Università Ca'Foscari Venezia

Dottorato di ricerca in
Economia Aziendale
Scuola Superiore di Economia
Ciclo 24
(A.A. 2010 - 2011)

Technology licensing in markets for ideas: empirical evidence from the biopharmaceutical industry

SETTORE SCIENTIFICO DISCIPLINARE DI AFFERENZA: SECS/P08

Tesi di dottorato di GIULIA TROMBINI, matricola 955546

Coordinatore del Dottorato | **Tutore del dottorando**

Prof. MASSIMO WARGLIEN | **Prof.ssa ANNA COMACCHIO**

Technology licensing in markets for ideas: empirical evidence from the biopharmaceutical industry

A dissertation by

Giulia Trombini

PhD Student in Business Economics – XXIV cycle

Advanced School of Economics

Ca' Foscari University of Venice

Thesis abstract

While past research has advanced our understanding of the reasons leading firms to access markets for ideas and helped frame phenomena such as the division of innovative labour and the rise of technology specialist firms (Arora et al., 2001; Gans & Stern, 2003), less is known on the functioning of markets relative to license formation and contract structuring. Notwithstanding the importance of investigating what drives two partners to enter into a license partnership and how license contracts are to be structured, few empirical studies have attempted to tackle these research questions (Kim & Vonortas, 2006; Anand & Khanna, 2000; Bessy & Brousseau, 1998). This dissertation aims to provide a micro-level analysis of firms' licensing practices. In order to fill the gap in the literature, the study shifts the level of analysis from that of a focal firm, usually adopted by past literature, to that of the dyad. The research setting selected for the study is the global biopharmaceutical industry over the period 1985-2004.

ACKNOWLEDGEMENTS

The following dissertation is the result of three years of research at the department of Management at Ca' Foscari University of Venice and six months visiting period at the department of Innovation and Organizational Economics at Copenhagen Business School.

I thank my doctoral advisor Anna Comacchio for believing in my work and supporting my research enthusiastically. I am grateful to Keld Laursen and Toke Reichstein for taking an interest in me and my research and providing the opportunity to access Recap database. My gratitude goes to Claudio Agostinelli, Fabio Manenti, Massimo Warglien and Francesco Zirpoli for their support and precious advice in improving my work.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

1.1 Background

Technology licensing has been the subject of a long tradition of scholarship both in industrial organization as well as managerial field. Research interests in this topic are founded on the implications of licensing both at an industry as well as firm level. Studies in industrial organization demonstrated the effect of licensing on industry overall R&D spending, diffusion of technology, product-market competition and economic utilization of patents (Gambardella, Giuri, & Luzzi, 2007; Katz & Shapiro, 1985; Rockett, 1990a; Shepard, 1987). Lately, with the increasing importance of distributed innovation models, strategy and innovation scholars started investigating what was the role of technology licensing within firms' innovation strategies. Since the publication of the book *Markets for technology* (Arora, Fosfuri, & Gambardella, 2001b), a number of theoretical and empirical studies inquired the role of technology licensing from different perspectives. Many contributions centred on the antecedents to firms' licensing strategy, namely what leads firms to sell their technologies to external partners. At an industry level, attributes such as the industry structure, the product market differentiation and the appropriability regime are put forward as the main determinants of firms' licensing behavior (Arora & Ceccagnoli, 2006; Fosfuri, 2006; Kim & Vonortas, 2006b; Lichtenthaler, 2008). At a firm level, the lack of control over downstream complementary assets is recognized to have an impact on firms' licensing propensity, explaining the rising of small technology-based firms (Gans & Stern, 2003). More recent contributions shifted the research focus to the demand side of the market, inquiring the link between in-licensing and firms' innovative activity (Ceccagnoli, Graham, Higgins, & Lee, 2010; Laursen, Leone, & Torrisi, 2010; Leone & Reichstein, forthcoming).

1.2 Purpose of the thesis

While past research has advanced our understanding of the reasons leading firms to access markets for ideas and helped frame phenomena such as the division of innovative labour and the rise of technology specialist firms, less is known on the functioning of these markets relative to license formation and contract structuring. Notwithstanding the importance of understanding what drives two partners to form a license partnership and how license contracts are to be structured, few empirical studies have attempted to tackle these research questions (Anand & Khanna, 2000; Bessy & Brousseau, 1998b; Kim & Vonortas, 2006a; Somaya, Kim, & Vonortas, 2010). The goal of this dissertation is to fill these gaps in the literature. The aim is to provide a micro-level analysis of firms' licensing practices and advance our current knowledge of markets for technology functioning.

In order to answer the research questions, I shift the level of analysis from that of a focal firm to that of the dyad. Traditionally, past studies on licensing have adopted a focal firm level of analysis (Arora & Gambardella, 2010). Although the adoption of such a lens allows to provide a robust investigation of the different drivers of the demand as well as the supply side of the market, it hinders our understanding of the functioning of market for ideas since it does not take into account the interdependence between the partners involved in the technology exchange. A license, in fact, is the result of a negotiation between two partners with different strategic objectives and expectations. Further, for each firm, the economic and strategic stakes deriving from licensing are tightly linked to the capability and commitment of the partner firm.

Building on this observation, I investigate license formation and contract structuring, adopting the perspective of both licensor and licensee.

To study these topics and test research hypotheses, I developed a research design relying on multiple sources of information. More specifically, I compiled a dataset based on the coding of 2018 original license agreements signed in the global biopharmaceutical industry over 20 years (1985-2004). The direct coding of license contracts made it possible to collect detailed and objective information relative to the firms involved in the partnership, the features of the license contract (i.e. exclusivity, geographic scope, provision of specific contractual clauses, etc.), the technology exchanged through the partnership and the presence of additional contracts integrating the license (i.e. R&D contracts, equity contracts, etc.). I then matched license data with information about the patenting activity and other attributes of the partners forming the license. These data were retrieved from NBER database (Hall, Jaffe, & Trajtenberg, 2001) and Compustat.

1.3 Structure and organization of the thesis

The thesis consists of three distinct papers that take different approaches to investigating license formation and contract structure. The first paper inquires the mechanisms underlying license formation, namely what brings two firms to enter into a license partnership. Drawing on past licensing and innovation literature, the study's central idea is that license formation is the outcome of two opposing forces: technology collaboration and market competition. The selection of the license partner balances the tension between firms' desire to find a partner with highest technological synergies and on the other the desire to minimize licensing competitive downsides and to access different resources in terms of product market and skills. This tension induces firms to seek partners with similar technology profiles but operating in different product markets. The findings integrate past research by providing empirical support to the idea that technology licensing impacts firms' strategies at two level of analysis: a technological and a market one. Past studies have mainly analyzed such a duality accounting for industry specific features, for instance the number of potential vendors of the same technology, market concentration (Fosfuri, 2006; Kim & Vonortas, 2006b). The adoption of a dyad level of analysis shows that such a duality is also linked to the partners involved in the transaction and more specifically to their interdependence both from a technological point of view as well as market positioning one.

The second and third papers focus on the structure of license contracts. More specifically, the second paper expands the first by introducing the concept of licensing combination and investigating when technology partners combine the license with R&D contract and minority equity links in order to maximize technology cooperation. The study proposes a new conceptualization of licensing that goes well beyond the traditional view of a market-based transaction for the exchange of IP rights (Anand & Khanna, 2000; Bessy & Brousseau, 1998b; Somaya et al., 2010), enriching the recent literature on license optimal structuring. The work aims to explain the substantial heterogeneity in the way firms access markets for knowledge through licensing. Factors that drive partners to integrate the license contract with R&D partnerships are therefore examined. Drawing on licensing and R&D partnership literature and adopting the "transactional value" perspective (Zajac & Olsen, 1993), two types of antecedents – knowledge and dyad features – are identified to explain licensing combination and the role of R&D and equity contracts in supporting inter-organizational exchange.

Finally, the third article analyzes one of the crucial structural choices of a license contract, namely the payment scheme the licensor and licensee agree upon. Past literature has outlined the importance of designing incentive-compatible contracts as a means to provide partners with mechanisms and incentives towards technology collaboration (Aghion & Tirole, 1994). Following this stream of research, the paper provides an overview of how different price schemes allow license partners to cope with uncertainty, asymmetric information and contract incompleteness. Building on agency theory, I develop a synthetic framework to predict empirically how fixed and/or variable payments allow partners to secure technology cooperation, even when uncertainty and information asymmetry threaten the technology exchange. Through its empirical analysis of sources of adverse selection and moral hazard, the article provides an overview of the efficiency of technology markets in allocating risks and resources between partners.

1.4 Contribution and implications

The thesis as a whole contributes to the licensing literature in different respects. Overall, it provides an empirical overview of firms' licensing practices, advancing current knowledge relative to how firms access markets for technology. It provides a framework of analysis to understand license formation and contract structuring. As per today, both phenomena have received relatively little attention from academic research. Secondly, the adoption of the dyad level of analysis and the focus on single license transactions highlight the cooperative stance of markets for knowledge. By mainly focusing the analysis on a focal firm, prior studies underestimated the tight interdependence between technology partners and consequently the cooperative nature of technology licensing. From all the three papers, it emerges the importance for both licensor and licensee to favour inter-firm collaboration in order to retain the highest benefits from accessing markets for knowledge. Both in choosing their licensing partner as well as in structuring the license contract, firms are driven by the need to secure technology collaboration.

The empirical evidence provided by the three articles has implications both from a managerial as well as policy makers' perspective. Given the strategic and monetary stakes associated to licensing, the thesis offers managers a framework of reference when accessing markets for knowledge. More specifically, it draws attention to two main issues. On the one hand, the importance of considering the dual effect of technology licensing both in terms of management of innovation and in terms of product market strategy. On the other, it sheds light on the importance of designing incentive-compatible contracts contingent on the partners to the transaction and the attributes of the technology underlying the partnership. Furthermore, it provides practical patent and license-based metrics managers can easily implement for selecting a technology partner, deciding which licensing combination to choose and determining the deal compensation.

For what concerns policy implications, the thesis highlights markets conditions as well as firms' specific capabilities that may favour the growth of technology markets. Further, the findings reveal that notwithstanding the ability of firms to cope with uncertainty and asymmetric information, still additional benefits could be derived by easing access to markets and by facilitating the structuring of license deals.

References

Aghion, P., & Tirole, J. 1994. On the Management of Innovation. ***Quarterly Journal of Economics***, 109(4): 1185-1207.

Anand, B., & Khanna, T. 2000. The structure of licensing contracts. ***Journal of Industrial Economics***, 48(1): 103-134.

Arora, A., & Ceccagnoli, M. 2006. Patent protection, complementary assets, and firms' incentives for technology licensing. ***Management Science***, 52(2): 293-308.

Arora, A., Fosfuri, A., & Gambardella, A. 2001. ***Markets for technology: The economics of innovation and corporate strategy***. Cambridge, Massachusetts: The MIT Press.

Arora, A., & Gambardella, A. 2010. Ideas for rent: an overview of markets for technology. ***Industrial and Corporate Change***, 19(3): 775-803.

Bessy, C., & Brousseau, E. 1998. Technology licensing contracts: features and diversity. ***International Review of Law and Economics***, 18(4): 451-489.

Ceccagnoli, M., Graham, S. J. H., Higgins, M. J., & Lee, J. 2010. Productivity and the role of complementary assets in firms' demand for technology innovations. ***Industrial and Corporate Change***, 19(3): 839-869.

Fosfuri, A. 2006. The licensing dilemma: understanding the determinants of the rate of technology licensing. ***Strategic Management Journal***, 27(12): 1141-1158.

Gambardella, A., Giuri, P., & Luzzi, A. 2007. The market for patents in Europe. ***Research Policy***, 36: 1163-1183.

Gans, J. S., & Stern, S. 2003. The product market and the market for ideas: commercialization strategies for technology entrepreneurs. ***Research Policy***, 32: 333-350.

Hall, B., Jaffe, A., & Trajtenberg, M. 2001. The NBER patent citations data file: lessons, insights, and methodological tools. ***NBER Working Paper***, 8498.

Katz, M., & Shapiro, C. 1985. On the licensing of innovations. ***RAND Journal of Economics***, 16(4): 504-520.

