets that can be addressed through the licensed technology are not well defined, and the value of potential cash-flows derived from exploiting the technology is particularly uncertain. For example, if a pharmaceutical firm purchases a license for a new compound, not only is the effectiveness of the compound uncertain until clinical tests have been completed, but other indications may arise, opening new potential markets for the compound. Thus, Pfizer's blockbuster "Viagra" is actually a by-product from a compound which was initially developed against hypertension (Chesbrough 2004). Similarly, Bode-Greuel and Greuel (2005) indicate that the uncertainty of sales forecasts decreases along the drug development process, as more information becomes available about the properties of the drug candidate in comparison to existing and future competitors.

When the uncertainty is reduced, the licensee can assess whether the expected cash-flows generated by the commercialization of the new product are higher than the investment cost that has to be incurred for the market introduction. This decision, which is the most expensive phase, will be made only in that case.
We can therefore consider that the licensing agreement is an option. The deal is acceptable for the licensee only if the option value is greater than the option premium. In Merck's case, the option premium corresponded to the sum of up-front and milestones license payments ($2m) as well as the development costs ($0.8m).

Technically, this option can be valued with more or less sophisticated models. Merck simplified the problem by considering the license as a simple option, and valued it with the standard "Black-Scholes" model (Bowman and Moskowitz 2001). More sophisticated models can frame the problem as a *compound* option (see Exhibit 1), i.e. an option on an option: the initial upfront-fee is an option to enter into the pre-clinical phase, which itself creates the option to go down further the pharmaceutical R&D chain.

Exhibit 1: Analyzing a technology license as a compound option



If option 1 is exercised, it creates a second option ("option 2"). Cash-flows are generated only in the case where option 2 is exercised.

To simplify the mathematics, the investment may be analyzed in two phases: the first phase is reached when the proof of concept is established, and the second phase when the new product is commercialized. In this case, the license can be valued with Geske Model, as is proposed in Perlitz et al (1999). Alternatively, Cassimon et al (2011) have developed a more realistic model, in which *n*-phases of R&D development can be taken into consideration in the real options valuation model.

The decision to license-in as an option to grow

Another possible type of real option within in a licensing agreement is the "option to grow". It may arise if the licensed technology is subject to future developments, which create potential commercial opportunities. This may be the case when the licensing agreement explicitly foresees future developments of the technology by the licensor (Caves, Crookell et al. 1983). Alternatively, the licensee himself may later on improve the technology and / or find further new applications for the technology, and commercialize them in new markets.
The licensee will exercise the growth option, i.e. enter these new markets, if it turns out that the cash-flows derived from selling products on these markets have a greater present value than the investment required for the product launch (e.g. building of production facilities, commercial and marketing sunk costs, etc.).
When the licensing agreement offers potential opportunities in future markets, the license may therefore be valued as an expanded NPV, which is the sum of (i) the NPV generated by selling the existing product in the current market of the licensee and of (ii) a growth option value.

Contractual options contained in technology licensing agreements

Technology license agreements usually contain many specific terms and conditions. For example, Anand and Khanna (2000) indicate that at least 37% of the contracts they studied involve some form of exclusive rights. The typical clauses of a license contract include: product, geographic or time restrictions; grant-back provisions (rights for the licensor to use improvements made by the licensee), restrictions on passing on the technology to other parties, minimal acceptability of quality standards, ownership by the licensee of technology improvements, requirements for the licensee to meet specific growth objectives, etc. (Anand and Khanna 2000; Amram 2005). The survey conducted by the Licensing Executives Society (LES) confirms the high frequency of dealmaking provisions. For example, field-of-use restrictions are very frequent (about 75%), as well as time and geographic restrictions (both about 50%) and exclusivity (about 60%) (Razgaitis 2004).

Some of these provisions may be analyzed as *contractual options* (see *section I*). For example, the parties may introduce a renegotiation clause on royalties, which guarantees the licensee that the share of the benefit he will pay to the licensor will not exceed the threshold defined during the negotiation. The price to be paid for this option granted to the licensee is that the parameters used in the initial negotiation will be slightly more favorable to the licensor (Salauze 2011). Empirical studies have shown that renegotiation provisions are very frequent. In the survey conducted by Bessy and Brousseau (1998), 63% of the licensing agreements contain renegotiation provisions, which can be applied on royalties, on the object of the TLA, on the exclusivity conditions or correspond to a "hardship" clause.

II.2. BENEFITS OF THE REAL OPTIONS APPROACH

Reducing the transaction costs of technology licensing agreements

If real options can help valuating licenses, they may contribute to foster the development of the technology market, which currently presents a strong growth potential: according to a survey conducted in 1998 by the technology transfer firm BTG International, 67% of the US companies interviewed say they own technology assets that they fail to exploit (Rivette and Kline 2000).

The literature has clearly pointed out the large transaction costs that exist on the market for technology licensing. The well-known information asymmetry about quality (Arrow's paradox) entails high transaction costs in every market transfer of information. In the case of the market for technology, the problem is compounded by the high level of uncertainty, in particular the uncertainty regarding the economic value of the invention (Bessy and Brousseau 1998).
The empirical study conducted by Gamberdella et al (2007) confirms that there are important transaction costs on the market for IP licensing. The authors demonstrate that there is a wide gap between the willingness to license out and the effective closing of a licensing deal, as 11% of the sample patents are licensed, yet for another 7% the owner was willing to patent but did not.

The difficulty to come up to an agreement on the terms of a technology licensing agreement is also highlighted by the survey conducted by the Licensing Executives Society (Razgaitis 2004). On average, once negotiations have started, a successful agreement is reached only in 57% of the cases. The main reason of failure cited by respondents (in the case of in-licensing negotiations) is the inability to arrive at mutually acceptable financial terms (32% of cases), followed by the inability to arrive at mutually acceptable non-financial terms (17% of the cases). Other reasons include inconsistency in the positions of internal stakeholders (11% of the cases) and the delay in reaching agreement (11%).
Similarly, Arora et al (2001) indicate that difficulty in valuation can significantly increase transaction costs, and the model developed by Arora and Fosfuri (2003) confirms that lower transaction costs lead to more licensing."

