

Analyzing technology licensing decisions with a real options perspective: a literature review and research agenda

Krychowski, Charlotte

TELECOM Ecole de Management

charlotte.krychowski@telecom-em.eu

Résumé :

As part of the growing trend towards Open Innovation, the market for technology licensing has experienced a tremendous growth since the beginning of the 1990s. This phenomenon has increased firms' strategy space, as they now have the choice between internal R&D or internal exploitation on the one hand, and external markets on the other hand.

Yet, licensing decisions are particularly difficult to make because they display a high level of technical, commercial and legal uncertainty. Therefore, technology licensing requires highly proficient management. In this regard the real options (RO) framework appears quite promising, because it is adapted to uncertain contexts. Patents have been early recognized by the literature as real options, and we have anecdotal evidence of the use of real options by firms for their licensing decisions.

In this article, our objective is to review the patent strategy literature dealing with real options, and lay out a foundation for future research on the application of the RO framework to licensing decisions. We find that the literature has concentrated on the use of real options in the domain of patent rights management, while RO applications to licensing decisions remain limited to specific uses. We therefore systematically investigate whether the various types of licensing-in and licensing-out decisions follow a real options logic.

We find that not all licensing decisions can be analogized to real options. Key determinants of the real options logic are in particular the maturity of the licensed technology, and the motivations pursued by the innovator to license-out the technology. We analyze the potential benefits and limits of applying real options to licensing decisions, both from a managerial and academic perspective. Finally, we derive a research agenda from our analysis.

Mots-clés : options réelles, licences technologiques, open innovation, management de l'innovation

Analyzing technology licensing decisions with a real options perspective: a literature review and research agenda

INTRODUCTION

Although the exact size of the market for patent licenses is not known, various sources indicate that it has recorded a tremendous growth since the beginning of the 1990s from about \$15 billion in 1990 to around \$110 billion at the beginning of the years 2000 (Degnan 1998; Rivette and Kline 2000; Rigby and Zook 2002; Kline 2003; Athreye and Cantwell 2007; 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).

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 a 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 or keep it unused. Open innovation can thus take place through *in-bound* as well as through *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 intrinsic value of a technology license very difficult to assess. In the context of open innovation, it may be particularly difficult for firms to evaluate a technology with potential applications outside their core business (Chesbrough 2004). Second, licensing decisions are exposed to the risk of opportunistic behavior from the partner, and this can trigger significant changes in the dynamics of competition. Lastly, patent holders face legal uncertainty, as patent protection is generally porous, imperfect and unclear (Somaya 2012).

Technology licensing therefore requires highly proficient management. 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. More specifically, firms 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). In his seminal paper on real options, Myers (1977) identified patents as options, and researchers in general have the intuition that real options are a very promising tool for the management of patents, as suggested for example by Pitkethly (2006, p.290): *“Valuation [...] for the purpose of sales and licensing of patents should ideally be carried out using option pricing based methods”*. 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. RO are not easy for managers to understand and implement (e.g. Lander and Pinches 1998). More fundamentally, 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.

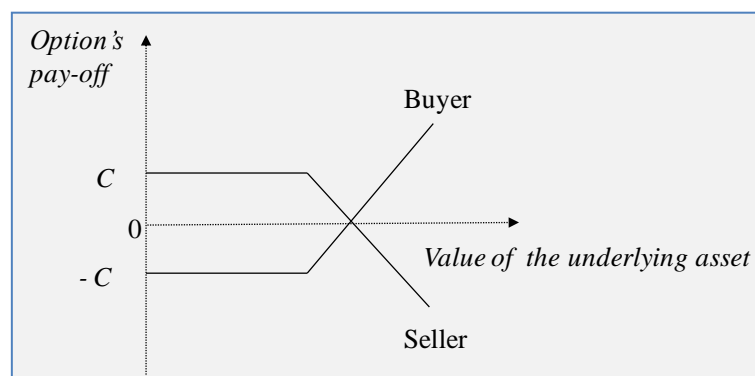
Therefore, the objective of this paper is to assess the research potential of real options as a framework to analyze licensing decisions. We first investigate the reasons why patents are usually analogized to real options by conducting a review of the patent strategy literature. We then focus on licensing decisions, and analyze to what extent specific real options applications found in the literature can be extended to all licensing decisions. We derive a research agenda from this analysis, both for licensing-in and licensing-out decisions.

The remainder of this paper is organized as follows: In section 1, we conduct a review of the use of real options in the patent strategy literature. Then, we review licensing-in decisions in section 2, and licensing-out decisions in section 3. In each of the sections 2 and 3, we also derive the implications and a research agenda.

1. REAL OPTIONS IN THE PATENT STRATEGY LITERATURE

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 premium. Thus, the specificity of the option's logic is the asymmetry of the pay-offs (Figure 1).