Kim, Y., & Vonortas, N. 2006a. Technology licensing partners. ***Journal of Economics and Business***, 58(4): 273-289.

Kim, Y., & Vonortas, N. S. 2006b. Determinants of technology licensing: the case of licensors. ***Managerial and Decision Economics***, 27(4): 235-249.

Laursen, K., Leone, M. I., & Torrisi, S. 2010. Technological exploration through licensing: new insights from the licensee's point of view. ***Industrial and Corporate Change***, 19(3): 871-897.

Leone, M. I., & Reichstein, T. 2011. Licensing-in fosters rapid invention! The effect of the grant-back clause and technological unfamiliarity. ***Strategic Management Journal***.

Lichtenthaler, U. 2008. Leveraging technology assets in the presence of markets for knowledge. ***European Management Journal***.

Rockett, K. 1990. Choosing the competition and patent licensing. ***RAND Journal of Economics***, 21(161-171).

Shepard, A. 1987. Licensing to enhance demand for new technologies. ***RAND Journal of Economics***, 18(3): 360-368.

Somaya, D., Kim, Y., & Vonortas, N. S. 2010. Exclusivity in licensing alliances: using hostages to support technology commercialization. ***Strategic Management Journal***, 32(2): 159-186.

2. WHOM TO CHOOSE AS A LICENSE PARTNER? A TRADE-OFF BETWEEN TECHNOLOGY COOPERATION AND PRODUCT-MARKET COMPETITION

ABSTRACT

The study investigates the drivers of license formation, namely what brings two firms to form a license partnership. Drawing on past licensing and innovation literature, we propose two dimensions along which license formation occurs: a technological and a product-market one. On the one hand, both the licensor as well as the licensee look for a partner with high technology synergies in order to maximize licensing benefits and obviate issues related to technology transfer and knowledge recombination. On the other hand, firms wish to select a partner operating in different product markets from the one they compete in order to minimize competitive downside issues as well as access different resources in terms of product markets and skills. Finally, we contend the interdependence between technology and market forces: firms balance the tension between technology cooperation and market competition by looking for a partner sharing similar knowledge foundations but operating in a different product market. To test the research hypotheses we use data on the formation of license partnerships in the global biopharmaceutical industry over the period 1994-2004. Empirical findings overall supports our theoretical predictions.

Keywords: license formation, technology cooperation, product-market competition

2.1 INTRODUCTION

It is well recognized in innovation literature that in a context of distributed knowledge and skills among different firms and organizations, establishing external linkages is key for successful management of innovation (Chesbrough, 2003; Chesbrough, Vanhaverbeke, & West, 2006). Among the different forms of R&D partnering, technology licensing represents one of the most flexible and widely used contractual mechanisms firms recur to access external knowledge, skills and markets (Arora, Fosfuri, & Gambardella, 2001a; Athreye & Cantwell, 2007; Hagedoorn, Lorenz-Orlean, & van Kranenburg, 2008). Recent studies have found the increasing efficiency of markets for technology and the central role of licensing to optimize firms' technology strategy (Ceccagnoli et al., 2010; Fosfuri, 2006; Lichtenthaler, 2007b). A central question in this regard pertains to the determinants of partner-choice in the context of technological licensing. Certainly, if the match between licensors and licensees is poor, the interests of the parties will be misaligned and the benefits from trade strongly reduced. This paper is concerned with this issue.

Past licensing literature has mostly focused on examining when and why firms recur to technology licensing. Answers have varied. Economic research focused on the role of transaction costs in shaping technology markets (Arora & Ceccagnoli, 2006; Gans & Stern, 2003). Strategy scholars considered firms' attributes as predictors of licensing behavior either from the licensor' standpoint (Fosfuri, 2006; Gambardella et al., 2007; Kim & Vonortas, 2006b) or the licensee's (Atuahene-Gima, 1992; Ceccagnoli et al., 2010; Laursen et al., 2010). Despite its rich contribution to our understanding of the industry and strategic factors leading firms to exploit markets for ideas, past research has left relatively unexplored the question of which firm choose as a license partner. The lack of empirical studies tackling such an issue is surprising given the costs and strategic importance related to identifying and accessing appropriate partners in license agreements (Danneels, 2007; Gans & Stern, 2003). To the best our knowledge only two empirical papers have examined the determinants of inter-firm license formation (Kim and Vonortas, 2006; Link and Scott, 2002). Despite the weighty contributions to the licensing literature, however, these papers suffer from two important limitations. First, both of the papers suggest central explanatory variables in this regard, and report important empirical findings, but they do not provide a theory of the links between these determinants and inter-firm license formation. Second, they do not analyze how these determinants interact and create contingencies for one another.

With this study we try to extend prior research, by developing a theory about determinants of license formation. In order to provide a framework of analysis about the drivers bringing two firms to form a license partnership, the study adopts the perspectives of both licensor and licensee. Such an approach derives from the observation that for both licensor and licensee, the positive effects of licensing are contingent on the synergies and complementarities with the technology partner (Gans & Stern, 2003). Considered such tight partners' interdependence, we posit that in the selection process firms look for a technology partner that guarantees the maximization of the economic and strategic stakes associated with licensing. Drawing on past licensing and innovation literature, the study's central idea is that license formation is the outcome of two opposing forces: collaboration and competition. The selection of the license partner balances the tension between firms' desire to find a partner with highest technological synergies and on the other the desire to minimize licensing competitive downsides. This tension induces firms to seek partners with similar technology profiles but to avoid partners operating in neighboring markets.

The paper advances technology strategy and licensing theory to make three contributions to the literature. Firstly, licensing has been shown to be a strategic tool for firms in order to optimize management of innovation (Arora et al., 2001a; Lichtenthaler, 2007a). As noted by Chesbrough (2003), a firm' strategy of internally and/or externally exploiting technology constitutes a major driver of performance in the context of growing markets for knowledge. Indeed, answering which firm to choose as a license partner provides insights to technology strategy theorists trying to understand how firms can best exploit external linkages to enhance their competitive positioning. Secondly, by analyzing firms' partnering choice along two dimensions – technology and market proximity – we shine light on the underlying forces determining the functioning of markets for ideas. On the one hand, we highlight the path-dependency nature of the partner' selection process. Technological capabilities define the boundaries of the external landscape firms are able to scout and guide the partner' selection process. On the other side, we provide overall support to the idea that the functioning of markets for technology is related to downstream product markets. Licensing has an impact both on firms' technology portfolio as well as on their product market positioning. We integrate Fosfuri's (2006) framework by taking into account the market positioning of the selected partner rather than the attributes of the product market. In order to concurrently minimize risks of competition and maximize the benefits of technology cooperation, firms would seek a partner operating in different market niches but sharing similar technology domains. Thirdly, past studies have analyzed the licensing phenomenon adopting the perspective of a focal firm (Ceccagnoli et al., 2010; Kim & Vonortas, 2006b; Leone & Reichstein, forthcoming). Although such a lens allows to gaining insights on the factors leading firms to access market for ideas either from the demand or supply side, it underestimates the interdependence between partners in technology exchange through licensing. By adopting a dyad level of analysis, our study provides evidence that the strategic and economic stakes deriving from the establishment a license partnership are linked not only to industry or firm's attributes but also to the synergies with the selected partner.

We test the research hypotheses using data on license agreements in the global biopharmaceutical industry over the period 1994-2004. Two main considerations motivated the choice of the biopharmaceutical industry as the setting of the study. Firstly, the industry is characterized by a distributed innovation model and technology licensing is at the core of firms' innovation strategy, both for large as well as small-medium firms (Arora & Gambardella, 1990; Gans & Stern, 2003). Partner' selection is crucial for firms in order to either feed their internal innovative activity or to appropriate returns from innovation (Arora & Gambardella, 2010; Lichtenthaler, 2007a; Teece, 1986). Secondly, markets for technology have a long tradition in the industry, allowing the gathering of detailed and reliable data.

The remainder of the paper is structured as follows: we first develop our theoretical framework and derive hypotheses. We then present the data and research methods, and report empirical results. Finally, we draw conclusions and identify directions for future research.

2.2 BACKGROUND LITERATURE

As noted by Chesbrough (2006, p. 1): "[f]irms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they look to advance their technology." In a context of distributed innovation, technology licensing represents the most widely used form of technology exchange due to its flexibility either to access external proprietary knowledge or to find markets for unexploited technologies (Arora et al., 2001a).

The existing literature on markets for ideas has posed its attention on two main streams of research: *what are the motives* leading firms to actively access markets for knowledge and *when firms adopt technology licensing* in their innovation strategy.

Concerning the former question, answers have varied. Lichtenthaler (2008) argues that outward technology licensing is determined by two main motives: monetary and strategic ones. On the one side, licensing represents a source of revenues for firms: they sell unexploited innovations, optimizing their internal technology portfolio. On the other side – from a strategic point of view – out-licensing is a way to entry into foreign markets, to set an industry standard and guarantee technological leadership.

The literature investigating the demand-side of markets for technology has proposed numerous factors explaining why firms access the markets. In-licensing provides access to proven technologies and allows firms to keep at the technological frontier (Atuahene-Gima, 1992). Other recent empirical studies have investigated the effect of in-licensing on firms' innovative activity, showing its positive impact both on firms' search strategy as well as time to invention (Laursen et al., 2010; Leone & Reichstein, forthcoming).

Relative to the latter question, namely when firms access markets for knowledge, past studies have provided different explanations. From the licensor's perspective, three main factors have been considered to explain firms' propensity to sell their technologies in the market. In his seminal work, Teece (1986) proposes out-licensing as a way for firms to profit from their innovations when lacking downstream complementary assets. Later, Gans and Stern (2003) and Arora and Ceccagnoli (2006) argue that firms' propensity to licensing is related to the appropriability regime of the industry: the stronger the IPR protection the higher it is firms' propensity to license, contingent on the lack of downstream specialized assets to commercialize new technologies. Finally, Fosfuri (2006) relates firms' licensing behavior to industry characteristics. He provides evidence of the effect of market conditions such as number of technology suppliers, licensor's market share and product differentiation on firms' decisions to sell their technologies.

From the licensee' standpoint, prior literature has proposed two main conditions leading firms to in-source external technologies: downsize in R&D productivity and shortfalls in specific technology domains. Ceccagnoli et al. (2010) show that decreases in firms' internal R&D productivity lead firms to buy technologies in the market, notwithstanding the control of downstream cospecialized assets. Differently, Lowe and Taylor (1998) link in-licensing decisions to firms' perceived technological shortfalls.

Albeit the rich contribution of extant literature in advancing our understanding of the licensing phenomenon, yet very little research has been conducted to investigate a central question in the licensing context: what drives firms in choosing their license partner? The lack of empirical studies investigating such issue is surprising. As pointed out by Vanhaverbeke (2006, p.205): "Companies are increasingly forced to team up with other companies to develop and absorb new technologies, commercialize new products, or simply stay in touch with the latest technological developments." Hence, in a context of distributed innovation, partner' selection process is of fundamental concern in order for firms to capture the benefits of external linkages. Relative to technology licensing, the choice of the partner is critical given the tight interdependence between licensor and licensee to optimize the individual benefits deriving from accessing markets for knowledge (Danneels, 2007). Both for the licensor and the licensee, the positive effects of licensing are contingent on the synergies and complementarities with the partner (Gans & Stern, 2003). Indeed, the effects of a poor partner-match might be detrimental, strongly reducing the benefits from trade for both partners.

The few empirical contributions investigating license formation are by Kim and Vonortas (2006) and Link and Scott (2002). The former study analyzes companies' propensity to engage in license agreements based on a multi-industry dataset on license transactions involving US-traded companies between 1990 and 1999. Firms' incentives to enter into license contracts are explained by sets of variables taking into account the relationship between licensor and licensee, the features of each partner, and the characteristics of the primary industry of the licensor. The empirical findings provided by the study suggest that two firms will likely engage in a license agreement the closer their technological and market profiles, the higher the number of prior agreements between partners, the higher their prior independent experience with licensing, and the stronger the intellectual property protection of the primary industry of the licensor. Differently, Link and Scott (2002) propose a set of measures based on patent citations between the prospective licensor and prospective licensee to predict technology flows through licensing (Link & Scott, 2002). Notwithstanding the empirical contributions to the licensing literature, both studies do not provide a theory about the underlying mechanisms guiding firms in the partner selection process. Further, they do not take into consideration how these mechanisms interact and generate contingencies for one another.