Therefore, it would clearly contribute to the development of the technology market if a tool like real options could enable managers to better estimate the value of licenses. Taking into account the value of real options present in licensing agreements would help managers in estimating the "intrinsic value" of the license in spite of the high level of uncertainty. In addition, the valuation of deal-making provisions that can be analyzed as contractual options would contribute to ease the negotiations of non-financial terms.
Similarly, the invention by Black & Scholes (1973) of their famous formula to value a European call option had largely contributed to the explosion of the market for financial derivatives. As suggested by Aroral et al (2001), we could in addition expect a self-sustaining process, as the increase of the market would in turn ease the valuation of technology licenses. This is due to the fact that the market provides an objective measure of the value, if the asset has been traded in the past or if similar assets have been traded. This remains true even if technology is highly differentiated and its price reflects idiosyncratic factors.

A more appropriate valuation of patent licenses?

Researches in the pharmaceutical industry demonstrate that the real options framework lead to more appropriate valuation of patent licenses than traditional valuation tools. In the case of Merck, the NPV analysis did not recommend Merck to sign the licensing agreement (in the sensitivity analysis, the project NPV was in almost all cases negative). In contrast, the real options approach took into account the value of flexibility, and produced a "go" recommendation in almost all of the cases in the sensitivity analysis.
Similarly, Hoe and Diltz (2012) show that real options tend to provide better recommendations that the NPV calculation, as ignoring the managerial flexibility in valuation may cause the licensee to either forego an acceptable deal or enter into an inferior deal.
Even firms using more sophisticated decision tools like Decision Tree Analysis (DTA) do not necessarily come up with satisfactory pricing. For example, Cassimon *et al* (2011) cite the case of a pharmaceutical firm which purchased a license to a biotech company, although it was not recommended by DTA. By contrast, the option model developed by the researchers showed that it was worth investing in the license.

The question is whether the real options approach developed in the pharmaceutical industry can be replicated in other settings.

Clearly, the case of *ex-ante* licensing agreements fits very well to the real options logic, because the level of uncertainty is high, and there are usually several formalized decision points between the initial payment of the upfront fee and the potential commercialization of the new product. In addition, the initial financial commitment is limited, and by the time the largest investment – i.e. the market entry of the new product – has to be decided, the level of technical, commercial and competitive uncertainty has been reduced.

By contrast, *ex-post* licensing agreements will not necessarily entail the creation of a real option.
In case of *ex-post* licensing agreements, the real options framework may be useful when the patent under negotiation corresponds to early-stage technology. At the stage of the negotiation, the definition of what the product will consist may not be not fully clarified, e.g. for patents covering more a technology than a well-defined product, or for technologies or products which are still very far from the marketing stage (Salauze 2011).
For example, Richards and Rickard (2013) develop a real option model to evaluate the property rights to the "Pink Lady", a new apple variety. The real option logic is working well, because there is uncertainty on the success of a new plant variety, which can be reduced through learning and experience before committing the investment of planting trees. The authors contend that this model would enable a better evaluation of licenses, and therefore contribute to a greater liquidity of the market for licenses.

At the other end of the continuum, there are cases in which the level of uncertainty of the cash-flows generated by the license is low, and does not justify the use of a real options model. For example, Van Triest and Vis (2007) develop an model in which the patent on cost-reducing process improvements is valued from the viewpoint of the patent holding firm. The model incorporates cash-flows derived from licensing and from the competitive advantage enabled by the patent. As there is no uncertainty on the cash-flows enabled by the technology, it is not necessary to use an option-based model.

Another limit of the real options framework appears in the context of industries relying on cumulative technologies. Whereas in the pharmaceutical industry there is usually a clear relationship between a patent and the drug covered by this patent, things become much more complicated in "multi-invention" contexts. In this type of industries, like electronics, the development of new products requires the combination of ever-larger numbers of invention, which are spread among a number of organizations (Somaya, Teece et al. 2012). In this case, performing a real options analysis would entail a portfolio approach, in which the option value from commercializing a new product should be compared against the value of all (potential) licensing agreements necessary to obtain the rights to the inventions from the different sources. There is the risk that this type of analysis becomes quickly very complex, and the solution may better be solved with cross-licensing agreements (see *section IV*).

Implementation issues

Even in the pharmaceutical industry, where real options seem to be the most promising, it appears that the real options framework is not frequently used (Hartmann and Hassan 2006). Indeed, putting into practice a complex tool like real options represents a real challenge. Ryan and Ryan (2002) survey reveals that generally speaking the complexity of management tools substantially reduces their usage, and real options, which are amongst the most complex decision making tools, are no exception to that. The study conducted by Hartmann and Hassan (2006) within 28 pharmaceutical groups confirms that the main reason why few R&D managers use real options is the complexity of this approach.

Amram (2005) recognizes that in spite of the potential of real options, their use is deemed too complex because there is no standard license contract. Indeed, closed-form solutions (like the Black and Scholes or Geske formulae, or the model developed by Cassimon et al) have a very limited probability of being used by firms, because of their mathematical opacity, and the difficulty of tailoring the model to the specificities of the investment project under study (Lander and Pinches 1998).

One particular risk of mathematically complex models is to use them in an inappropriate manner. For example, Bowman and Moskowitz (2001) explain that Merck omitted to take into account the dividends in their real option model derived from Black-and-Scholes formula. In the valuation of real options, the "dividends" correspond to the loss in project value when the decision is postponed (Lander 2000). They show that this error lead to believe that it was optimal to postpone the exercise decision as much as possible. In fact, postponing the investment was reducing the project value, because it was reducing the time length during which the firm was protected by the patent.