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



Call options give the right to purchase the underlying asset, while *put* options give the right to sell it. European options can be exercised only at maturity, while American options can be exercised at any time before the option expires. 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.

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. 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 in case competitors manage to “invent around” or following the apparition of a superior technology or of a substitute. 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 infringers, or else sharing the technology with a Joint Venture partner (McGrath and Nerkar 2004; Cotropia 2009).

Decisions related to patent strategy take place in three main domains: patent rights, licensing and enforcement (Somaya 2003). We review below the use of real options by the literature in each of these domains (Table 1).

Table 1: Overview of real options in the patent strategy literature

Key references	Studied decision	Benefits of using Real Options
Rights		
Goldenberg & Linton (2012)	Decision to patent	Define the threshold of expected damages in case of lawsuit beyond which it is worth patenting
Laxman & Aggarwal (2003); Pitkethly (2006)	Decision to pursue the patent application procedure	For each stage of the procedure, evaluate whether it is worth pursuing the patent application
Pakes (1986); Baudry & Dumont, (2006)	Decision to renew the patent	Recommendations on the structure of patent renewal fees
Bloom and Van Reenen (2002)	Decision to commercialize a patented technology	Understand the role of uncertainty on the relationship between patenting and productivity
Licensing		
Jiang et al (2009)	Decision to license-out in a foreign market	Understand the determinants of licensing duration
Nichols (1994); Bowman & Moskowitz (2001); Cassimon et al (2011) ; Hoe & Diltz (2012)	Decision to license-in	Valuation of an ex-ante licensing contract in the pharmaceutical industry
Enforcement		
Nerkar et al (2007); Marco, (2005)	Decision to litigate against infringers	Characteristics of patents that are the most likely to be litigated
Cotropia (2009)	Decision to exercise the option through commercialization Vs patent lawsuit	Recommendations for patent rules to avoid the proliferation of “patent trolls”

1.1.PATENT RIGHTS DECISIONS

In the domain of patent rights management, the literature on real options is dominated by economics contributions, which investigate four main types of decisions.

First, the real options approach is used to understand firm's decisions to patent an invention, and help policy makers design a patent system that supports innovation. For instance, Goldenberg and Linton (2012) analogize a patent to a two-steps compound option: patenting an invention provides a firm with the option to sue potential infringers. If this option is exercised, the firm then obtains the option to collect payments from the infringer if the damages awarded by the court are higher than the cost of collection. The model is used to derive the threshold for expected collected damages beyond which it is worth applying for a patent. Second, the patent application procedure is a succession of decisions, which can be viewed as a compound option: at each stage, the potential future benefits of continuing the application have to be balanced against the official and professional fees due for proceeding to the next stage (Pitkethly 2006). Thus, Laxman and Aggarwal (2003) use a compound option model to value a 3G-telecom patent. Third, economists have used the options analogy to analyze firms' decision to renew patent fees (e.g. Pakes 1986) and to produce some recommendations on the structure of patent renewal fees (Baudry and Dumont 2006).

Last, once the patent has been granted and maintenance fees have been paid for, the question arises of when to exercise the option, i.e. of the optimal time to exploit the innovation. Real options are used to explain the role of uncertainty on the relationship between patenting on the one hand, and firm-level productivity on the other hand: in a context of higher uncertainty, the value of the "option to wait" increases, and patentees tend to defer the investment that would enable exploiting the patented technology (Bloom and Van Reenen 2002). As said earlier, another way to exercise the option corresponding to the patent is either to license it, or to sue firms breaching the patent. We analyze in turn the decisions dealing with licensing and with the enforcement of patents.

1.2.LICENSING DECISIONS

In the licensing literature, real options have been used mainly to analyze licensing-in decisions, whereas the optional nature of licensing-out decisions is limited to international licensing. According to Jiang et al (2009), licensing-out can be considered as an initial trial of a foreign market before a firm fully commits to it through other investment modes. It may thus be interpreted as a European-style option, during which the firm the licensor accumulates

information on the foreign market. At the end of the contract, the licensor may exercise the option by establishing a Joint-Venture with the licensee or by investing in a wholly owned subsidiary. Alternatively, he may renew the licensing contract, and would in that case have to pay for the corresponding transaction costs.

As far as licensing-in decisions are concerned, research using real options concentrates on the case of *ex-ante* patent licensing agreements in the pharmaceutical industry. As opposed to *ex-post* contracts, *ex-ante* contracts are dealing with patents that have not been granted yet. This sort of agreement can be typically observed in research medicines industries: 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 decides whether or not to commercialize the new drug. If this is the case, the licensor receives a royalty, which is usually computed as a fixed percentage of the drug sales revenues.