2.3 RESEARCH HYPOTHESES

The study extends past research through the investigation of the underlying mechanisms guiding two firms to enter into a license partnership. The main ingredients of the proposed theoretical framework are the following. First, in developing the research hypotheses we build on the fact that when accessing markets for knowledge both the licensor and licensee aim at achieving specific objectives. For instance, the licensor aims to maximize the expected revenues linked to the sale its technology or differently to maximize the expected probability of successful commercialization of its technology (Lichtenthaler, 2007a; Teece, 1986). Similarly, the licensee aims to exploit the licensed innovation within its internal knowledge endowment effectively. Departing from this observation, it follows that in the partner selection process, firms look for a technology partner that best guarantees the achievement of the expected economic and strategic stakes associated with licensing. The second ingredient of the framework is related to the level of analysis adopted to explain license partnership formation. Due to the tight interdependence between technology partners in benefiting from licensing, we adopt a dyad level of analysis, taking into account the perspective of both licensor and licensee. For instance, licensor' stream of revenues are linked to the capability of the licensee to effectively exploit the licensed innovation. Similarly, for the licensee, the benefits from licensing are linked to the type of skills or markets the licensor provide access with. Finally, the last ingredient of the framework is related to the underlying determinants proposed to explain license formation. Building on innovation and licensing literature, we suggest two underlying dimensions along which license formation occurs: a technology dimension and a product market one. The choice of these two dimensions is due to the fact that technology licensing impacts both firms' technology as well as product-market space (Fosfuri, 2006; Gans & Stern, 2003). In the following subsections, we argue that firms' decision to enter into a license is related to the synergies with the specific technology partner both in terms of management of innovation as well as product-market strategy. We posit that license formation is contingent on both the technology and product-market features of the dyad.

2.3.1 Dyad's technology features

Being the benefits of licensing linked to the technological capabilities of the partner involved in the partnership, we believe it is important to take into account how the dyad's technology attributes impact license formation. More specifically, we focus on two main attributes: partners' differences in terms of technological profiles and the familiarity the licensee has cumulated relative to the licensor's specific technology. Past research on licensing has generally overlooked these constructs, restraining the attention to the link between the licensee's prior knowledge and the licensed technology. For instance, Laursen et al. (2010) decompose licensee's potential absorptive capacity into assimilation capacity and monitoring ability to examine the distance of the in-licensed innovation from the licensee's technology portfolio. Leone and Reichstein (2011) investigate the effect of licensee's familiarity with the specific patent class of the licensed innovation on licensee' speed on invention. Unlike past studies, we posit that the technological interdependencies between partners should be also taken into account in explaining license partner-choice. In the next subsections, we develop hypotheses on the effects of respectively partners' technological diversity and licensee's ex-ante familiarity with licensor's technology on license formation. Following prior studies (Branstetter & Sakakibara, 2002; Jaffe, 1986), we refer to technological diversity as the differences in terms of technological background between partners. Differently, licensee's familiarity with licensor's technology relates to the prior experience the licensee has cumulated about the licensor's specific knowledge base. Building on Roberts and Berry (1985, p.3), we refer to familiarity as "the degree to which knowledge about licensor's technology exists within the company, not necessarily embodied in the products".

2.3.1.1 Partners' technological diversity

An increase in the diversity of the technological domains mastered by the partner firms negatively affect license formation. When partners master different technology domains, the achievement of licensing benefits is at risk for both partners since the absence of a common knowledge set hampers the feasibility of knowledge transfer. Differently from other partnership forms, licensing does not entail communication and interaction mechanisms such as quarterly meetings, joint research teams, etc. (Hagedoorn, 2002). Indeed, when a common shared language between partners is lacking and difficult to develop over time, the feasibility of technology transfer is at risk and consequently the economic and strategic benefits deriving from licensing. For instance, from the licensor' standpoint, choosing a partner with different knowledge foundations might be sup-optimal since it might be difficult and costly to transmit all the knowledge to the licensee in order for the latter to efficiently exploit the licensed technology. Additionally, a large difference in partners' knowledge foundations implies a low degree of technology complementarity and a low level of synergies deriving from the combination of licensor's technology with licensee's. Being the licensee specialized in different technological domains compared to those of the licensor, it might lack fundamental competences and skills to properly assimilate and internalize the licensor's technology. Indeed, the benefits from licensing might be reduced for both partners. The licensee, missing relevant competences, is limited in its ability to learn from a partner with distant knowledge and skills as well as to benefit from the external knowledge acquisition strategy. Similarly, by relying on a partner that lacks important capabilities, the licensor might earn sub-optimal revenues from the external exploitation of its technology portfolio.

Hence, we posit that partners' technology dissimilarities obstacle licensing formation: the costs of knowledge transfer and the absence of a common knowledge ground threaten the benefits firms might derive from entering into the license partnership.

Hypothesis 1 – the likelihood of technology license partnership formation decreases with partners' technological diversity.

2.3.1.2 Licensee's ex-ante familiarity with licensor's technology

Licensee's ex-ante familiarity with licensor' specific technology positively affects license formation through at least three mechanisms. First, licensee's familiarity guides the partner' selection process and decreases search costs relative to finding a technology partner. As contended by organizational learning scholars, firms' search and invention practices tend to be path-dependent (Cohen & Levinthal, 1990). Firms' knowledge base both determines what they make and the directions in which they search: firms tend to cumulate tangible and intangible resources that can be used across a family of related products (Pavitt, 1998). Specifically, earlier studies on technology licensing suggest that the technological trajectories firms pursue when in-licensing new technologies are guided by their pre-existing technological background (Lowe & Taylor, 1998). Following this argumentation, when scouting markets for knowledge and searching for a partner, a licensee is likely to choose the one that allows to best leverage its internal knowledge endowment and whose technology is already familiar with.

Second, the higher the licensee's familiarity with licensor' specific technology the higher the likelihood of success of the knowledge transfer and consequently the higher the benefits partners can derive from entering into the license partnership. Beyond patents and blueprints, licensing often entails the transfer of tacit and highly-contextual knowledge in order to enable the licensee to exploit and internalize the licensed technology (Arora, 1996). Indeed, as outlined by the literature on knowledge transfer, the possession of specific and related knowledge by the recipient firm tends to be an enabling factor in the transfer and absorption process (Cohen & Levinthal, 1990; Mowery, Oxley, & Silverman, 1996; Veugelers & Cassiman, 1999). From the licensor's point of view, the licensee' specific knowledge obviates the need for disclosing additional information to enable the licensee to optimally exploit the licensed innovation. From the licensee' standpoint, it reduces the learning costs since it obviates the need for investments to understand and evaluate the technology. Hence, licensee's familiarity reduces the costs of the knowledge transfer process.

Finally, high familiarity is likely to increase the licensee's effectiveness in commercially exploiting the licensed technology (Leone & Reichstein, forthcoming) and consequently increase the potential benefits deriving from licensing. Prior knowledge about the licensor's specific technology eases both technology integration and recombination with licensee's technology base. Being acquainted with its partner's technology, the licensee is more effective and efficient in mastering the licensed innovation and recombining it with its internal knowledge endowment.

In turn, for both partners, licensee's ex-ante familiarity represents a "win-win situation" in license formation. For the licensor, selecting a knowledgeable partner guarantees a higher probability of successful commercialization of the licensed innovation and consequently higher expected returns from licensing. From the licensee' standpoint, familiarity decreases partner' search costs and enlarges the magnitude of the positive effects deriving from in-sourcing an external technology.

We posit the following:

Hypothesis 2 – the likelihood of technology license partnership formation increases with licensee's ex-ante familiarity with licensor's technology.

2.3.1.3 Combination of licensee's familiarity and partners' technological diversity

The above hypotheses focus on the distinct effect of partners' technology differences and licensee's ex-ante familiarity on license formation. In this section, we propose that these two constructs have interactive effects. More specifically, we argue that the negative effect of partners' technological diversity on license formation is tempered by licensee's familiarity. Licensee's acquaintance with the licensor's technology mitigates issues deriving from the lack of a shared communication language between partners and dissimilarities in knowledge foundations. Being the licensee familiar with the licensor's technology, it possesses that relevant knowledge to properly assimilate and internalize distant knowledge. The licensee's ex-ante familiarity decreases the costs of selecting a partner with distant competences and allows both firms to benefit from the combination of distant knowledge domains. From the licensor' standpoint, partnering with an acquainted licensee that masters distant technology domains represents the opportunity to find new technological applications of its innovation. For the licensee, it represents the opportunity to leverage its prior knowledge and access distant technological niches through licensing.

Hypothesis 3 – the likelihood of technology license partnership formation is positively related to the interaction between licensee's ex-ante familiarity with licensor's technology and partners' technological diversity.

2.3.2 Dyad's market feature

2.3.2.1 Partners' market proximity

Past licensing literature has emphasized the double level of analysis that should be adopted in evaluating firm's licensing behavior: technology and market level. Licensing decisions impact both a firm's technology space as well as market one (Arora et al., 2001a; Fosfuri, 2006). Indeed, we argue that in selecting their licensing partner, firms should also consider the implications and effects of their partner's relative market positioning. More specifically, we expect that if two firms operate in the same market, they are less likely to form a license partnership. Two mechanisms underlie our hypothesis: market competition and firms' strategic interdependence.

From the licensor's perspective, selling a technology to a firm operating in the same product market might be sub-optimal for at least two reasons. When out-licensing its technology, the licensor signs over the intellectual property on its technology, providing the licensee with the right to exploit and sell the innovation. Hence, prospective licensors are loath to license their technology to firms with similar market profiles due to the high potential for creating strong competitors (Kim & Vonortas, 2006a). Following Fosfuri (2006), such a choice would generate a profit dissipation effect: licensor's profits from its innovation would reduce as a consequence of an additional firm competing in the product market. Secondly, by partnering with a market proximate licensee, the licensor might lose its technological leadership and consequently weaken its competitive advantage (Choi, 2002). Since the licensee is akin to the licensor's in terms of market segment knowledge and skills, it might be capable to further develop the licensed innovation and produce an improved version of it, undermining licensor's competitive advantage.

The other mechanism determining the negative effect of partners' market proximity on license formation is related to the concept of strategic interdependence, widely used to explain inter-firm partnership formation (Chung, Singh, & Lee, 2000; Gans & Stern, 2003; Gulati, 1995b; Teece, 1986). As posited by Gulati (1995) strategic interdependence refers to a situation in which one organization has resources and capabilities beneficial but not possessed by the other. According to this view, firms are likely to establish links with those firms that guarantee access to resources such as specialized skills and access to particular kinds of markets. By applying the concept of strategic interdependence to license formation, it follows that from both partners' perspective, signing a license with a market proximate partner might not provide novelty in terms of access to market resources and skills. Since the licensor and the licensee operate in the same product market, they share similar operating protocols and market-knowledge foundations, hence the benefits in terms of access to new resources is low for both.

Hypothesis 4 – the likelihood of technology license partnership formation decreases if partners are market proximate.

2.3.2.2 Interaction between partners' market proximity and technological diversity

In the previous section we argued that licensing decisions impact both the technology space as well as the product market space of the firm. Hence, in assessing how firms choose their licensing partner, we need to take into account the interaction between the two forces and their concurrent effect on license formation. On the one side, firms look for a partner operating according to similar knowledge foundations in order to maximize the effectiveness of knowledge transfer and the benefits deriving from licensing (Hypothesis 1). On the other side, firms wish to profit from strategic interdependence and avoid the negative downsides related to increased competition, searching for a partner operating in different market segments (Hypothesis 4). Despite the importance of avoiding competitive threats and leverage strategic interdependence, we argue that the benefits of selecting a partner operating in different product markets might negatively impact the knowledge transfer process if partners possess different technology foundations. As a matter of fact, we expect firms to balance the tension between technology and market forces. In order to maximize the benefits from partnering either in terms of technology as well as market positioning, firms are likely to choose partners operating in different product markets but sharing similar technology domains. From the licensor's point of view such a choice is beneficial for at least two reasons. First, it can rely on a partner that shares similar knowledge foundations but does not compete in the same product market. Further, given the possibility of selling its technology in different product markets from the one it competes, the licensor can best exploit its technology portfolio by maximizing the revenue effect deriving from licensing (Gambardella & Giarratana, 2011). From the licensee' standpoint, selecting a partner operating in a different product market but operating according to similar technology foundations might be an important source of product innovation. As noted by Pavitt (1998), from the same or very similar base of technological knowledge different product or process configurations can be generated. The licensee might introduce in its market novel combinations in terms of products.