However, numerical methods like option valuation models based on Monte Carlo Simulations hold a great promise, because they are both intuitive and flexible. In addition, it should be kept in mind that, as opposed to financial options, the objective of real options is not to come up with a precise number – which would be wrong anyway since the input parameters are not known with any precision. What matters most is the reasoning by which managers can understand why traditional valuation methods do not capture the value that is intuitively perceived by managers. For example, although the Black and Scholes formula was not used by Merck in an appropriate manner, it was still beneficial for the firm to use the RO approach because it enabled managers to understand why traditional valuation methods were not producing an appropriate recommendation (Bowman and Moskowitz 2001).

III. THE DECISION TO LICENSE OUT

III.1. REVERSING THE PERSPECTIVE

One might think that the decision to license out can be analyzed in a symmetrical way compared to the decision to license in. It is true that the real option model that we have described above to evaluate a license has been analyzed from the licensee's perspective, but can also be used by the licensor as a support for the negotiations. However, the strategic dilemmas raised by licensing are not necessarily the same for the two parties, and "*licensing decisions need consideration from licensee and licensor viewpoints*" (Pitkethly 2001, p.425).

The differences in the two viewpoints are suggested by the results of the LES survey (see summary in Table 1 below). We have mentioned above that the main reason for failure in the negotiations from the potential licensee viewpoint was the inability to reach a mutual agreement on financial terms. However, when the same question is asked to the potential licensor, it turns out that the problem is not necessarily only about "the money". The disagreement on the license price has a lower citation rate (26%) than in the case of in-licensing negotiations (32%). By contrast, disagreement on non-financial terms seems to have an impact almost as important as disagreement on financial terms. The fact that financial terms are not the only determinants in the success of licensing negotiations reflects the diversity of firms' motivations for licensing out.

Table 1: Main reasons explaining the failure of licensing negotiations

(% of times the reason occurred)	**In-licensing negotiations**	**Out-licensing negotiations**
Inability to arrive at mutually acceptable financial terms	32%	26%
Inability to arrive at mutually acceptable non financial terms	17%	23%
Delay in reaching agreement	11%	20%
Inconsistent positions of internal stakeholders	15%	17%

Source: Razgaitis, 2004, p.144

Arora *et al* (2001) explore the strategic implications of the development of market for technology licensing. They develop a typology of licensing agreements along two dimensions: the first one is dealing with the relative positioning of the licensor and the licensee: does the agreement involve potential or current competitors, or are we in the case of a vertical market or non-rival transaction? The second dimension is dealing with the stage of technology that is licensed: is it an existing or a future technology? We will see in this section that the real options potential created by a licensing agreement depends to a large extent on the position of the licensing deal on this matrix[1].

In addition, in the case of "horizontal" licensing transactions, when the innovator has stakes in the final market, Lichtenthaler (2008) has found out that there may be very different motives for licensing out. Depending on the "dominant" strategic motive, the RO analysis will be very different.

In Table 2, we summarize in which case the licensing agreement leads to the creation of a real option, and in which case it does not.

[1] Please note that the two types of transactions are in fact not necessarily exclusive. A firm may license a technology to rivals as well as to non-rivals (see example of Procter & Gamble in Kline 2003). For the sake of simplicity, we will keep the two cases separate

Table 2: Synoptic view of real options created by licensing-out transactions

Motivation for licensing out	Options logic	References	Context / examples	Main risk
Vertical market / licensing to non-rivals				
Developed technology	None	Lichtenthaler 2008	Residual technology	No major strategic issue
		van Triest & Vis 2007	Licensor does not have complementary assets (e.g. semi-conductors industry)	Poor commercial performance of the licensee
Early-stage technology	Receive a share of the option to develop and commercialize a technology	*See section II: Nichols 1992, Richards and Rickard 2013*	Licensor (e.g. biotech start-up, university) does not have complementary assets	Licensee abandons the technology
Horizontal market / licensing to actual or potential rivals				
Monetary motives				
Developed technology	None	Fosfuri 2006, Kline 2003	"Keep-and-sell" (e.g. chemical industry)	Rent-dissipation
Early-stage / future technology	Sell the option to grow	Kline 2003, Rigby & Zook, 2002	Sun licensing Java to IBM	Selling the « crown jewels » and deteriorating firm's long term position
Prospective technology	Abandon the option to wait	Teece, 1986; Chesbrough, 2006; Rigby & Zook, 2002	Xerox licensing GUI and computer mouse	Underestimating the upside potential
Strategic motives				
Product oriented				
Foreign market entry	Option to transform into JV / wholly owned subsidiary	Jiang et al, 2008; Simonet 2002		Choose the wrong partner
Setting an industry standard	None (situation of a "bet", not an option)	Conner 1995	High network externalities; Dominant design not yet emerged	Failure in setting the standard
Technology oriented				
Freedom to operate and access to knowledge	Swap option (cross-licensing)	*See section IV. The decision to cross-license*	Cumulative technology	Unbalanced bargaining power
Mixed strategic motives				
Learning effect	Purchase the "option to learn" (contractual option)	Caves et al, 1983; Bessy and Brousseau, 1998	Licensing agreement with a "grant back" clause	-
Enhance firm's reputation and strengthen firm's network	None (path-dependence logic)	Lichtenthaler 2008	Fast paced, cumulative technologies	Opportunity cost (sell the license below its value)

III.2. CASE OF LICENSING TO NON-RIVALS

Main categories of licensing agreements to non-rivals

Licensing agreements involving non-rivals can typically arise in three types of situations.
First, a firm may develop a technology that does not prove useful to its core market. Rather than keeping the technology unused, the trend towards open innovation has encouraged an increasing number of firms to seek out potential users of the technology in other industries, and to license it to them.
Second, the licensor may be a non-practicing entity (NPE), typically a university or a public organization dedicated to fundamental research.
Third, licensing transactions may take place vertically between actors who are positioned on different stages of the value chain. Some firms adopt a business model in which they do not invest in downstream complementary assets needed for the exploitation of their innovations. These firms rely on the selling of their intellectual property to organizations operating in the final market. Examples can be found in the semiconductor industry, in which "fabless" organizations like Rambus, ARM or Qualcomm live from licensing their IP to chip manufacturers (Teece 2006; Somaya, Teece et al. 2012). Another example of fabless organizations are Specialized Engineering Firms (SEF) in the chemical industry (Arora 1997).