Nichols (1994), as well as Bowman and Moskowitz (2001) describe how the pharmaceutical company Merck used real options to evaluate an *ex-ante* patent agreement with a biotechnology company for an asthma drug. Merck considered that the licensing agreement gave them the option, i.e. the right but not the obligation, to introduce the drug on the market. The underlying asset of this option corresponded to the present value of the cash-flows S generated by the selling of the new product using the licensed technology. The exercise price corresponded to the investment (residual R&D costs, production facilities, marketing costs, distribution network) that was necessary to launch the new product. Exercising the option meant introducing the new drug on the market. The time to expiration of the option corresponded to the timeframe during which the product could be launched before a competitive product may get clearly established. In Merck's case, 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 would progressively get reduced. Merck could then assess whether the expected cash-flows generated by the commercialization of the new drug were higher than the investment cost that had to be incurred for the market introduction. Therefore, the maximum price that Merck would accept for "sunk payments" (i.e. the sum of up-front and milestones license payments as well as the development costs) was the value of the option.

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 frame the contract as a *compound* 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. Cassimon et al (2011) have developed a model, in which n -phases of R&D development can be taken into consideration in the real options valuation model. Similarly, Hoe and Diltz (2012) model a licensing contract in the pharmaceutical industry as a five-steps abandonment compound option.

1.3.PATENT ENFORCEMENT DECISIONS

Researchers have used the real options framework to analyze which patents are the most likely to be litigated. Nerkar and colleagues (2007) compare a patent to an American call option, giving the right to litigate against infringers. Patentees will do so if they believe that the potential benefits accruing from litigation (i.e. the underlying asset) far outweigh the cost of litigation (i.e. the exercise price). This line of reasoning is applied to understand which types of business methods patents are the most likely to be litigated. Marco (2005) investigates a similar question, but analogizes the patent to an American put option. Indeed, firms would sue for infringement when the cash-flows they derive from their invention are too low. When there is widespread belief that the patent holder will not enforce its property rights, these cash-flows will be low (due to small bids for licenses or due to infringement preventing the patent holder to derive increased revenues from his invention). Below a certain point, it is worth for the patent holder to exercise the option, i.e. to sell the current profit flow in return for the court-imposed outcome. However, there is the risk that the court does not confirm the validity of the patent, which would result in the patent holder losing the entire patent. The author uses the real option reasoning to explain the impact of patent characteristics (age, forward citations, backward citations, etc.) on the litigation rate.

Cotropia (2009) considers that the option corresponding to a patent can be exercised in two main ways: either by commercializing the invention, or by asserting it through a patent lawsuit. He observes that the “assert-only” exercise price is much cheaper than the “commercialize” exercise price, and that the price to be paid to obtain the option – i.e. the cost associated with filing for the patent – is very low compared to potential pay-off. As a result, current patent rules encourage the exercise of the patent option through litigation, which may explain the recent development of “patent trolls”. The real options framework may thus have interesting policy implications.

This literature review has shown that real options have been used by researchers primarily to analyze patent rights decisions, and mainly from an economics perspective with a view to maximize economic and societal benefits of innovation. In contrast, the application of the RO framework to licensing decisions appears limited to specific uses in the pharmaceutical industry. Yet the financial stakes for firms are much higher in the licensing and enforcement domains, than in the patent rights domain (e.g. Goldenberg and Linton 2012). In the following sections, we investigate to what extent real options may be useful to analyze licensing-in and licensing-out decisions, from a managerial perspective.

2. THE DECISION TO LICENSE IN

In this section, we investigate to what extent the application of RO in the pharmaceutical industry can be replicated to other licensing contracts. For those license-in decisions that can be viewed as options, what are the potential benefits and limits? Finally, we propose a research agenda on the licensing-in domain.

2.1. LICENSING-IN DECISIONS THAT MAY BE ANALYZED AS OPTIONS

Not all strategic decisions can be analyzed as options. Among important determinants of option's value are the level of uncertainty, and the possibility of information revelation. Finance theory has shown that the option's value is positively correlated with the level of uncertainty on the value of the underlying asset. In addition, there should be some possibility of information revelation, so that the option holder can make a conscious decision at exercise time (e.g. Huchzermeier and Loch 2001).

The case of *ex-ante* licensing agreements fits very well to the real options logic, as the level of technical and commercial uncertainty is high when the licensing contract is signed. In addition, by the time the patent is granted, it can be expected that the level of uncertainty will decrease. In the pharmaceutical industry, the uncertainty of sales forecasts decreases along the drug development process (e.g. Bode-Greuel and Greuel 2005). It can be expected that similar information revelation mechanisms apply to *ex-ante* licensing contracts in other industries.