Hence, we posit that:

Hypothesis 5 – if partners are market distant, the likelihood of technology license contractual partnership decreases with partners' technological diversity.

2.4 DATA AND METHODS[1]

2.4.1 Research setting and sample

The sample for this study was drawn from the population of technology license partnerships in the global pharmaceutical and biotechnology industry during the period 1994-2004. Three considerations motivated the choice of the biopharmaceutical industry as the research setting of the study. Firstly, licensing is a key strategic instrument in order for firms both to stay at the forefront of technological development and optimize the internal R&D activity (Arora et al., 2001a). In the past 30 years, with the advent of the biotechnology trajectory and the decoupling of drug discovery from drug development, the industry experienced a vertical division of innovative labor between firms (Arora & Gambardella, 1990; Pisano, 2006). Consequently, due to the industry structure and the change in the locus of learning, choosing and establishing links with external partners have become vital for both large and small-medium firms (Powell, Koput, & Smith-Doerr, 1996). Secondly, markets for knowledge have a long tradition in the industry (Fosfuri & Giarratana, 2010), allowing to gather detailed and reliable data on technology license agreements. Finally, the industry is characterized by a "tight" appropriability regime: the strength of intellectual property right protection is high compared to other

[1] Since the thesis builds on a single dataset, the "methods" sections of the three papers share common arguments and information relative to the choice of the research setting, the creation of the research sample, and variables' operationalization.

industries (Cohen, Nelson, & Walsh, 2000). Such industry condition allows to avoid potential bias in explaining license formation caused by licensors' inability to profit from the licensed technology[2].

Since the study investigates the factors affecting the likelihood two firms will form a license partnership, the unit of analysis is the dyad between a potential licensor and a potential licensee. The analysis covers the period 1994-2004. For each year, from the set of available license contracts, we identified unique licensors, licensees and firms, which were both licensors and licensees; we then created the opportunity set of potential license partnerships that is represented by all the feasible dyads within that year. In order to avoid bias in the analysis, dyads involving as licensor and licensee the same firm were deleted. On the contrary, reverse-ordered dyads were kept, that is if firm A sells a technology to firm B, its reverse, namely firm B sells a technology to firm A, is kept[3].

The resulting data structure is a cross-section dataset where the unit of analysis is the dyad and each record reports the state of the dependent variable indicating whether the license actually occurred or not and a set of variables related to the dyad's attributes as well as to both licensor and licensee's characteristics. We did not compile the dataset according to a panel structure, since the analysis includes both large and small-medium firms and for these latter types we were not able to reconstruct their history and infer whether they were active during all the period under analysis (1994-2004). Unlike previous studies on license formation (Kim & Vonortas, 2006a; Link & Scott, 2002), we did not restrain our attention just to large firms. This

[2] Arora and Ceccagnoli (2006) provide evidence that the industry appropriability regime affects firms' licensing behavior. Similarly, Gans and Stern (2003) analyze entrepreneurial companies' decisions to out-license their technologies contingent of the type of appropriability of an industry, highlighting that patents favour the rise and growth of markets for ideas.

[3] This case occurs if both firm A and firm B in that particular year act both as licensor as well as licensee.

choice provides a deeper and more general understanding of the underlying mechanisms guiding license formation, especially in an industrial setting where most transactions occur between small-medium and large firms (Stuart, Ozdemir, & Ding, 2007).

2.4.2 Data

The main source of information we used to compile the dataset was Deloitte Recap database. The dataset represents the most complete reference for R&D partnerships in the biopharmaceutical industry (Schilling, 2009). It provides access to original contractual agreements, covering a wide range of collaborations: technology licensing, R&D collaborations, joint ventures, co-marketing agreements, etc. Beyond Deloitte Recap dataset, for each firm in the sample, we retrieved information relative to its patenting and market activity as well as size and complementary assets from three other major data sources: the National Bureau Economic Research dataset, the FDA database and Compustat. By matching the name of both partners with assignees' names recorded in the NBER dataset (Hall et al., 2001), we could obtain firms' patent portfolios and statistics related to their innovative activity. Next, we used the FDA dataset, which contains information relative to the drugs approved by the US Food and Drug Administration. Such data allowed to proxy for licensees' downstream complementary assets. Finally, from Compustat we retrieved data on firms' primary reference market – SIC codes – and size in terms of number of employees.

Since the industry comprises a set of large firms usually operating in the market through a set of affiliates and subsidiaries, we computed all the variables at the firm level, using *Who Owns Whom* (1999) database to reconstruct each firm company structure in terms of subsidiaries and affiliates. We also took into account major M&A activities during the period under analysis.

2.4.3 Variables

Dependent variable Our model investigates the likelihood firms *i* and *j* enter into a license partnership. Hence, the dependent variable is a categorical one taking value of 1 if partners sign a license, 0 otherwise.

Independent variables Following the aim of the study, three explanatory variables are taken into account to explain license partnership formation: partners' technological diversity, licensee's ex-ante familiarity with licensor's technology and partners' market proximity.

For each dyad in the sample, we computed the degree to which partners' knowledge bases were drawing from the same technological domains. Similarly to Kim and Vonortas (2006), we operationalized *partners' technological diversity* taking into consideration partners' patent distributions across three-digits USPTO patent classes. Next, on the base of partners' patent distributions we constructed an index that measures the degree of technological overlap between the potential licensor and licensee:

$$\text{Technological diversity} = 1 - \frac{F_i F_j^{'}}{(F_i F_i^{'})(F_j F_j^{'})} \text{ with } i \neq j$$

The variable ranges from 0 to 1 with values close to 1 indicating the highest technological diversity between partners. F_i is the patent distribution of firm *i* across USPTO patent classes; F_j is the patent distribution of firm *j* across USPTO patent classes. The choice of measuring partners' technological synergies using patent classes is due to the fact that patents are classified according to the underlying technology rather than to the final product market (Griliches, 1990; Patel & Pavitt, 1995). Hence, by using patent classes we were able to differentiate between partners' similarities in the technology space from partners' similarities in the product space.

Licensee's ex-ante familiarity with licensor's technology was measured through patent citations. The choice of using patent citations is linked to the fact that they represent knowledge flows and more importantly a technology lineage between firms (Jaffe, Trajtenberg, & Henderson, 1993; Mowery et al., 1996). For instance, citations of the patents of firm A by the patents of firm B means that B is building on the technology of A and consequently that B is familiar with firm A's technology. For each dyad in the sample the ratio between the licensee's citations to the licensor's patents and the potential licensee's overall citations up to the license year was computed. Such operationalization allows to measure the degree to which the potential licensee has experimented the potential partner's technology in its innovative activity before the license year. Indeed, it proxies the relative prior knowledge about licensor's technology the potential licensee has cumulated before the license year. The higher the number of citations to licensor's patents relative to the licensee's overall citations, the higher the licensee's prior knowledge of its potential partner.

Partners' market positioning is measured on the basis of firms' primary SIC codes. We created the variable *market proximity*, which equals to 1 if the potential licensor and potential licensee operate in the same product market, 0 otherwise. Unlike past studies (Kim & Vonortas, 2006a; Leone & Reichstein, forthcoming), for constructing the variable we took into account firms' primary SIC codes at four digits level. Such choice allows to have a narrower market classification. Indeed, according to the U.S. classification system, the first two digits of the code identify the major industry group, the third digit identifies the industry group and the fourth digit identifies the industry (USCensusBureau, 1993).

Control variables In order to account for other effects, we included a number of controls that according to prior research are expected to affect license formation.

The first control is *partners' past ties*. License formation might be guided by the familiarity partners have cumulated through prior ties. Past interactions, in fact, favour learning and cooperation. Additionally, being firms familiar with one another behavior and managerial style, knowledge transfer is eased (Gulati, 1995a; Kim & Vonortas, 2006a). Hence, we expect the existence of prior ties to positively influence license formation. In order to control for such competing explanation, we created the variable *partners' past ties,* which counts the number of prior license partnerships partners have formed before the license year.

Past research considers licensing as a way to access complementary upstream or downstream assets (Ceccagnoli et al., 2010; Teece, 1986). In the selection process, firms might be guided by the type and level of complementary assets owned by the potential partner. To account for this alternative explanation, we created the variable: *licensee's downstream assets*. In selecting a prospective licensee, the licensor might look for a partner with extensive downstream capabilities in order to maximize the likelihood of successful commercialization of its technology. We operationalized licensee's downstream asset counting the number of drugs commercialized by the prospective licensee up to the license year. Given the vertical division of labor characterizing the pharmaceutical industry and the high barriers to commercialize a new drug (Pisano, 2006), we consider the variable to be a good proxy for measuring the level of specific downstream complementary assets controlled by a prospective licensee. Differently, adopting the licensee' standpoint, it might look for a partner with extensive upstream capabilities in terms of research and development in order to feed its internal innovative activity (Ceccagnoli et al., 2010). For capturing the licensor's upstream assets, we constructed two variables: *prospective licensor's patent stock* and *licensor's upstream research capabilities*. Following prior studies (Gambardella et al., 2007), the former was used to proxy the scale of licensor's inventive activity and thereby the pool of potential technologies that might be out-licensed; the latter for licensor's attractiveness as a research partner. For each prospective licensor, we computed respectively the number of patents applied up to the license year and the number of R&D contracts signed up to the license year. The information relative to R&D contracts was retrieved from Recap dataset.

Since we believe the prospective licensee's patenting activity might positively influence license formation, we account for this introducing the variable *licensee's patent stock*. The variable counts the number of patents applied by the prospective licensee up to the license year. The variable was used to proxy licensee's overall absorptive capacity. Compared to the explanatory variable licensee's ex-ante familiarity with licensor's technology, it is a more crude proxy since it does not directly relate to licensor' specific technology. However, it accounts for a global capability of the licensee to identify and exploit external knowledge.

We also control for firms' size by including in the model *licensor and licensee' size*, which measure the number of employees of respectively the prospective licensor and licensee. Past literature points out the different exploitation of markets for technology by large and small-medium firms (Gambardella et al., 2007; Gans & Stern, 2003).

Finally, we created a set of dummy variables for each year of the period under analysis to account for time trends and industry shocks that might affect license formation.

2.4.4 Econometric method

The empirical analysis is based on the estimation of a discrete choice model, namely a standard logit model[4]. Since our dependent variable – license formation – is a binary one, the OLS is inappropriate as it assumes the dependent variable to be continuous and unbounded (Long & Freese, 2006). We estimate the model using interaction terms:

$$\Pr(Y = 1) = \pi_i = \Lambda(\beta_0 + \beta_1 TD + \beta_2 AC + \beta_3 AC \times TD + \beta_4 MKT + \beta_5 MKT \times TD + \varepsilon_i)$$

More specifically, the equation estimates the probability two firms will form a license partnership as a function of a set of covariates. On the right hand side of the equation, *TD* measures the diversity of partners' technology profiles; *AC* is the ratio between licensee's citations to licensor's technology and licensee's overall citations; *MKT* is the dummy variable indicating whether firms are market proximate. The first interaction term serves to assess the tempering effect of licensee's familiarity on partners' technological diversity; the second one is a formal test of the interactive effect of partners' market proximity and technological diversity on license formation. Finally, *e* is the error term.

For robustness check, a rare event logit is also estimated. We fit a rare event logit in order to account for the large number of zero counts in the data and avoid potential

[4] Results are significantly robust under a probit specification. We chose to fit a logit model rather than a conditional logit model due to our focus on both partners' perspectives.

downward biases in probability estimation that could arise fitting a logit model (King and Zend, 2001).

2.5 RESULTS

Table 1 and 2 show respectively the descriptive statistics and correlation coefficients for all variables. We observe a total of 13379 possible dyad combinations and the average of license formation is 3 percent. The absence of high correlations between the independent variables as well as the controls suggests that multicollinearity is unlikely to be problematic in this analysis. Moreover, prior to the creation of interaction terms, *licensee's familiarity with licensor's technology* and *partners' technological diversity* were mean-centered to reduce potential multicollinearity issues (Jaccard, Turrisi, & Wan, 1990).