Real options created by licensing agreements to non-rivals

When the licensing agreements involve non rivals (whether existing or potential), the main motivation of the licensor is to generate revenues. In the case of a residual technology, the goal pursued by the licensor is the optimization of her I.P. portfolio, and there is no major strategic issue raised by the licensing agreement (Lichtenthaler 2008). In the case of NPEs, the goal of out-licensing is simply to find another source of funding for cash-strapped universities. As for licensors who do not possess complementary assets, the revenues derived from out-licensing constitute the core of their business.

Therefore, licensing transactions involving non-rivals do not pursue any strategic goals beyond monetary motives that could be analyzed from a real options perspective by the licensor. Rather, real options may only be useful for the licensor to understand the licensee's point of view during the contract negotiations. This will be the case when the license acquired by the licensee may be compared to an option because of the high level of uncertainty, in particular in the case of early-stage technology (*see Section II*). In contrast, in the case of an established technology, e.g. for licensing agreements in the semi-conductors industry, there is little uncertainty on the commercial value of the technology, and there is no benefit in conducting a real options analysis.

When the licensing agreement is involving non-rivals, and is providing the licensee with an option to develop and commercialize (an early-staged technology), the interests of the licensor and of the licensee are aligned. In other words, the more successful the product using the new technology will be, the better for both partners.
Where real options reasoning can play a role in the negotiations is about the sharing of the profits between the two parties. It is true that in case of a high uncertainty on the commercial success of the innovation, the licensee should be rewarded because he is supporting both the investment cost to develop and commercialize the innovation, and the risk on the commercial success. On the other hand,

we have seen in *section II* that the licensee benefits from a certain flexibility in the commitment of these investments. Using a real options thinking, the licensor may argue that this flexibility has value, and may therefore justify a higher royalty than the one envisaged by the licensee.

Benefits of the real options framework to support governance decisions regarding the exploitation of an invention

Now the question arises whether it is advisable to rely exclusively on out-licensing, and to not invest in complementary assets in the first place.

An organization can exploit an invention through three main governance modes: internal exploitation (hierarchy), through an alliance (hybrid form) or by licensing-out the technology (market). In the literature, the choice of the optimal governance mode to exploit an innovation is studied from three main complementary perspectives: Transaction Costs Economics (TCE), Innovation theory and Economic theory. According to TCE, the market solution, i.e. selling out the license, is best suited when transaction costs are low. The major sources of transaction costs in technology transfers are (i) incomplete contracts which leave the risk of opportunistic behavior; (ii) transaction-specific investments that may lead to "lock-in" problems; and (iii) leakage of valuable information to competitors (Fosfuri 2006).

The Profiting from Innovation (PFI) framework developed by Teece (1986) builds on TCE, but also takes into account replicability issues, which depend of the nature of complementary assets. If complementary assets are generic, the inventor may better choose the "contract" solution, whereas if they are specialized, the inventor may either choose the "integrate" solution, or form a strategic alliance to access complementary assets.

Economic theory points out that the licensing-only solution presents the advantage of avoiding conflicts of interest, of necessitating less capital to be employed and of staying away from the final market, which is usually very competitive. On the other hand, the exploitation of complementary assets enables firms to generate higher margins. In addition, staying out of the final market exposes the firm to the risk of becoming too dependent on the licensee: in case of a poor commercial performance of the licensee, the firm will incur a durable decrease of its royalties, which are its main source of revenues (Arora, Fosfuri et al. 2001).

The real options framework could be used in complement to these theories, because it sheds light on the value of flexibility that can be achieved through the creation of an alliance. Indeed, when a firm is forming a joint-venture, it acquires both (i) the option to purchase later the rest of the capital to its partner if it wishes to grow in the market on which the joint-venture operates and (ii) the option to resell its stake to its partner if, on the contrary, it prefers to refocus its activities on its core business (Kogut 1991). All else being equal, the higher the uncertainty, the higher is the probability that firms will choose a flexible governance mode like alliances. As a consequence, scholars have used the RO theory to understand why firms form alliances or joint-ventures, compared to the alternative of acquisition (Folta and Miller 2002) and/or of divestiture (Villalonga and McGahan 2005).

The same line of reasoning could be used to analyze governance decisions regarding the exploitation of an invention. Indeed, the decision to invest in complementary assets appears quite irreversible, given the amount of the investment. Similarly, firms that have not invested early on in complementary assets will probably face a lock-out effect and will lack the flexibility to enter later on the final market. In contrast, the intermediate solution of forming a joint-venture with a firm that already possesses complementary assets can be viewed as an option, which provides the technology holder with the

possibility later on to transform the joint-venture into a wholly-owned subsidiary, or in the contrary to sell its stake to its partner.
Consequently, it would be very interesting in the future to investigate whether the flexibility offered by this option plays an important role in the governance decisions of firms regarding the exploitation of their inventions.

III.3. CASE OF LICENSING TO CURRENT OR POTENTIAL RIVALS

Motivations for out-licensing to rivals

We now consider the case where a firm is involved in the product market, as opposed to relying exclusively on licensing revenues. Two questions are raised in this context: should the firm license out its technology to current or potential competitors, and if yes, at what price?

Lichtenthaler and Ernst (2007) have conducted a survey of medium-sized and large firms whose main business is internal technology exploitation in three industries: automotive / machinery; chemicals / pharmaceuticals; electronics / semiconductors. They found out that generating royalty revenues arrives only at the seventh position in the reasons for licensing, out of a total of eleven possible motivations. Interestingly, all motivations play a role in the three studied industries, and the relative ranking of the motivations is relatively similar across the three industries, even if they obtain different scores in absolute values.
The authors distinguish between monetary motivations and strategic motivations for licensing. Strategic drivers may be (1) product oriented or (2) technology oriented or (3) mixed. Product oriented licensing strategies are notably the case of foreign market entry and the establishment of industry standards. Technology oriented licensing strategies correspond to the objective of securing freedom to operate and of gaining access to external knowledge. Mixed product and technology oriented licensing strategies correspond to the objective of learning and of enhancing the firm's reputation and strengthening the firm's network.