In the case of *ex-post* licensing agreements, the level of uncertainty will probably depend on the degree of maturity of the technology. If the technology is still early-stage, the level of commercial and / or technical uncertainty will probably be high. Commercial uncertainty may

be particularly high if the definition of what the product will consist is 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). Alternatively, the product may be well defined, but there may be a high level of technical uncertainty, as the production costs at the industrial phase may be difficult to derive from production costs in laboratory conditions. For example in the electronics industry, production costs may be much higher than anticipated due to a high defect rate of products on the production line. The two types of uncertainty may be combined, as is the case in the agriculture sector: Richards and Rickard (2013) develop a real option model to evaluate the property rights to the “Pink Lady”, a new apple variety. The level of uncertainty may be reduced through different mechanisms: (1) by observation, in particular of market introduction of competitive products, or of the price of the product on the market in the agricultural sector or (2) by performing tests, for example by building a pilot plant to estimate industrial production costs or in the agriculture by testing the trees on a limited area before planting them on a large scale. But in some cases there may be no possibility to reduce significantly the uncertainty before commercialization, for example when the success of a new product or service relies on high network externalities. 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. As there is no uncertainty on the cash-flows enabled by the technology, there is no benefit in using an option-based model. Finally, the level of uncertainty also depends on the type of technology: it may be higher for product than for process technologies, and for general-purpose than for specialized technology.

Beyond the necessary conditions of uncertainty and information revelation, it should also be noted that the real options logic that we have described earlier in this paper applies to relatively discrete technologies, for which there is a one-to-one relationship between the patent and the product that can be manufactured with the patented technology (as in the case in the pharmaceutical industry). The analysis becomes much more complicated for cumulative or “multi-invention” technologies. In industries involving this type of technologies, like electronics, the development of new products requires the combination of ever-larger numbers of inventions, 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.

2.2. AN IMPROVED VALUATION CONTRIBUTING TO A GREATER LIQUIDITY OF THE MARKET FOR LICENSES

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 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. 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. 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. 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 going back over 10 years has shown that the 25 per cent rule is not commonly used nor appropriate (Borshell and Dawkes 2010). 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).

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. 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. Consistent with the real options theory (among numerous references, see e.g. Dixit and Pindyck 1995; Trigeorgis 1996), the literature using real options to evaluate licensing contracts has shown that this approach produces a more appropriate valuation than traditional NPV calculation because real options take into account managerial flexibility (Bowman and Moskowitz 2001; Hoe and Diltz 2012). Even firms using more sophisticated decision tools like Decision Tree Analysis (DTA) do not necessarily come up with satisfactory pricing compared to RO analysis (Cassimon, De Backer et al. 2011).

If real options can help valuating licenses, they may contribute to foster the development of the technology licensing market, which is hampered by large transaction costs (Bessy and Brousseau 1998; Gambardella, Giuri et al. 2007). 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, a tool like real options enabling managers to better estimate the value of licenses would clearly contribute to the development of the technology licensing market. The famous Black & Scholes (1973) formula to value a European call option had largely contributed to the explosion of the market for financial derivatives. Similarly, we could expect a self-sustaining process, as the increase of the licensing market would in turn ease the valuation of technology licenses (Arora, Fosfuri et al. 2001).

2.3. IMPLEMENTATION ISSUES

Even in the pharmaceutical industry, where real options seem to be the most promising, the real options framework is not frequently used because R&D managers feel it is difficult to put

into practice (Hartmann and Hassan 2006). This confirms the results of a survey by Ryan and Ryan (2002) revealing that the complexity of management tools substantially reduces their usage. Amram (2005) recognizes that in spite of the potential of real options, their use is deemed too complex because each transaction is unique, and it is difficult to adapt RO valuation models to the specificities of the technology licensing agreement that is negotiated. 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. 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 real options approach because it enabled managers to understand why traditional valuation methods were not producing an appropriate recommendation (Bowman and Moskowitz 2001).

2.4. IMPLICATIONS AND RESEARCH AGENDA

As we have shown that not all in-licensing decisions follow a real options logic, it would be interesting to investigate the impact of various drivers (e.g. nature and maturity of the patented technology, industry, ...) on the applicability of the real options reasoning on in-licensing decisions. This could be achieved by analyzing in which conditions firms exploit the flexibility offered by technology licensing agreements. For example, what proportion of licensees 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?

Another implication of the real options framework concerns the payment structure. The effective royalty rate of a licensing agreement can be decomposed into fixed and variable components: upfront payments and development milestones may be considered as “sunk” costs, whereas royalty payments will depend on the sales revenues generated thanks to the licensed technology. The NPV approach concentrates on the total amount paid by the licensee, but is indifferent to the decomposition of this amount into these various components. By contrast, the value of the real option held by the licensee will depend on the structure of payments. The higher the level of uncertainty, the more the licensee would benefit in paying as much as possible through royalty fees. As a consequence, it would be very interesting to use a real options lens in studying the impact of uncertainty on the structure of payments in licensing contracts.