Insert Table 1 and 2 about here

Table 3 depicts our statistical analysis results. Model 1 is the base model that includes only control variables. Model 2 to 6 introduce variables in differing combinations to test for robustness in our results.

Insert Table 3 about here

The logit model is a non-linear model, hence the regression coefficients cannot be interpreted as marginal effects as in linear models. As noted by Hoekter (2007, p.334): "[t]he effect of the change in one variable depends on the initial probability of the event occurring (equivalently, on the values of other variables)." Hence, we also compute marginal effects and report them in table 4. Further, results interpretation is non-trivial when interaction terms are included in the model. Unlike in the OLS case, in a logit specification the marginal effect of an interaction between two variables is not simply the coefficient for their interaction: the magnitude and sign can differ across observations (Norton, Wan, & Ai, 2004). In order to overcome such an issue and provide a consistent statistical testing of the effects of interaction terms on license formation, we computed marginal effects both setting variables at meaningful values (Hoetker, 2007) as well as through a simulation procedure (Zelner, 2009).

Insert Table 4 about here

Insert Figure 1 and 2 about here

Hypothesis 1 predicts a negative relationship between partners' technological diversity and the likelihood of license partnership formation. In table 3, the coefficient is negative as expected and significant. Hence, hypothesis 1 is supported.

Hypothesis 2 predicts a positive relationship between licensee's familiarity with licensor's technology and the likelihood of license partnership formation. Results support our conjecture: the estimated coefficient is positive and significant.

Hypothesis 3 tests the positive effect on license formation of the interaction between partners' technological diversity and licensee's familiarity. To test the sign and significance of the interactive term, we used both the STATA 11 function "margins" as well as the simulation approach proposed by Zelner (2009). In both cases, we tested the significance of the change in probability for changes in licensee's familiarity and technological diversity between partners, obtaining empirical support for hypothesis 3. Figure 1 depicts the change in predicted probability of our dependent variable, reporting 95 percent confidence intervals.

Hypothesis 4 states that there is a negative relationship between partners' market proximity and the likelihood of license partnership formation. Looking at model 6 in table 3, we find empirical support of the negative effect of firms' market proximity on the likelihood of license formation. The coefficient is negative and significant at 10 percent level[5].

Hypothesis 5 states positive interaction effects between partners' market proximity and technological diversity. To test the empirical validity of hypothesis 5, we followed the procedure adopted to test hypothesis 3. Both using a simulation approach as well as computing average marginal effects of market proximity for different values of technological diversity we get a confirmation of our hypothesis. When partners have distant technological bases and are market proximate, the likelihood of license formation increases. Or put differently, when partners are not market proximate but share similar knowledge foundations, the likelihood of license formation increases.

The results of the control variables provide interesting insights. The existence of former license ties between partners has a positive effect on license formation. From the analysis it emerges the role of past ties in guiding firms in discovering new opportunities of collaboration. This result is in line with past research on alliances, where past ties have been documented to reduce partners' information asymmetries,

[5] The result contrasts with the empirical findings provided by past studies (Kim & Vonortas, 2006). We conjecture that the difference in the results is related to the fact that in measuring partners' market proximity we employed a more fined-grained level of analysis, taking into consideration a narrower definition of market. This allowed to proxy the market segmentation of the industry.

generate trust and ease the discovery of new technological opportunities (Gulati, 1995b; Kim & Vonortas, 2006b). Results also report the effect of partners' technological size on license formation. As expected, the larger the licensee's knowledge stock the higher the likelihood to form a license. Differently, an increase in the licensor's knowledge stock has a negative effect on license formation. The result confirms prior literature relative to the potential adverse selection issues deriving from partnering with a large counterpart. Large firms usually tend to out-license low value technologies (Gambardella et al., 2007; Sakakibara, 2010). Hence, such a risk might induce firms to avoid in-sourcing technologies from a licensor with a large patent stock.

2.5.1 Robustness check

As discussed in the previous section, one important econometric concern is the large number of zeros in the dependent variable. To account for this potential problem, we estimated a rare event logit (King & Langche, 2001). A rare event logit computes probability estimates that correct problems due to rare events. More specifically, it generates approximately unbiased and lower-variance estimates of logit coefficients and their variance-covariance matrix, correcting for downward biases in probability estimation. Estimation results are shown in table 5. All variables maintain their sign and significance[6].

Insert Table 5 about here

----

[6] Marginal effects were also computed with no substantial differences compared to those estimated through the logit model.

We also tested the robustness of our results by changing the specification of some theoretical variables.

We restimated the model by operationalizing market proximity on the base of licensor and licensee' SIC codes at two and three digit levels. Under both specifications, the estimated coefficients measuring partners' market proximity present a negative sign as predicted, however main coefficients are not significant. Differently, the interaction effect with the variable partners' technological diversity remains positive and significant as in the model with four digits level specification.

The second explanatory variable whose specification we change is partners' technological diversity. In the previous section we measured the degree of partners' overlapping knowledge bases by taking into account licensor and licensee's patent distributions across all USPTO patent classes. Such a choice was mainly due to the fact that in the biopharmaceutical industry firms have heterogeneous knowledge stocks encompassing different technical classes, in some cases well beyond the pharmaceutical and biotech domains (Patel & Pavitt, 1995). We restimated the model by restricting our attention to major technological classes of the biopharmaceutical industry, in order to check if the previous specification was simply capturing industrial differences in technology domains. We obtain qualitatively similar results from this specification.

2.6 DISCUSSION

In this study we examined factors guiding firms in selecting their license partner. By adopting as unit of analysis the dyad, we tested the effect of dyad's technology and market attributes on the likelihood of license partnership formation. The results indicate support for our theoretical predictions. On the one hand, both the licensor as well as the licensee look for a partner with high technology synergies, in order to maximize licensing benefits and obviate issues related to technology transfer and knowledge recombination. On the other hand, firms wish to find a partner operating in different product markets from the one they compete in order to minimize competitive downside issues as well as access different resources in terms of product markets and skills. Interestingly, we show the interdependence between technology and market forces. License formation is likely when firms compete in different product markets but share similar knowledge foundations.

2.6.1 Theoretical contributions

The study advances current technology strategy and licensing literature into three main respects. First, we have examined in detail what guides firms to select their license partner and enter into a license partnership. As such, the paper is among the first quantitative study analyzing license formation. Past literature has devoted much of its attention to understand why and when firms access markets for knowledge, analyzing the demand and supply side of the market separately (Arora et al., 2001a; Arora & Gambardella, 2010). The adoption of a dyad level of analysis rather than that of a focal firm helped us in understanding the factors determining firms' choice of their licensing partner and more importantly factors that may prevent the formation of license partnerships and consequently the growth of markets for ideas. Results show the key importance of licensee's prior knowledge about its potential partner and the presence of technological similarities between potential partners.

Second, by analyzing whom firms select as a license partner, we shed light on the underlying forces determining the functioning of markets for knowledge. Specifically, we integrate past research by providing empirical support to the idea that technology licensing impacts firms' strategies at two level of analysis: a technological and a market one. Past studies have mainly analyzed such a duality accounting for industry specific features, for instance number of potential vendors of the same technology, market concentration (Fosfuri, 2006; Kim & Vonortas, 2006b). The adoption of a dyad level of analysis allowed to show that such a duality is also linked to the partners involved in the transaction and more specifically to their interdependence both from a technological point of view as well as market positioning one. When forming a license partnership, firms should maximize technology cooperation with the partner in order to extract the highest benefits from the linkage and concurrently minimize the risks of competitive downsides in product markets.

Finally, the empirical analysis highlights important factors that may thrive technology markets growth. At an industry level, due to the tight interdependence between technology cooperation and market competition, the presence of fragmented product markets would ease markets for ideas growth. The presence of different market segments would relax competitive issues, allowing firms to optimally exploit markets for ideas (Gambardella & Giarratana, 2011). Differently, at a firm level, the findings highlight the central role of specific abilities in order for firms to benefit from the establishment of external linkages through licensing. We provide support to the idea that the capability of developing general purpose technologies is key for firms to benefit from technology licensing (Arora et al., 2001a; Gambardella & Giarratana, 2011). From the licensor's point of view, it is core to develop technologies that can be amenable to many market applications and underlie many products that are unrelated to its own product business. Indeed, such ability would provide with the opportunity to maximize licensing benefits and minimize risks of competition when selecting a partner. Another key related factor the study highlights is firm's capability of identifying licensing opportunities. Innovation research notes that the potential of firm's technological competencies may extend beyond the boundary sets of its product market strategy (Danneels, 2007; Gambardella & Torrisi, 1998; Pavitt, 1998). Hence, in order to balance the trade-off between technology cooperation and product-market competition, it is key for the licensor to develop a broad understanding of applications and markets. This capability of opportunity identification would allow to best leverage its technology portfolio by finding potential partners in distant product markets. Differently, from the licensee's perspective, the study shows that opportunity identification is mainly dependent on its prior knowledge and more specifically on the level of prior experience with potential partners' specific technologies. The licensee is able to scout and identify distant technology partners by leveraging its prior specific knowledge.

2.6.2 Managerial implications

The study has clear managerial implications. Given the strategic and monetary stakes deriving from engage in a license partnership, the study provides a framework of reference for licensing managers in order to determine which license partner to choose. More specifically, it draws attention to the importance of considering the dual effect of technology licensing both in terms of management of innovation as well as in terms of product market strategy.

Further, from the licensee's perspective, our findings justify firms' long term investments in internal innovative activity and more importantly in cumulating knowledge and experimenting with other firms' technology. Such investments represent an important leverage to access technology markets and establish links with partners operating in distant knowledge domains.

2.6.3 Limitations and future research directions

Our work is inevitably limited by a number of considerations, which also represent future research opportunities. First, the study restrained its analysis to license formation and did not take into account any performance measure. Hence, from the analysis we cannot infer about the potential success of the license partnership and eventually on its effect on each partner's performance. Future research might investigate the link between the dyad structure of a license partnership and its performance over time.

Second, we measured partners' market proximity using SIC codes. If on the one side, this choice allowed to get an objective and robust measure of the primary market positioning of each firm (Kim & Vonortas, 2006a; Mowery, Oxley, & Silverman, 1998); on the other hand, it does not capture the fact that many firms operate in different market segments given their heterogeneous and large knowledge bases (Patel & Pavitt, 1995). Hence, future studies could analyze license formation employing a more fine-grained measure of partners' market proximity taking into account that some firms are multi-products. This would allow to include in the analysis the effect of the number of market segments potential partner firms directly compete.

Lastly, although we believe our hypotheses are general enough to be extended to other settings, we should be cautious in generalizing the results. We developed our study in a science-based industry where "bodies of practice" are tightly linked to "bodies of knowledge" (Pavitt, 1998). Hence, we hope that future studies will extend our analysis to other industries where the distance between technical knowledge and market knowledge is larger. Such an extension might further reinforce our findings relative to the tight interdependence between technology cooperation and product-market competition.

2.7 CONCLUSIONS

The study investigates license formation and the underlying mechanisms guiding firms in choosing their license partner. By doing so, it sheds light on the dual level of analysis at which license formation occurs. From a technological point of view, firms look for a partner with high technology overlapping and which has cumulated prior specific experience. Differently, from a product-market perspective, firms look for a partner operating in different market segments in order to avoid competitive downsides as well as to access different sets of skills in terms of product and market knowledge. Centrally, we show the interdependence between technology and market forces: if partners are market distant, the likelihood of technology license contractual partnership decreases with partners' technological diversity.

Since markets for knowledge are central to firms' technology strategy, we hope this study will help reinforce the exploration of the factors leading to the rise, development and success of license partnerships.

References

Arora, A. 1996. Contracting for tacit knowledge: the provisions of technical services in technology licensing contracts. ***Journal of Development Economics***, 50(2): 233-256.

Arora, A., & Ceccagnoli, M. 2006. Patent protection, complementary assets, and firms' incentives for technology licensing. ***Management Science***, 52(2): 293-308.