Each of these motivations raises specific strategic issues. We explore below in which cases the decision to license out may lead to the creation of a real option, except for the "*freedom to operate*" and "*access to knowledge*" motivations, which correspond to the case of cross-licensing, and are discussed in *section IV*.

Monetary motives

A technology holder may contemplate licensing out its technology for monetary motives in two types of situations. First, the innovating firm may use the technology for its own products, but wish to license it out in order to extract more value from its IP. Second, the firm may have developed a particularly innovative technology, for which it does not see any use in its product portfolio. The firm may consider licensing-out this technology to other players in the industry, in order to avoid the opportunity cost of keeping the technology unused. We discuss each of the two cases in turn.

Traditional wisdom holds that when a firm has superior access to complementary assets compared to its rivals, it should better commercialize the innovation itself (e.g. Teece 1986). Therefore, it appears quite as a puzzle to academics that some innovators make the decision to share the rent with

competitors. Under certain conditions, this decision may make sense, as shown by Fosfuri (2006) in the chemical industry when there are multiple technology holders. In any case, firms contemplating licensing out their technology to potential competitors should perform a trade-off between the "revenue effect" from licensing payments, and the "rent dissipation effect", which corresponds to the erosion of profits that the licensor experiences in his own business due to an additional competitor.
When the technology involved is already in use and quite mature, the rent-dissipation effect is quite predictable. An example is the case of Xerox, which invented the laser printer in 1969 and subsequently registered record profits. Following an anti-trust suit with the Federal Trade Commission, the Xerox consent decree resulted in the forced licensing of the company's entire patent portfolio, mainly to Japanese competitors. Within four years of the consent decree, Xerox's share of the U.S. copier market dropped from nearly 100% to less than 14%. This rent-dissipation effect experienced by Xerox was quite predictable, and in the case of an established technology it is not necessary to resort to real options to analyze it.

The analysis differs when we are dealing with a technology agreement that also involves a future technology, e.g. Sun Microsystems licensing out Java language to IBM (Arora, Fosfuri et al. 2001). In this case, there is considerable uncertainty on the economic value of the future developments of the technology, and the licensor is in the position of an option's seller.
We have indicated in *section II* that when the licensing agreement involves a future technology, or a technology that is expected to evolve, the licensee acquires an "option to grow". Indeed, beyond the use of the current technology in the scope of the licensing agreement, the licensee may assimilate the technology and invent further developments to exploit the technology in other markets.

On the other side of the mirror, the licensor plays the role of the bank selling a financial option (*see Figure 1 in section I*): the maximum amount of money that the licensor can earn is limited to the licensing fee, whereas the losses incurred by the selling of the license can be very high if the firm sells "the crown jewels".
For example, Hill et al (1990) report the case of RCA, which licensed its color TV technology to Japanese firms for exclusive exploitation in Japan. However, the Japanese companies quickly assimilated the technology, and used it to compete directly with RCA in the U.S. market. Indeed, the authors indicate that patents can be "invented around", and are difficult to enforce in the international arena. Eventually, Japanese firms captured a bigger share of the U.S. market than the RCA brand.
As a consequence, calculating the value of selling the "option to grow" to the licensee may be particularly useful for the licensor trying to make a trade-off between the revenue effect and the rent dissipation effect. This type of analysis should be conducted at firm level, since a technology to external partners may be positive for certain business units, and prejudicial to other business units (Kline 2003).

Lets us now consider the case of an emerging technology, for which the inventor does not see any use for its own product portfolio. A puzzle that researchers face is why firms keep some technologies unused, instead of out-licensing them. For example, when Procter and Gamble surveyed all of the patents it owned, it determined that about 10% of them were in active use in at least one P&G business, and that many of the remaining 90% of patents had no business value of any kind to P&G (Sakkab 2002). Among several reasons, "the option to wait" can contribute to explain this phenomenon.
A firm holds an "option to wait" or "option to defer" in the case where it has the possibility to postpone the investment decision. Instead of investing immediately in a project whose value is either uncertain or only marginally positive, a firm may better, under certain circumstances, postpone the

decision to invest in a project, until it receives more information on the project value or until the economic context is more favorable. For example, a petroleum firm may acquire the license to exploit an oil field, but keep it undeveloped until the oil prices are higher. Even if the exploitation of the oil field is NPV positive when oil prices are low, the value of the “option to wait” may be higher. In this case, since the opportunity cost represented by the option to wait is higher than the NPV generated by the immediate exploitation of the oil field, it is optimal to defer the development of the oil field.
Similarly, Teece (1986) indicates that when the dominant design has not emerged yet, it is more advisable for a firm to keep the technology undeveloped, rather than to out-license it or to exploit it internally. This option to wait can be more or less formalized within organizations: in some cases, internal business units have some defined interval of time during which they can use the technology; afterwards, the technology can be sold to external firms (Kline 2003; Chesbrough 2006). In other words, the business units prefer to keep the option to wait alive, rather than “losing” the technology to an external organization.
By contrast, the case of Xerox giving away almost for free its invention of the computer mouse and graphical user interface (GUI) is a good example of an inventor who has not perceived the very high value of the option to wait in a context of high volatility.

Strategic motives

Product oriented strategic motives include foreign market entry and setting up a standard. In the later case, the firm may compromise for a low royalty rate, in the hope of transforming a proprietary technology into an industry standard. This strategy may put the firm in the enviable position of essentially taxing its competitors for their help in building the industry. Even more importantly, having competitors using its own technology enables a firm to control the direction of R&D for the whole industry (Kline 2003). However, this type of licensing transaction cannot be analyzed as a real option, since the innovating firm does not have any strategic flexibility if it fails to impose its technology as an industry standard. In this case, we are in a “bet” logic, rather than in an optional logic.
The total value of the licensing agreement is therefore the sum of the royalty payments and of the long-term benefits of establishing an industry standard, but those cannot be estimated by an option calculation.