Third, it would be interesting to investigate whether other types of real options may be held by the licensee, such as the *option to grow* and *contractual options*. Whereas we have so far concentrated on the option to abandon (i.e. not to commercialize the licensed technology), there is also the possibility for the licensee to acquire an “option to grow” if the licensed technology is subject to future developments that 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. In this case, the license may 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 (ii) a growth option value. In addition, technology licensing agreements (TLAs) may contain “*contractual options*” (Amram and Kulatilaka 1999). TLAs usually contain many specific terms and conditions (Bessy and Brousseau 1998; Anand and Khanna 2000; Razgaitis 2004; Brousseau, Coeurderoy et al. 2007), which may be analyzed as *contractual options*. For example, the parties may introduce a renegotiation clause on royalties, which guarantees that the share of the benefit paid by the licensee 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).

Lastly, it would be interesting to study whether real options play an implicit role in licensees governance decisions, a.k.a. the “*make Vs. license Vs. buy decisions*”. The literature mentions the choice between licensing-in and inventing around thanks to in-house R&D developments.

Another possibility is to simply acquire a patent, as the market for the sales of patent has shown an exponential growth since 2005 (even if its size is still modest compared to the licensing market). Compared to the licensing of a patent, the purchase of the patent is much more risky because it does not follow an option's logic: if the patented technology cannot be commercialized, the whole amount paid to purchase the patent is lost, whereas only the upfront fee would be lost in the case of licensing. Therefore, it would be interesting to explore the role of uncertainty on the decision of buying V. licensing a patent.

3. THE DECISION TO LICENSE OUT

One might think that the decision to license out can be analyzed in a symmetrical way compared to the decision to license in. Yet, 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 2 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 2: 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

In this section, we explore the optional logic of licensing-out decisions by using the typology developed by Arora *et al* (2001). They classify the strategic implications of licensing along two dimensions: (1) the maturity of technology that is licensed: is it an existing or a future technology? and (2) 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? In the case of “horizontal” licensing transactions – i.e. when the innovator has stakes in the final market – we further distinguish between the various motivations identified by the literature for licensing out. Table 3 summarizes our findings regarding the potential existence of a real option in the various cases.

Table 3: Synoptic view of real options created by licensing-out transactions

Motivation for licensing out	Option’s logic	References	Context / examples
Vertical market / licensing to non-rivals			
Developed technology	None	Lichtenthaler 2008	Residual technology
		van Triest & Vis 2007	Licensor does not have complementary assets (e.g. semi-conductors industry)
Early-stage technology	The option to abandon is owned by the licensee (see Section 2)		Licensor does not have complementary assets
Horizontal market / licensing to actual or potential rivals			
Monetary motives			
Developed technology	None	Fosfuri 2006, Kline 2003	“Keep-and-sell” (e.g. chemical industry)
Early-stage / future technology	Sell the option to grow	Kline 2003, Rigby & Zook, 2002	Sun licensing Java to IBM
	Abandon the option to wait	Teece, 1986; Chesbrough, 2006; Rigby & Zook, 2002	Xerox licensing GUI and computer mouse
Strategic motives			
Foreign market entry	Option to transform into JV / wholly owned subsidiary	Jiang et al, 2009; Simonet 2002	Astra Merk Inc
Setting an industry standard	None (logic of a “bet”)	Conner 1995	High network externalities; Dominant design not yet emerged
Freedom to operate and access to knowledge	Swap option (cross-licensing)	Grindley & Teece, 1997; Hall & Ziedonis, 2001	Cumulative technology
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

Key: ☐ Real options logic not applicable

3.1. LICENSING-OUT 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. 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 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.

In these three situations, 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, firms licensing-out to non-rivals do not pursue any strategic goals beyond monetary motives that could be analyzed from a real options perspective. Rather, real options may only be useful for the licensor during contract negotiations in order to discuss the sharing of the profits between the two parties: in the case of an early-stage technology, 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 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. If the contracts involves 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.

3.2. LICENSING-OUT TO CURRENT OR POTENTIAL RIVALS

Lichtenthaler and Ernst's (2007) survey has shown that firms may license-out for a variety of strategic reasons, and that in fact generating royalty revenues arrives only at the seventh position in the reasons for licensing, out of a total of eleven possible motivations. For each type of motivation, we explore below whether the decision to license out may lead to the creation of a real option.

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, and 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 2* 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*): 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 (P&G) 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. 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.

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. In contrast, we have seen earlier that there may be a “learning” option value attached to a licensing agreement as a mean to enter a foreign market. 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.

Outside foreign licensing agreements, learning can also take place through technology flowback provisions, 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 learning 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.