Arora, A., Fosfuri, A., & Gambardella, A. 2001. ***Markets for technology: The economics of innovation and corporate strategy***. Cambridge, Massachusetts: The MIT Press.

Arora, A., & Gambardella, A. 1990. Complementarity and external linkages: the strategies of the large firms in biotechnology. ***Journal of Industrial Economics***, 38(4): 361-379.

Arora, A., & Gambardella, A. 2010. Ideas for rent: an overview of markets for technology. ***Industrial and Corporate Change***, 19(3): 775-803.

Athreye, S., & Cantwell, J. 2007. Creating competition? Globalisation and the emergence of new technology producers. ***Research Policy***, 36(2): 209-226.

Atuahene-Gima, K. 1992. Inward technology licensing as an alternative to internal R&D in new product development: a conceptual framework. ***Journal of Product Innovation Management***, 9: 156-167.

Branstetter, L. G., & Sakakibara, M. 2002. When do research consortia work well and why? Evidence from Japanese panel data. ***The American Economic Review***, 92(1): 143-159.

Ceccagnoli, M., Graham, S. J. H., Higgins, M. J., & Lee, J. 2010. Productivity and the role of complementary assets in firms' demand for technology innovations. ***Industrial and Corporate Change***, 19(3): 839-869.

Chesbrough, H. 2003. ***Open Innovation: the new imperative for creating and profiting from technology***. Boston: Harvard Business School Press.

Chesbrough, H., Vanhaverbeke, W., & West, J. 2006. ***Open innovation: Researching a new paradigm***. Oxford: Oxford University Press.

Choi, J. P. 2002. A Dynamic Analysis of licensing: the "Boomerang" effect and grant-back clauses. ***International Economic Review***, 43(3): 803-829.

Chung, S., Singh, H., & Lee, K. 2000. Complementarity, status similarity and social capital as drivers of alliance formation. ***Strategic Management Journal***, 21(1): 1-22.

Cohen, W., Nelson, R., & Walsh, JP. 2000. Protecting their intellectual assets: appropiability conditions and why U.S. manufacturing firms patent or not. ***NBER Working Paper n. 7552***.

Cohen, W. M., & Levinthal, D. 1990. Absorptive capacity: A new perspective on learning and innovation. ***Administrative Science Quarterly***, 35(1): 128-152.

Danneels, E. 2007. The process of technological competence leveraging. ***Strategic Management Journal***, 28(5): 511-533.

Fosfuri, A. 2006. The licensing dilemma: understanding the determinants of the rate of technology licensing. ***Strategic Management Journal***, 27(12): 1141-1158.

Fosfuri, A., & Giarratana, M. S. 2010. Introduction: Trading under the Buttonwood--a foreword to the markets for technology and ideas. ***Industrial and Corporate Change***, 19(3): 767-773.

Gambardella, A., & Giarratana, M. S. 2011. General technological capabilities, product market fragmentation and markets for technology: evidence from the software security industry. ***Working paper***.

Gambardella, A., Giuri, P., & Luzzi, A. 2007. The market for patents in Europe. ***Research Policy***, 36: 1163-1183.

Gambardella, A., & Torrisi, S. 1998. Does technological convergence imply convergence in markets? Evidence from the electronics industry. ***Research Policy***, 27(5): 445-463.

Gans, J. S., & Stern, S. 2003. The product market and the market for ideas: commercialization strategies for technology entrepreneurs. ***Research Policy***, 32: 333-350.

Griliches, Z. 1990. Patent statistics as economic indicators: A survey. ***Journal of Economic Literature***, 28(4): 1661-1707.

Gulati, R. 1995a. Does familiarity breed trust? The implications of repeated ties for contractual choice in alliances. ***Academy of Management Journal***, 38(1): 85-112.

Gulati, R. 1995b. Social structure and alliance formation patterns: a longitudinal analysis. ***Administrative Science Quarterly***, 40(4): 619-652.

Hagedoorn, J. 2002. Inter-firm R&D partnerships: an overview of major trends and patterns since 1960. ***Research Policy***, 31: 477-492.

Hagedoorn, J., Lorenz-Orlean, S., & van Kranenburg, H. 2008. Inter-firm technology transfer: partnership-embedded licensing or standard licensing agreements? ***Industrial and Corporate Change***, 18(3): 529-550.

Hall, B., Jaffe, A., & Trajtenberg, M. 2001. The NBER patent citations data file: lessons, insights, and methodological tools. ***NBER Working Paper***, 8498.

Hoetker, G. 2007. The use of logit and probit models in strategic management research: critical issues. ***Strategic Management Journal***, 28: 331-343.

Jaccard, J., Turrisi, R., & Wan, C. 1990. ***Interaction effects in multiple regression***. Newbury Park, California: Sage Publications Inc.

Jaffe, A. 1986. Technological opportunity and spillovers of R&D: evidence from firms' patents, profits and market value. ***The American Economic Review***, 76(5): 984-1001.

Jaffe, A., Trajtenberg, M., & Henderson, R. 1993. Geographic localization of knowledge spillovers as evidenced by patent citations. ***The Quarterly Journal of Economics***, 108(3): 577-598.

Kim, Y., & Vonortas, N. 2006a. Technology licensing partners. ***Journal of Economics and Business***, 58(4): 273-289.

Kim, Y., & Vonortas, N. S. 2006b. Determinants of technology licensing: the case of licensors. ***Managerial and Decision Economics***, 27(4): 235-249.

King, G., & Langche, Z. 2001. Logistic regression in rare events data. ***Political Analysis***, 9(2): 137-163.

Laursen, K., Leone, M. I., & Torrisi, S. 2010. Technological exploration through licensing: new insights from the licensee's point of view. ***Industrial and Corporate Change***, 19(3): 871-897.

Leone, M. I., & Reichstein, T. forthcoming. Licensing-in fosters rapid invention! The effect of the grant-back clause and technological unfamiliarity. ***Strategic Management Journal***.

Lichtenthaler, U. 2007a. Corporate technology out-licensing: Motives and scope. ***World Patent Information***, 29(2): 117-121.

Lichtenthaler, U. 2007b. The drivers of technology licensing: an industry comparison. ***California Management Review***, 49(4): 67-89.

Link, A., & Scott, J. 2002. Explaining observed licensing agreements: toward a broader understanding of technology flows. ***Economis of Innovation and New Technology***, 11(3): 211-231.

Long, J. S., & Freese, J. 2006. ***Regression models for categorical dependent variables using Stata***. College Station, Texas: Stata Press.

Lowe, J., & Taylor, P. 1998. R&D and technology purchase through licence agreements: complementary strategies and complementary assets. ***R&D Management***, 28(4): 263-278.

Mowery, D. C., Oxley, J. E., & Silverman, B. S. 1996. Strategic alliances and interfirm knowledge transfer. ***Strategic Management Journal***, 17: 77-91.

Mowery, D. C., Oxley, J. E., & Silverman, B. S. 1998. Technological overlap and interfirm cooperation: implications for the resource-based view of the firm. ***Research Policy***, 27(5): 507-523.

Norton, E. C., Wan, C., & Ai, C. 2004. Computing interaction effects and standard errors in logit and probit models. ***The Stata Journal***, 4(2): 154-167.

Patel, P., & Pavitt, P. 1995. Patterns of technological activity: their measurement and interpretation., ***Handbook of the Economics of Innovation and Technical Change***. Oxford: Blackwell.

Pavitt, P. 1998. Technologies, products and organization in the innovating firm: what Adam Smith tells us and Joseph Schumpeter doesn't. ***Industrial and Corporate Change***, 7(3): 433-452.

Pisano, G. 2006. Can science be a business? Lessons from biotech. ***Harvard Business Review***, 84(10): 114-125.

Powell, W. W., Koput, K., & Smith-Doerr, L. 1996. Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology. ***Administrative Science Quarterly***, 41: 116-145.

Roberts, E., & Berry, C. 1985. Entering new businesses: Selecting strategies for success. ***Sloan Management Review***, 26(3): 3-17.

Sakakibara, M. 2010. An empirical analysis of pricing in patent licensing contracts. ***Industrial and Corporate Change***, 19(3): 927-945.

Schilling, M. A. 2009. Understanding the alliance data. ***Strategic Management Journal***, 30(3): 233-260.

Stuart, T., Ozdemir, S., & Ding, W. 2007. Vertical alliance networks: The case of university–biotechnology–pharmaceutical alliance chains. ***Research Policy***, 36(4): 477-498.

Teece, D. J. 1986. Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. ***Research Policy***, 15: 285-305.

USCensusBureau. 1993. Aggregation structures and hierachies. ***US Census Bureau Issue paper n.2***.

Veugelers, R., & Cassiman, B. 1999. Make and buy in innovation strategies: evidence from Belgian manufacturing firms. ***Research Policy***, 28: 63-80.

Zelner, B. A. 2009. Using simulation to interpret results from logit, probit, and other nonlinear models. ***Strategic Management Journal***, 30(12): 1335-1348.

APPENDIX: MAIN TABLES AND FIGURES

TABLE 1. Descriptive statistics

	Source	N	Mean	s.d.	Min	Max
Dependent variable						
Probability to form a license partnership	Deloitte Recap	13379	0.02	0.15	0.0	1
Main independent variables						
Technological diversity	NBER	13379	0.66	0.32	0.0	1
Licensee's familiarity	NBER	13379	0.002	0.01	0.0	0.33
Market proximity	Compustat	13379	0.31	0.46	0.0	1
Control variables						
Past ties	Deloitte Recap	13379	0.01	0.10	0.0	2
Licensor's past R&D collaborations	Deloitte Recap	13379	1.13	2.10	0.0	12
Licensor's patent stock	NBER	13379	1555.02	4041.12	0.0	27998
Licensee's downstream assets (n. drugs)	FDA	13379	11.20	21.75	0.0	112
Licensee's patent stock	NBER	13379	2614.53	5047.26	0.0	23558
Licensor' size	Compustat	13379	104.19	255.47	0.0	173
Licensee' size	Compustat	13379	181.63	322.18	0.0	242
Year		13379	1998.33	2.73	1994.0	2004

TABLE 2. Correlation matrix

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1. Probability to form license	1.00									
2. Technological diversity	**-0.04**									
3. Licensee's familiarity	**0.07**	**-0.12**								
4. Market proximity	**0.02**	**-0.27**	**0.08**							
5. Past ties	**0.09**	**-0.04**	**0.06**	**0.04**						
6. Licensor's past R&D collaborations	0.02	**-0.09**	**0.07**	**0.08**	**0.07**					
7. Log(licensor's patents)	0.00	**-0.20**	**0.24**	**0.10**	**0.03**	**0.22**				
8. Licensee's downstream assets	**0.04**	**-0.19**	-0.01	**0.15**	**0.12**	-0.00	-0.00			
9. Log(licensee's patents)	**0.04**	**-0.25**	0.01	**0.11**	**0.09**	0.00	-0.01	**0.67**		
10. Licensor' size	0.00	**-0.09**	**0.24**	**0.09**	0.01	**0.20**	**0.66**	-0.01	-0.01	
11. Licensee' size	**0.04**	**-0.10**	-0.01	**0.06**	**0.10**	-0.00	-0.01	**0.70**	**0.70**	-0.01

Correlation coefficients in bold are significant at 5% level.