In contrast, there may be an option value attached to a licensing agreement as a mean to enter a foreign market. Indeed, a licensing agreement may be viewed as a first step to enter a foreign market. In case of commercial success and good relationships with the licensee, a simple licensing agreement may subsequently evolve into a joint-venture, and even an acquisition. For example, the Swedish laboratory Astra AB signed in 1982 a licensing agreement with Merck & Co in order to commercialize all its new medicines in the USA. Due to the success of Astra products with American consumers, the two partners later formed an autonomous joint firm, Astra Merck Inc (Simonet 2002). Using the analogy of the licensing agreement as an option to commit to other investment modes, Jiang et al (2008) analyze the impact of the level of uncertainty and of the threat of preemption by competitors on the duration of licensing agreements. Indeed, options theory has established that the volatility, the dividend rate and the time left until the option expires are key determinants of an option value. In the case of licensing in a foreign market, the volatility corresponds to the level of uncertainty, the dividend rate to the probability of competitive preemption and the time left to expiration to the length of the licensing agreement.
In case of foreign market entry, the value of the licensing agreement is therefore the sum of the royalty payments and of the option value to transform the agreement into a JV or a wholly owned subsidiary.

One of the strategic motivations for licensing out may be learning. Learning can take place through technology flowback requirements, which require the licensee to share with the licensor any advances or improvement in the subject technology, usually free of charge. This “grant back” clause could be found in 43% of the licensing agreements surveyed by Caves et al (1983), and in 65% of the agreements in the survey conducted by Bessy and Brousseau (1998). Caves and colleagues found that technology flowback restrictions are particularly frequent in licensing agreements involving current and future technology (60% of the contracts contain this clause), as opposed to licensing agreements involving current technology only (14% of contracts contain this clause). This sort of provision is clearly a way of dealing with the uncertainty regarding the technology’s developments, and provides the licensor with a hedge for strengthening its competitive status. Since the licensor has no obligation to use the technology improvements, this clause can be interpreted as an option. In this context, the value of the licensing agreement is the sum of the royalty payments and of the option value of the grant back clause. Caves and colleagues could in fact not confirm that the presence of technology flowback restrictions entails a reduction of effective royalty rate. However, they established that technology flowback restrictions tend to be compensated by awarding benefits, such as the exclusivity in some specified market.

Lastly, one possible strategic motivation for out-licensing is to enhance the firm’s reputation and strengthen firm’s network. A large interorganizational network and a strong reputation as a technology provider will facilitate both the acquisition of external knowledge, e.g. through cross-licensing, and the search of potential licenses. The effect functions in a self-reinforcing cycle, but does not offer the flexibility that is inherent to the real options logic.
In this case, the total value of the licensing agreement is therefore the sum of the royalty payments and of the long-term benefits of strengthening the firm’s reputation and network, but those cannot be estimated by an option calculation.

Benefits of the real options framework

Today, there is an apparent contradiction between two trends. On the one hand, firms acknowledge that generating revenues is only one possible motivation for licensing out, and in most cases not the main one. On the other hand, there seems to be an overemphasis of firms on monetary issues, as suggested by a quote from Lichtenhaler’s survey: “*Despite strategic issues, we focus very much on revenues in managing technology licensing*” (Lichtenthaler 2008, p.79).
This situation is probably due to the fact that IP managers have difficulties in evaluating the strategic implications of the decision to license out. It seems that firms currently rely on traditional financial tools like the net present value in order to make a trade-off between the advantages and the drawbacks of licensing out. For example at Motorola *“Managers now have to come to us with a business plan that quantifies the dollars-and-cents, net present value of licensing versus not licensing a technology. We compare the exclusivity value of keeping a core technology in-house against the economic value of licensing it to other companies.”(Kline 2003 p.92).*
However, we have seen earlier that DCF-based methods are not necessarily adapted to support decisions in a context of a high uncertainty. In contrast, when the medium to long term implications of out-licensing can be analyzed as options, the real options framework can be very useful to guide managers in their licensing decisions. In this case, the total value of the licensing agreement is the sum of the NPV from licenses payments and of the real options value created by the licensing agreement for the licensor. Under these circumstances, such reasoning could just justify why a firm may accept to

enter a licensing deal, even if the licensing revenues do not cover the firm's expenses for the particular technology transaction.
Alternatively, the total value of the licensing agreement is equal to the NPV from licenses payments minus the value of real options "sold" by the licensor to the licensee (case of the "option to grow") or minus the value of the real option destroyed by the licensing decision (case of the "option to wait"). This would explain why a firm foregoes a licensing agreement despite attractive potential licensing revenues.

To summarize, we may say that there are three types of situations: (1) the real options framework is not applicable; (2) real options are applicable, in a quantitative way; (3) real options are applicable, but rather in a qualitative way.
When the main motivation of licensing out is establishing an industry standard, enhancing the firm's technological reputation or strengthening the firm's technological network, the real options logic does not apply.
For other strategic motives of licensing, such as "foreign market entry" and "learning", we have seen that the decision can be analyzed with an option's logic. The potential pay-offs from exercising the option to transform a licensing agreement into a joint-venture can be reasonably estimated. Similarly, it is possible to make some financial projections on the potential improved or preserved margin and on additional sales that can be achieved if the "grant back" clause is exercised by the licensor. Therefore, it should be possible to evaluate the "option to transform into a JV" and the "option to learn". Taking into account the value of these options (when applicable) would thus enable the licensor to negotiate a fairer licensing agreement with the licensee.