Another possible strategic motivation for out-licensing is to enhance the firm's reputation and strengthen the firm's network. A large inter-organizational 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.

Last, but not least, two important motivations for licensing are "*Freedom to operate*" and "*Access to knowledge*", which are crucial in cross-licensing agreements. These agreements are described by Grindley and Teece (1997) or Hall and Ziedonis (2001) in the electronics and semi-conductor industries and by Bekkers et al (2002) in the mobile telecommunications industry. 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.

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.

Cross-licensing negotiations are very complex, because they involve a high number of patents and because it is very difficult to assess the value of a single patent. 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. In addition,

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 patents 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.

3.3. BENEFITS OF THE REAL OPTIONS FRAMEWORK FOR LICENSING-OUT DECISIONS

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 (2008, p79) survey: “*Despite strategic issues, we focus very much on revenues in managing technology licensing*”.

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 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.

3.4. IMPLICATIONS AND RESEARCH AGENDA

For those out-licensing decisions that can be analyzed with a real options lens, it would be very interesting to investigate to what extent firms exploit the flexibility offered by technology licensing agreements: which proportion of firms transforms foreign licensing agreements into other commitments such as joint-ventures? How frequently do licensors “exercise” the grant-back clause?

In the specific case of vertical licensing agreement, we have focused on this paper on the use of real options as a mean of valuing the contract. The real options framework could also be mobilized to explore governance issues, and more specifically the question of 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 (e.g. Fosfuri 2006). The Profiting from Innovation (PFI) framework builds on TCE, but also takes into account replicability issues, which depend of the nature of complementary assets. (Teece 1986). 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 (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 and (ii) the option to resell its stake to its partner (Kogut 1991). 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.

Lastly, there is an interesting research potential in the domain of patent enforcement, which is closely linked to the licensing out decision. The literature has concentrated on using real options for the decision to start a litigation procedure. Another important question is also 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.

CONCLUSION

The objective of the paper was to conduct a review of the literature in order to lay a foundation for further research on real options and licensing management. The literature review has established that while patents have been traditionally analyzed as options, there is only scattered and limited analysis on the impact of this analogy for firms' technology licensing decisions. Therefore, we conducted 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 both for scholars and practitioners and (3) suggestions for future research.

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. Depending on the decision involved, it may be the licensor or the licensee who holds the option. In addition, 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.

We also 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.

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. From an academic perspective, real options 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 payment structure of a licensing agreement.

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, or the case of the patent trolls. Also, it seems that the domain of patent enforcement presents an interesting research potential for the real options approach. Generally speaking, 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. 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.

REFERENCES

- Adner, R. and D. A. Levinthal (2004). "What is not a real option: considering boundaries for the application of real options to business strategy." Academy of Management Review **29**(1): 74-85.
- Amram, M. and N. Kulatilaka (1999). "Uncertainty: The new rules for strategy." Journal of Business Strategy **20**(3): 25.
- Anand, B. N. and T. Khanna (2000). "THE STRUCTURE OF LICENSING CONTRACTS." Journal of Industrial Economics **48**(1): 103-135.
- Arora, A. and A. Fosfuri (2003). "Licensing the market for technology." Journal of Economic Behavior & Organization **52**(2): 277-295.
- Arora, A., A. Fosfuri, et al. (2001). "Markets for Technology and their Implications for Corporate Strategy." Industrial & Corporate Change **10**(2): 419-451.
- Athreye, S. and J. Cantwell (2007). "Creating competition?: Globalisation and the emergence of new technology producers." Research Policy **36**(2): 209-226.
- Baudry, M. and B. Dumont (2006). "Patent Renewals as Options: Improving the Mechanism for Weeding Out Lousy Patents." Review of Industrial Organization **28**(1): 41-62.
- Bekkers, R., G. Duysters, et al. (2002). "Intellectual property rights, strategic technology agreements and market structure: The case of GSM." Research Policy **31**(7): 1141-1161.
- Bessy, C. and E. Brousseau (1998). "Technology licensing contracts features and diversity." International Review of Law and Economics **18**(4): 451-489.
- Black, F. and M. Scholes (1973). "The Pricing of Options and Corporate Liabilities." Journal of Political Economy **81**(3): 637.
- Bloom, N. and J. Van Reenen (2002). "Patents, Real Options and Firm Performance." Economic Journal **112**(478): C97.
- Bode-Greuel, K. M. and J. M. Greuel (2005). "Determining the value of drug development candidates and technology platforms." Journal of Commercial Biotechnology **11**(2): 155-170.
- Borshell, N. and A. Dawkes (2010). "Pharmaceutical royalties in licensing deals: No place for the 25 per cent rule of thumb." Journal of Commercial Biotechnology **16**(1): 8-16.
- Bowman, E. H. and G. T. Moskowitz (2001). "Real Options Analysis and Strategic Decision Making." Organization Science **12**(6): 772.
- Brousseau, E., R. Coeurderoy, et al. (2007). "The Governance of Contracts: Empirical Evidence on Technology Licensing Agreements." Journal of Institutional and Theoretical Economics **163**: 205-235.
- Cartwright, H. and N. Borshell, Eds. (2012). The Royalty Rate Report 2012 - A Comprehensive Assessment of Valuation in the Pharmaceutical Sector. Oxford, PharmaDeals.
- Cassimon, D., M. De Backer, et al. (2011). "Incorporating technical risk in compound real option models to value a pharmaceutical R&D licensing opportunity." Research Policy **40**(9): 1200-1216.
- Caves, R. E., H. Crookell, et al. (1983). "THE IMPERFECT MARKET FOR TECHNOLOGY LICENSES." Oxford Bulletin of Economics & Statistics **45**(3): 249-267.
- Chesbrough, H. (2003). Open Innovation: the New Imperative for Creating and Profiting from Technology. Boston, MA, Harvard Business School Press.
- Chesbrough, H. (2004). "MANAGING OPEN INNOVATION." Research Technology Management **47**(1): 23-26.