TABLE 3. Likelihood of forming a license partnership (Logit regression)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Main independent variables						
TECHNOLOGICAL DIVERSITY		-0.64*** (0.192)	-0.56** (0.194)	-0.60** (0.194)	-0.57** (0.200)	-0.94*** (0.247)
LICENSEE'S FAMILIARITY			14.81*** (2.435)	21.04*** (3.256)	21.09*** (3.255)	20.67*** (3.254)
TECH. DIVERSITY X LICENSEE'S FAMILIARITY				20.76* (8.600)	20.91* (8.601)	19.89* (8.572)
PARTNERS' MARKET PROXIMITY					0.08 (0.131)	-0.42+ (0.245)
MKT PROXIMITY X TECH DIVERSITY						0.91* (0.376)
Dyad level control variables						
PARTNERS' PAST RELATIONS	1.61*** (0.242)	1.61*** (0.243)	1.51*** (0.245)	1.48*** (0.247)	1.48*** (0.247)	1.46*** (0.246)
Firms level control variables						
LICENSOR'S PAST R&D COLL.	0.04 (0.027)	0.03 (0.028)	0.04 (0.028)	0.04 (0.027)	0.04 (0.027)	0.04 (0.027)
Log (LICENSOR'S PATENT STOCK)	-0.01 (0.033)	-0.04 (0.034)	-0.06+ (0.035)	-0.06+ (0.035)	-0.06+ (0.035)	-0.05 (0.035)
LICENSEE'S DOWNSTREAM ASS.	0.00 (0.003)	0.00 (0.003)	0.00 (0.003)	0.00 (0.003)	0.00 (0.003)	0.00 (0.003)
Log (LICENSEE'S PATENT STOCK)	0.07* (0.031)	0.05 (0.032)	0.05+ (0.032)	0.06+ (0.032)	0.06+ (0.032)	0.06+ (0.032)
LICENSOR' SIZE	-0.00 (0.000)	0.00 (0.000)	-0.00 (0.000)	-0.00 (0.000)	-0.00 (0.000)	-0.00 (0.000)
LICENSEE' SIZE	-0.00 (0.000)	-0.00 (0.000)	-0.00 (0.000)	-0.00 (0.000)	-0.00 (0.000)	0.00 (0.000)
YEAR DUMMIES	Yes	Yes	Yes	Yes	Yes	Yes
COSTANT	-3.82*** (0.272)	-3.64*** (0.275)	-3.63*** (0.278)	-3.63*** (0.278)	-3.65*** (0.281)	-3.70*** (0.282)
Observations	13,379	13,379	13,379	13,379	13,379	13,379
Log-likelihood	-1376.44	-1371.04	-1357.93	-1355.02	-1354.85	-1351.95

Robust standard errors in parentheses; *** p<0.001, ** p<0.01, * p<0.05, + p<0.1.

Table 4. Marginal effects (Logit regression)

	Marginal effects
Main independent variables	
TECHNOLOGICAL DIVERSITY	-0.0198*** (0.00533)
LICENSEE'S FAMILIARITY	0.438*** (0.0714)
TECH. DIVERSITY x LICENSEE'S FAMILIARITY	0.421* (0.182)
PARTNERS' MARKET PROXIMITY[a]	-0.00887+ (0.00520)
MKT PROXIMITY x TECH. DIVERSITY	0.0192* (0.00802)
Dyad level control variables	
PARTNERS' PAST RELATIONS	0.0309*** (0.00537)
Firms level control variables	
LICENSOR'S PAST R&D COLL.	0.000844 (0.000582)
Log(LICENSOR'S PATENT STOCK)	-0.00116 (0.000743)
LICENSEE'S DOWNSTREAM ASSETS	8.05e-05 (7.39e-05)
Log(LICENSEE'S PATENT STOCK)	0.00125+ (0.000683)
LICENSOR' SIZE	-1.54e-06 (7.15e-06)
LICENSEE' SIZE	3.09e-07 (6.03e-06)
YEAR DUMMIES	Yes
Observations	13,379

[a] Change in probability is for a discrete change of dummy variable from 0 to 1.

TABLE 5. Estimates of logit and rare event logit models

	Logit Model	Rare Event Logit Model
Main independent variables		
TECHNOLOGICAL DIVERSITY	-0.94*** (0.247)	-0.94*** (0.239)
LICENSEE'S FAMILIARITY	20.67*** (3.254)	20.72*** (3.329)
TECH. DIVERSITY X LICENSEE'S FAMILIARITY	19.89* (8.572)	19.15* (8.525)
PARTNERS' MARKET PROXIMITY	-0.42+ (0.245)	-0.42+ (0.253)
MKT PROXIMITY X TECH DIV	0.91* (0.376)	0.92* (0.378)
Dyad level control variable		
PARTNERS' PAST RELATIONS	1.46*** (0.246)	1.46*** (0.256)
Firms level control variables		
LICENSOR'S PAST R&D COLL.	0.04 (0.027)	0.04 (0.028)
Log (LICENSOR'S PATENT STOCK)	-0.05 (0.035)	-0.06 (0.035)
LICENSEE'S DOWNSTREAM ASS.	0.00 (0.003)	0.00 (0.004)
Log (LICENSEE'S PATENT STOCK)	0.06+ (0.032)	0.06+ (0.033)
LICENSOR' SIZE	-0.00 (0.000)	-0.00 (0.000)
LICENSEE' SIZE	0.00 (0.000)	0.00 (0.000)
YEAR DUMMIES	Yes	Yes
COSTANT	-3.70*** (0.282)	-3.66*** (0.268)
Observations	13,379	13,379
Log-likelihood	-1351.95	.

Standard errors in parentheses; *** p<0.001, ** p<0.01, * p<0.05, + p<0.1.

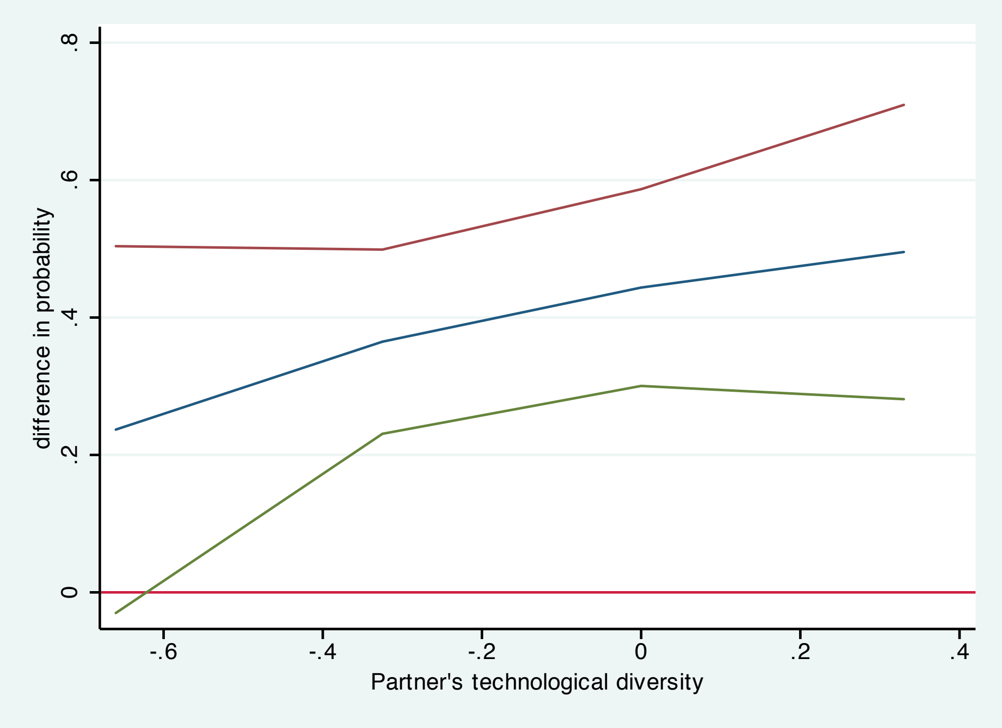


FIGURE 1 Simulation of the interaction effect: technological diversity*licensee's familiarity with licensor's technology (alpha=.05)

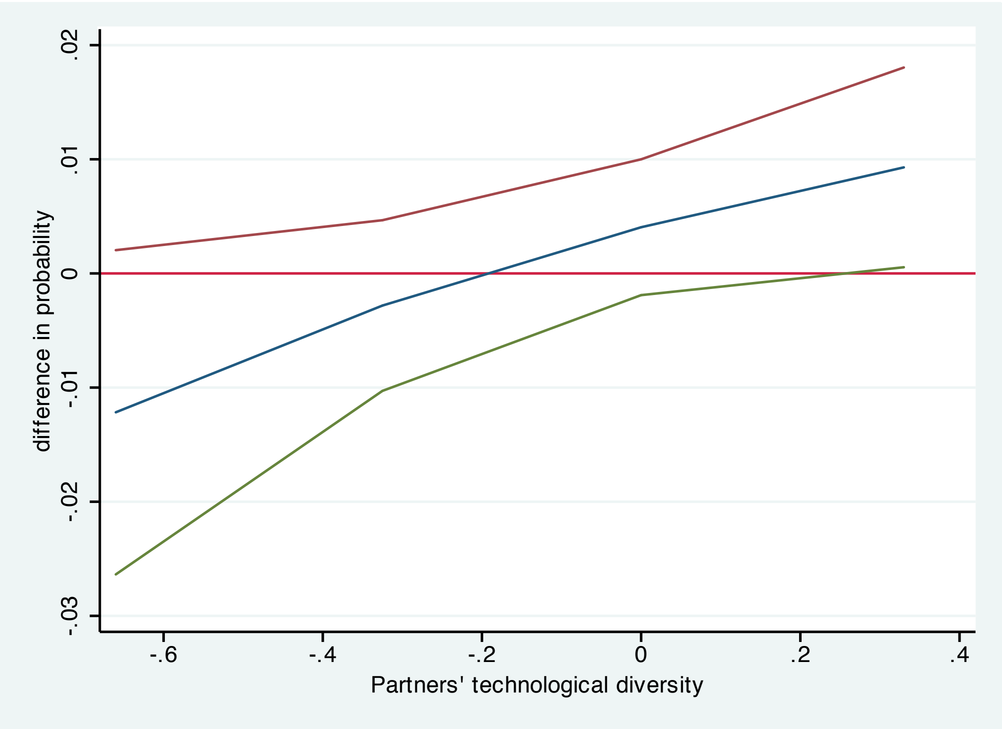


FIGURE 2 Simulation of the interaction effect: technological diversity*market proximity (alpha=.05)

3. COOPERATIVE MARKETS FOR IDEAS: WHEN DOES TECHNOLOGY LICENSING COMBINE WITH R&D PARTNERSHIPS?

ABSTRACT

The study departs from the traditional view of licensing as a spot market transaction and investigates license integration with R&D partnerships, introducing the concept of licensing combination. Drawing on licensing and R&D partnership literature and adopting the "transactional value" approach, we propose two types of antecedents – knowledge and dyad features – to investigate licensing combination. Using a dataset combining 441 original license agreements with firms' patenting and market activity in the global biopharmaceutical industry, we find a substantial heterogeneity in the ways licensors and licensees jointly exploit markets for knowledge and the specific role of R&D collaboration and minority equity in inter-organizational exchange through licensing. Results show that licensing combination with R&D collaboration is likely when the licensed innovation is embryonic, the licensee is unfamiliar with the licensor's technology and partners have different technological backgrounds. Instead, licensing of highly specific knowledge is likely to be supported by minority equity participation on the part of the licensee. Finally, licensing is combined with both forms of partnership in case of competence distance between partners. In the light of the empirical results, four types of licensing combination are proposed for future research.

Keywords: license, R&D collaboration, minority equity links, transactional value approach, knowledge transfer

3.1 INTRODUCTION

Licensing is central to firms' technology strategy. Empirical evidence highlights its increasing importance among inter-firm R&D partnerships (Arora et al., 2001a; Hagedoorn, 2002). From the licensor's point of view, it represents a flexible mechanism to find markets for unexploited technologies, to set an industry standard and to access complementary asset for technology commercialization (Arora, 2003; Fosfuri, 2006; Lichtenthaler & Ernst, 2009; Teece, 1986). From the licensee's perspective, it is a valuable tool to access external proprietary knowledge, to compress the time to market by speeding up the invention process, to widen knowledge search and boost firm's absorptive capacity (Arora & Gambardella, 2010; Laursen et al., 2010). Most academic studies pertaining to both the licensing literature and R&D partnership literature have examined licensing as an arm's length market transaction where technology transfer is limited to proprietary knowledge. Such a focus is understandable since, compared to other R&D partnerships such as equity joint ventures, licensing is by far more similar to a market transaction (Fosfuri, 2006). However, a recent study by Hagedoorn, Lorenz-Orlean and van Kranenburg (2008) suggests that licensing actually entails knowledge transfer and partners' cooperation to a far greater extent than is generally recognized. Licensing is frequently embedded in broader inter-firm collaborations including activities such as co-development, co-marketing, and supply agreements. For instance, a fundamental breakthrough in the global pharmaceutical industry – Humira (i.e. a drug to reduce the symptoms of rheumatoid arthritis) – was the result of a license-R&D collaboration between Cambridge Antibody Technology and BASF. The former out-licensed the molecule to BASF and at the same time the parties formed an R&D collaboration in order for BASF to successfully commercialize the licensed drug. Thus, contrary to common perceptions, there is substantial heterogeneity in the way firms access markets for knowledge through licensing. Despite its importance, the phenomenon has been overlooked in the literature on markets for technology. In this study, we depart from the traditional view of licensing as an arm's length market transaction and attempt to fill the gap in the literature by examining when technology licensing combines with other R&D partnerships and which factors determine firms' combination choice.