In contrast, the two potential options that we have identified in licensing transactions pursuing monetary motives may rather be analyzed in a qualitative way.
When there is the risk that the licensee assimilates and develops the technology, the licensor should take into account in his decision the value lost from giving the licensee the "option to grow". However, we have here an "exotic option" whose pay-offs are not symmetric between the buyer (licensee) and the seller (licensor) of the option. Indeed, from the licensee point of view, the option pay-off is equal to the difference between the revenues generated by the selling of the new product (e.g. from selling color TV in the US for Japanese firms) and the investment cost necessary to launch the new product (e.g. marketing expenses and possibly the building of production facilities to penetrate the US color TV market). In the case of a standard financial option, the pay-off for the option seller is the symmetric to the pay-off received by the option buyer (*see Figure 1 in section I*). In the case of a license, the loss that will be incurred by the licensor if the licensee exercises the option is different from the pay-off received by the licensee: it is equal to the loss of market share and / or margin incurred by the licensor – which is not necessarily the same as the increase in revenue gained by the licensee.
Even if the option is difficult to value, real options thinking may play an important role in guiding the management in their decision to license out their technology. As noted by Fosfuri (2006, p.1157), managers do not necessarily have the visibility on the whole picture to make the trade-off between licensing revenues and rent dissipation and "it becomes crucial to educate business managers about the net value added from sale of products vs. that from licensing". In the decision to license-out, one may expect strong divergence between, on the one hand IP managers who are eager to optimize the management of the firm's IP portfolio, and on the other hand operations people who are scared of losing out to competition. In this regard, the main benefit of the RO approach here is to encapsulate into one framework both sides of the equation. Hence, real options could be used as an internal communication tool in order to ease the decision to out-license or not.

Similarly, in the "option to wait", we are dealing with a prospective technology whose potential applications are by definition very difficult to identify and evaluate. In that case, real options thinking (using very crude hypotheses on potential cash-flows, investment cost and volatility) could essentially give management an order of magnitude for the value of the option to wait, and make them aware of this lost opportunity if the company decides to license out the technology.

IV. THE DECISION TO CROSS-LICENSE

IV.1. BENEFITS AND MECHANISM OF CROSS-LICENSING TRANSACTIONS

The two functions "*Freedom to operate*" and "*Access to knowledge*" are crucial in cross-licensing agreements, as described by Grindley and Teece (1997) or Hall and Ziedonis (2001) in the electronics and semi-conductor industries. Another example is given by Bekkers et al (2002) in the mobile telecommunications industry, where three out of the four dominant network players in GSM (Global System for Mobile communications) based their market power on the ownership of essential IPRs.
Such industries are characterized by rapid technological change and cumulative innovation. For many products, the range of technology is too great for a single firm to develop entire needs internally. As innovations build on each other, there are inevitably overlapping developments and mutually blocking patents (Grindley and Teece, 1997). Through cross-licensing agreements, firms use their patents as "bargaining chips" in negotiating access to other firms' technologies; at the same time, they acquire a "freedom to operate" i.e. the assurance that they can manufacture and sell their products without running the risk of patents infringement lawsuits.

The two partners compare samples of their best patents, which are assessed in their quality and market coverage. Balancing royalty payments are determined according to the relative value of the patent portfolio of each party.
The cross-licensing mechanism enables firms to concentrate their R&D efforts on the areas where they have the greatest comparative advantage to develop new patents. The key for firms is to create high quality patents in technical fields that their competitors need.

IV.2. THE REAL OPTION IN THE DECISION TO CROSS-LICENSE

Two firms A and B entering into a cross-licensing agreement can be analyzed as two parties swapping options.
Firm A acquires from firm B the possibility to use patents developed by firm B. This gives A the right, but not the obligation to operate freely on market segment A. The option's premium "paid" by firm A to firm B does not take the form of a licensing fee; instead, the option's premium correspond to the right given by Firm A to Firm B to use Firm A's patent and benefit from a freedom to operate on market segment B.

Anand and Khanna's (2000) empirical study reveals that about 13% of deals are cross-licensing agreements. The occurrence of cross-licensing deals is particularly high in Electronics (20%), where most of the deals concern semiconductor technologies.

Cross-licensing negotiations are very complex: the establishment and the valuation of the "proud list" of leading patents on which the negotiations will be held may take one year of effort (Grindley and Teece, 1997). In addition, it is very difficult to assess the value of a single patent, so that in some cases licensing negotiations are conducted using patent *counts* as the unit of currency (Hall and Ziedonis, 2001).
Beyond the formal mechanism that is used to estimate the economic and technological contribution of the patent portfolios of the two firms, it appears that the individual needs of the parties and broader strategic considerations have often a significant impact into the final negotiations of a cross-licensing agreement.
Therefore, a RO approach in which the underlying asset corresponds to the value of the market where the firm acquires the "freedom to operate" might be useful to capture the strategic considerations that motivate the cross-licensing agreement.

Similarly to the contractual options mentioned in *section II*, the RO approach may also be useful to negotiate the specific terms of the cross-licensing agreement. The two main models used are the "capture" and "fixed period" (Grindley and Teece, 1997). The "capture" model gives "survivorship" rights until the patent expire, whereas the "fixed period" model requires full renegotiation of the cross-license after a given period (typically five years). The "fixed period" model can be viewed as an option, since it provides the possibility to adjust for changes in competitive conditions and the value of the technology. The RO approach can therefore contribute to evaluate this strategic flexibility, and hence to ease the design of the licensing contract.

Conclusion

The literature has established that patents can be analyzed as options, but there is only scattered and limited analysis on the impact of this analogy for firms' technology licensing decisions. The objective of this paper was to conduct a systematic analysis of the presence of real options in technology licensing agreements, and on the role of the real options framework to explain firms' licensing practices. The main findings are dealing with (1) the description of real options present (or not) in licensing agreements, (2) the benefits of the real options framework and (3) the limits and conditions of utilization of real options.

First, this paper has shown that there is no "universal use" of the RO approach in technology licensing decisions, as there is a vast array of real options that may arise from licensing agreements. In fact, some licensing decisions cannot be analyzed with a real options lens because not all conditions for the existence of a real option are met. The characteristics of the real options that we have identified notably depend on (i) the type of transaction, which can be vertical or horizontal (ii) the degree of maturity of the technology involved and (iii) the motivation of the firm for entering into a licensing negotiation.