- Chesbrough, H. (2006). New Puzzles and New Findings. Open Innovation: Researching a New Paradigm. W. V. a. J. W. Henry Chesbrough, editors. Oxford, Oxford University Press: 15-34.
- Chesbrough, H. (2007). "The Market for Innovation: IMPLICATIONS FOR CORPORATE STRATEGY." California Management Review **49**(3): 45-66.
- Cotropia, C. A. (2009). "Describing Patents as Real Options." Journal of Corporation Law **34**(4): 1127-1149.
- Cuypers, I. and X. Martin (2010). "What makes and what does *not* make a real option? A study of equity shares in international joint ventures." Journal of International Business Studies **41**: 47-69.
- Degnan, S. A. (1998). "The licensing payoff from U.S. R&D." Journal of the Licensing Executive Society **33**: 1-8.
- Dixit, A. K. and R. S. Pindyck (1995). "The Options Approach to Capital Investment." Harvard Business Review **73**(3): 105.
- Economist, t. (2010). "The great patent battle." The Economist: 69-70.
- Folta, T. B. and K. D. Miller (2002). "REAL OPTIONS IN EQUITY PARTNERSHIPS." Strategic Management Journal **23**(1): 77.
- Fosfuri, A. (2006). "The licensing dilemma: understanding the determinants of the rate of technology licensing." Strategic Management Journal **27**(12): 1141-1158.
- Gallini, N. T. and B. D. Wright (1990). "Technology transfer under asymmetric information." RAND Journal of Economics (RAND Journal of Economics) **21**(1): 147-160.
- Gambardella, A., P. Giuri, et al. (2007). "The market for patents in Europe." Research Policy **36**(8): 1163-1183.
- Goldenberg, D. H. and J. D. Linton (2012). "The patent paradox – New insights through decision support using compound options." Technological Forecasting and Social Change **79**(1): 180-185.
- Grindley, P. C. and D. J. Teece (1997). "Managing Intellectual Capital: LICENSING AND CROSS-LICENSING IN SEMICONDUCTORS AND ELECTRONICS." California Management Review **39**(2): 8-41.
- Grundfest, J. A. and P. H. Huang (2006). "The Unexpected Value of Litigation: A Real Options Perspective." Stanford Law Review **58**.
- Hall, B. H. and R. H. Ziedonis (2001). "The patent paradox revisited: an empirical study of patenting in the U.S. semiconductor industry, 1979-1995." RAND Journal of Economics (RAND Journal of Economics) **32**(1): 101-128.
- Hartmann, M. and A. Hassan (2006). "Application of real options analysis for pharmaceutical R&D project valuation - Empirical results from a survey." Research Policy **35**(3): 343-354.
- Hill, C. W. L., P. Hwang, et al. (1990). "AN ECLECTIC THEORY OF THE CHOICE OF INTERNATIONAL ENTRY MODE." Strategic Management Journal **11**(2): 117-128.
- Hoe, C. and J. D. Diltz (2012). "A Real Options Approach to Valuing and Negotiating Licensing Agreements." The Quarterly Review of Economics and Finance(0).
- Huchzermeier, A. and C. H. Loch (2001). "Project Management Under Risk: Using the Real Options Approach to Evaluate Flexibility in R&D." Management Science **47**(1): 85.
- Jiang, M. S., P. S. Aulakh, et al. (2009). "Licensing duration in foreign markets: A real options perspective." Journal of International Business Studies **40**(4): 559-577.
- Kline, D. (2003). "Sharing the Corporate Crown Jewels." MIT Sloan Management Review **44**(3): 89-93.
- Kogut, B. (1991). "Joint Ventures and the option to expand and acquire." Management Science **37**(1): 19-33.

- Lander, D. M. and G. E. Pinches (1998). "Challenges to the Practical Implementation of Modeling and Valuing Real Options." Quarterly Review of Economics & Finance **38**(4): 537.
- Laxman, P. R. and S. Aggarwal (2003). "Patent Valuation Using Real Options." IIMB Management Review (Indian Institute of Management Bangalore) **15**(4): 44-51.
- Lichtenthaler, U. (2008). "Leveraging technology assets in the presence of markets for knowledge." European Management Journal **26**(2): 122-134.
- Lichtenthaler, U. and H. Ernst (2007). "External technology commercialization in large firms: results of a quantitative benchmarking study." R&D Management **37**(5): 383-397.
- Marco, A. C. (2005). "The option value of patent litigation: Theory and evidence." Review of Financial Economics **14**(3/4): 323-351.
- McGrath, R. G. and A. Nerkar (2004). "Real options reasoning and a new look at the R&D investment strategies of pharmaceutical firms." Strategic Management Journal **25**(1): 1-22.
- Myers, S. C. (1977). "Determinants of corporate borrowing." Journal of Financial Economics **5**(2): 147-175.
- Myers, S. C. (1984). "Finance theory and financial strategy." Interfaces **14**(1): 126-137.
- Nerkar, A., S. Paruchuri, et al. (2007). Business Methods Patents as Real Options: Value and Disclosure as Drivers of Litigation. Advances in Strategic Management, **24**: 275-303.
- Nichols, N. (1994). "Scientific Management at Merck: an interview with CFO Judy Lewent." Harvard Business Review: pp. 89-99.
- Pakes, A. (1986). "PATENTS AS OPTIONS: SOME ESTIMATES OF THE VALUE OF HOLDING EUROPEAN PATENT STOCKS." Econometrica **54**(4): 755-784.
- Pitkethly, R. (2006). "Patent valuation and real options". The Management of Intellectual Property. E. Webster and D. L. Bosworth. Cheltenham, UK, Edward Elgar Publishing Ltd: 268-292.
- Pitkethly, R. H. (2001). "Intellectual property strategy in Japanese and UK companies: patent licensing decisions and learning opportunities." Research Policy **30**(3): 425-442.
- Razgaitis, R. (2004). "US/Canadian licensing in 2003: survey results." Journal of the Licensing Executive Society **34**: 139-151.
- Richards, T. J. and B. Rickards (2013). Patent as Options: Path-Dependency and Patent Value. Agriculture & Applied Economics Association, AAEA & CAES Joint Annual Meeting. Washington DC, August 4-6, 2013.
- Rigby, D. and C. Zook (2002). "Open-Market Innovation." Harvard Business Review **80**(10): 80-89.
- Rivette, K. G. and D. Kline (2000). "Discovering New Value in Intellectual Property." Harvard Business Review **78**(1): 54-66.
- Ryan, P. A. and G. P. Ryan (2002). "Capital Budgeting Practices of the Fortune 1000: How Have Things Changed?" Journal of Business & Management **8**(4): 355-364.
- Sakkab, N. Y. (2002). "CONNECT & DEVELOP COMPLEMENTS RESEARCH & DEVELOP AT P&G." Research Technology Management **45**(2): 38.
- Salauze, D. (2011). "A Simple Method For Calculating A "Fair" Royalty Rate." Les Nouvelles: 210-215.
- Shapiro, S. J. (2010). "Pitfalls in Determining the Reasonable Royalty in Patent Cases." Journal of Legal Economics **17**(1): 75-85.
- Shapiro, S. J. (2011). "More Pitfalls in Determining the Reasonable Royalty in Patent Cases." Journal of Legal Economics **18**(1): 91-107.
- Somaya, D. (2003). "STRATEGIC DETERMINANTS OF DECISIONS NOT TO SETTLE PATENT LITIGATION." Strategic Management Journal **24**(1): 17.

- Somaya, D., D. J. Teece, et al. (2012). "BUSINESS MODELS AND PATENT STRATEGIES IN MULTI-INVENTION CONTEXTS." Ivey Business Journal **76**(5): 9-11.
- Teece, D. J. (1986). "Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy." Research Policy **15**(6): 285-305.
- Trigeorgis, L. (1996). Real Options: Managerial Flexibility and Strategy in Resource Allocation. Cambridge, MA, MIT Press.
- van Triest, S. and W. Vis (2007). "Valuing patents on cost-reducing technology: A case study." International Journal of Production Economics **105**(1): 282-292.
- Villalonga, B. and A. M. McGahan (2005). "The choice among acquisitions, alliances, and divestitures." Strategic Management Journal **26**(13): 1183-1208.