Second, this paper highlighted both managerial and academic benefits of the real options framework. In some cases, e.g. in *ex-ante* licensing agreements, real options may be used as a powerful valuation tool, in order to estimate the intrinsic value of the license, as well as specific contractual provisions. In this sense, real options have an important role to play in easing the negotiations between the two parties, and therefore in contributing to the development of the market for technology licenses, which

is hindered by serious transaction costs. Real options may also guide firms in their governance decisions regarding the exploitation of an invention. Depending on the maturity of the subject technology, and on the motivations of the firm for licensing out, licensing out a technology may lead to create a real option for the licensor (e.g. option to *learn*), or to the contrary to destroy a real option owned by the licensor (e.g. option to *wait*) or to give away an option to the licensee (e.g. option to *grow*). In this context, one benefit of the real options approach is to translate the strategic intuition of managers into a clear decision rule, on whether the firm should license-out, and under which conditions. Depending on the context, real options can thus be used rather as a conceptual framework, or as a quantitative valuation tool. Yet, even in the later case, we believe that what matters most may not necessarily be the final "number" given by the option valuation model, but rather the *reasoning* provided by the RO approach. In this regard, real options may serve not only as a valuation tool, but also as a communication tool. RO may be used both as (i) an external communication tool – if real options are used as a support for licensing negotiations with external parties – and as (ii) an internal communication tool, in order to help the different stakeholders reconcile their diverging interests and incentives.
From an academic perspective, RO theory may be mobilized by scholars as an underlying framework to analyze the optimal governance mode to exploit an innovation or to understand the optimal structure of a licensing agreement (e.g. impact of the length of the contract).

Third, we found out that real options contained in licensing decisions are "exotic", i.e. they do not have the characteristics of standard financial options (numerous contractual provisions; value of the pay-off not necessarily symmetric for the buyer and the seller, etc.). This implies that we need to describe thoroughly the characteristics of the real option(s) contained in the licensing decision under study. Moreover, even if the real option does not need to be upraised with precision, we need to develop user-friendly and flexible option models, which can take into account the specificities of the option. If we do not stick to this strict discipline when performing RO analysis, there is the risk that the RO approach leads to evident conclusions and are used by managers to justify the decisions they want to get adopted.

This is an exploratory paper, which presents important limits. First, we did not address specific licensing issues such as the decision to join a patent pool. Generally speaking, the licensor needs to determine the optimal deal structure to license out his technology. For example, Gandal and Rockett (1995) investigated to what extent it is more advisable to include future improvements into the licensing contract, or rather to license out the future improvements in a separate negotiation. As such decisions have to be made in a context of high uncertainty, real options could prove a useful framework to support them. For example, is it more advantageous for a licensor to sell a technology through a patent pool, or on its own? Similarly, can real options help determine the optimal fee structure between upfront, milestones and royalties payments?
Second, I.P. management issues related to firms' patent licensing strategy are missing in this article. For example, we did not investigate the question of whether it is optimal to settle a patent lawsuit (e.g. Somaya 2003). Grundfest and Huang (2006) have developed a real options model to determine whether it is optimal to pursue a litigation process or to settle. It would be interesting to apply this model to the specific case of patent lawsuits. Also, we have seen above that an alternative to out-licensing is to form a joint-venture. An interesting question would be whether real options can help in the negotiation of the joint-venture to evaluate assets corresponding to a portfolio of patents.
Finally, this article analyzes the out-licensing decision from the innovator's point of view. We did not discuss the case of patent trolls.

Last but not least, the main limit of this article is that it is based on general and theoretical considerations. Consequently, a promising area for future research will be to conduct both in-depth case studies and large-scale empirical studies, in order to validate the existence of the various types of real options that we have described in this paper, describe their characteristics and assess their potential value.
As one necessary condition for the existence of a real option is managerial flexibility, it would be very interesting to investigate to what extent firms exploit the flexibility offered by technology licensing agreements. For example, what proportion of licensees does not exercise the "option to develop and commercialize a technology", i.e. abandons the commercialization of the product using the licensed technology, or reduces the scope of the project (reduction of the geographical target market or modification of the product features), or else postpones the market introduction? To the contrary, what proportion of licensees exercises the "option to grow", i.e. extends the commercial value of the licensed technology by performing further technological developments and / or by extending the geographical scope of their operations? From the licensor's point of view, which percentage of firms transforms foreign licensing agreements into other commitments such as joint-ventures? How frequently do licensors "exercise" the grant-back clause?

If we can indeed establish that licensors and / or licensees use the managerial flexibility embedded in technology licensing agreements, scholars may then explore whether firms are implicitly using a real options logic in determining the price of a license. If this is the case, the effective royalty rate of a license (including upfront payments, development milestones, royalty payments and commercial milestones) should vary according to the main determinants of financial options, such as the volatility, the dividend rate and the time remaining until the option expires. The volatility parameter, which corresponds to the level of uncertainty for real options, could be measured in particular by the degree of maturity of the technology (and if applicable the age of the product), the type of technology (whether specific or general purpose) and the "distance" between the core business of the licensor and the core business of the licensee. The dividend rate corresponds to the reduction in project value as time passes, due to the increased risk of competitive preemption or to the reduced number of years of exploitation until the patent expires.
In the case of compound options, there should be also a positive correlation between options value (i.e. license price), and the number of decision points (i.e. the number of times during which the licensee can abandon the license in the case of *ex-ante* TLAs).

The third step will consist in testing the real options framework as a decision making tool for IP managers. As a valuation tool, real options could prove useful in the negotiations on the license price and on the structure of the agreement. A necessary condition will be to devise option valuation models, e.g. models based on Monte Carlo simulations, which are flexible enough to take into account the specificities of the agreement under negotiation, and at the same time sufficiently simple to be understood and adopted by managers and senior decision makers. As a conceptual framework, it remains to be tested whether real options can guide potential licensors in their governance decisions.

The main challenge for this kind of empirical research will be to convince organizations to share information on licensing issues, which have a strategic importance, and are therefore very sensitive. As the management of IP becomes a highly strategic activity, and many firms still lack a systematic licensing process (Lichtenthaler and Ernst 2007), it is hoped that firms will have an incentive to collaborate with researchers on this promising subject.

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