Understanding the combination of licensing with other R&D forms of inter-firm collaboration has rich theoretical and empirical implications from the perspectives of markets for technology and R&D partnerships. The empirical research on licensing has studied the structure of license contracts and the use of different contractual clauses to support technology exchange and mitigate transactional hazards (Arora, 1996; Cebrian, 2009; Palomeras, 2007; Somaya et al., 2010). This literature implicitly assumes the dichotomous market-hierarchy classification of governance modes provided by transaction cost theory. The paper advances the current understanding of licensing practices, proposing a new conceptualization of the phenomenon that goes well beyond the standard market exchange classification. The main argument of the study is that, under specific conditions, licensing entails much more than the transfer of "tightly packaged" and codified knowledge and that technology transfer needs to be supported in order for firms to maximize the value from partnering. Indeed, studying the determinants of licensing combination with R&D partnerships provides insights into the different ways firms leverage technology licensing to access and benefit from markets for knowledge. This issue is of fundamental concern to technology strategy theorists trying to explain the mechanisms allowing firms to benefit from external R&D linkages.

Our analysis is further enriched by the consideration of the interests of both partners involved in the technology exchange. Unlike past studies that analyzed technology licensing from the perspective of a focal firm (Fosfuri, 2006; Laursen et al., 2010; Lichtenthaler, 2007a; Teece, 1986), we conceive of the exchange underlying the combined license as a cooperative tie between interdependent partners. Such a view highlights the importance of taking into account both parties' perspectives in explaining the choice of optimal license combination.

The study also provides insights into the broader literature on R&D partnerships. In the past, much attention has been paid to the choice between equity forms and contractual arrangements to effectively transfer knowledge, considering these forms as substitute governance mechanisms along a market-hierarchy continuum (Colombo, 2003; Gulati, 1995a; Oxley, 1989). Although the R&D partnership literature has developed an increasing interest in how these different types of governance are interrelated, most empirical evidence has been gathered at the company level of analysis, examining the reasons why firms should pursue different R&D partnerships to benefit from external knowledge (Arora & Gambardella, 1990; Hagedoorn, 1993). The present study contributes to the literature by investigating the determinants of licensing combination with either equity forms and/or contractual R&D partnerships, focusing on the transaction level of analysis. The shift to a transaction level of analysis highlights that the combination derives from a tension between firms' need for flexible access to specialized external knowledge as well as other resources through market, and firms' need to learn and integrate new knowledge and skills into existing in-house competences.

In the next sections, drawing on the knowledge-based view we propose a theoretical model linking firms' licensing combination choice to the attributes of the licensed technology and the features of the tie. The model has the following main characteristics. First, we adhere to the "joint value maximization perspective" proposed by Zajac and Olsen (1993), conceiving licensing as a voluntarily agreement between two interdependent firms. Both parties use the inter-organizational strategy to establish an ongoing relationship to create value that could otherwise not be created by either firm independently. Second, following past research on inter-firm partnerships (Arora & Gambardella, 1990), we limit the domain of our model to R&D partnerships, more specifically to R&D collaboration agreements and minority equity links. In turn, we examine when licensing is likely to be coupled with R&D collaboration, with minority equity links or with both.

Our empirical analysis draws on a sample of 441 license agreements in the global biopharmaceutical industry over the period 1985-2004. To test the research hypotheses we develop a research design relying on multiple sources of information: licensing information is combined with information about the parties to the transaction and their patenting and market activities.

3.2 THEORETICAL BACKGROUND

3.2.1 Licensing and R&D partnerships

Although licensing is the least integrated and hierarchical form among inter-firm partnerships, cooperation between partners is central for knowledge transfer to occur. The licensing literature outlines the importance of designing incentive-compatible contracts as a means to align partners' incentive to cooperate and overcome threats to technology transfer (Aghion & Tirole, 1994; Choi, 2001; Gallini & Wright, 1990). Recent studies have advanced our understanding of the licensing phenomenon, focusing on license contract structuring and the function of specific contractual clauses in easing technology exchange and mitigating issues related to partners' opportunism (Anand & Khanna, 2000; Arora, 1996; Bessy & Brousseau, 1998a). Much attention has been paid to transaction costs and transactional hazards such as contract incompleteness, knowledge leakage and hold-up issues. For instance, Somaya, Kim and Vonortas (2010) examine why exclusivity provisions are used in licensing contracts and when licensing scope restrictions are enforced. The results highlight the use of exclusivity clause as contractual hostage to safeguard licensee investments in complementary assets and to enable contracting over embryonic technologies. Cebrian (2008) analyzes licensing payment structure and how royalties, fixed payments or a combination of the two are a means to mitigate contractual hazards between parties.

Relatively few research studies on licensing have analyzed the issues linked to knowledge transfer and the mechanisms partners use to support technology exchange. Although Hagedoorn, Lorenz-Orlean and Van Kranenburg (2008) provide a preliminary investigation of firms' preferences between standard and partnership-embedded licensing, little is known about the type of licensing combination as a choice and its contingent factors relative to either the exchanged technology or the partners involved in the exchange. Yet, understanding the impact of knowledge features and firms' competences on the choice of license combination would deepen our knowledge of firms' licensing practices. Further, the analysis of the governance mechanisms combined with licensing would complement the above studies, highlighting the dynamic perspective of licensing and its cooperative stance.

The study also attempts to fill a gap in the broader stream of research on R&D partnerships. Previous research has traditionally examined forms of inter-firm collaborations along a market-hierarchy continuum, assuming a substitution effect between the different forms when moving up along the hierarchy. For instance, Oxley (1997) examines firms' preferences for unilateral, bilateral or equity-based alliances as a function of the contractual hazards parties face when entering into the agreement. Similarly, Colombo (2003) analyzes firms' preferences between contractual agreements versus equity-based ones. Very few studies have examined how different governance modes are related to one another, overlooking firms' common practices of structuring hybrid transactions to organize technology exchange.

3.2.2 Licensing combination

In developing our model, we adhere to the "transactional value" approach proposed by Zajac and Olsen (1993) and conceive licensing as a cooperative dyad between two interdependent parties whose aim is to maximize the value of partnering. When drawing up a license, the parties choose the exchange structure that maximizes the joint value of both licensor and licensee and guarantees the success of the knowledge transfer. The adoption of this view has two main implications. Firstly, in terms of the partners' cooperation, there are conditions when the joint value maximization is not reached through standard licensing. Although the licensing contract per se, through the provision of contractual clauses and payment schemes, provides financial and economic incentives for exchanging "tightly packaged technology", it might not be effective in transferring tacit and specific knowledge. Unlike other partnerships, licensing does not entail the use of collaborative mechanisms for knowledge sharing, partners' interaction and communication. We argue that in response, firms draw up complex contracts combining licensing with other inter-firm collaboration forms as a means to integrate technology transfer beyond the proprietary knowledge elicited in the contract.

Secondly, conceiving licensing as a dyad between interdependent partners reveals the importance of taking into account the perspective of both licensor and licensee in explaining how the technology exchange is structured.

In order to provide a detailed analysis of different licensing combinations, we focus on two specific types of partnership to be coupled with licensing: R&D collaboration contracts and minority equity links.

Contractual research partnerships are project-based collaborations that span a medium-term time period. For instance in the pharmaceutical industry, they last on average between four and eight years (DiMasi, Hansen, & Grabowski, 2003). The parties usually agree to act collaboratively, share common goals toward the development and commercialization of a specific technology. They can either pool funds for co-developing and co-marketing the technology; or the joining party can buy into the project and finance the subsequent development of the technology relying on its partner's technical competences. Project managers are appointed by both partners and are responsible for inter-firm communications and knowledge sharing. Usually, a management committee composed of two or more representatives of each party coordinates the partnership (Hagedoorn & Hesen, 2007). During the collaboration, inter-firm communication relies mainly on quarterly meetings, sharing of research facilities, extended visits by research personnel.

From the above description, the link between licensing and R&D collaboration emerges. Partners' collaboration in R&D activity favors knowledge transfer. The setting up of regular meetings and visits to partners' research facilities enable the parties to understand and exchange highly contextual and tacit knowledge that would be difficult to transfer through licensing alone. Further, the R&D collaboration eases inter-organizational learning: partners access each other's capabilities, enabling the licensee to efficiently internalize the licensor's skills relative to the licensed technology. Learning occurs along a knowledge depth dimension: working jointly on a specific project, partners collaborate along different stages of the development process (Prencipe, 2000). Finally, by pooling skills and resources, the parties are better able to cope with technological uncertainty. The licensee can rely on the licensor's skills and know-how during the exploitation of the licensed innovation.

Minority equity holdings, unlike R&D partnerships, are company-based collaborations. One research partner invests a small stake in another company. Typically, given the private structure of companies, the investor is represented on the board of directors of the company. When combined with licensing[7], a minority equity stake serves two main functions. By acquiring part of the capital stock, the investing firm – usually the licensee – establishes a preferential long-term link to future projects with the licensor (Arora & Gambardella, 1990). It provides the investing partner with the opportunity to explore other promising new technologies beyond the one being licensed. The objective of the licensee is to keep in touch and acquire some familiarity with the research skills of the partner company. Unlike an R&D collaboration, where learning occurs along a knowledge depth dimension, in the case of a minority equity contract learning occurs along a knowledge breadth dimension: the licensee aims to acquire knowledge about a set of different projects/technologies. From the licensor's perspective, opening up its capital to the licensee is a way to access its partner's managerial skills as well as to raise additional funds for internal R&D activity. The second function of minority equity in supporting licensing is related to Pisano's view of minority equity as "token of good faith". The equity participation creates a

[7] In the context of licensing, the licensee usually acquires a share of the licensor's equity capital.

common ownership structure, safeguarding both partners from opportunistic behavior (Pisano, 1989).

In the hypotheses presented in the next sections, two types of antecedents are taken into account to explain licensing combination and the different role of R&D and equity contracts in supporting inter-organization exchange. In line with prior studies on knowledge transfer (van Wijk, Jansen, & Lyles, 2008), and consistently with the "transactional value" approach (Zajac & Olsen, 1993), we suggest that the characteristics of the exchanged technology as well as the attributes of the dyad have an impact on licensing combination. In the following subsections, we theoretically ground the discussion of each type of antecedent and develop hypotheses, taking into consideration the perspective of both licensor and licensee.

3.3 RESEARCH HYPOTHESES

3.3.1 Knowledge features

The impact of knowledge features on inter-firm technology transfer has been a subject of a long tradition of scholarship. Great attention has been paid to the tacitness of the knowledge to be transferred, its embeddedness in context, its idiosyncrasy and specificity (Grant, 1996; Kogut, 1988; Reed & Defilippi, 1990; Simonin, 1999). Findings have highlighted the negative impact of such characteristics on technology transfer: firms are hindered in their capability to share knowledge and need to resort to mechanisms easing partners' interaction and communication. Notwithstanding their importance to technology transfer, licensing literature has paid less attention to the features of the knowledge underlying the transaction and how such attributes impact the ways firms leverage licensing. To test the relationship, we focus on two main knowledge attributes: the development stage of the licensed innovation and its specificity.

3.3.1.1 Early stage technology

Previous empirical studies provide evidence of a frequent recurrence to *ex-ante* licensing: the licensor transfers a prospective technology to the licensee (Anand & Khanna, 2000; Arora et al., 2001a). In many industries, especially technology-intensive ones, firms exchange technologies at an embryonic stage of development. This trend has been explained in terms of either locking proprietary rights over a rising technology or accessing new technological domains that are key for the future competitive advantage of the licensee (Pisano, 2006; Roijakkers & Hagedoorn, 2006). From the licensor's perspective, selling an embryonic technology represents a way to guarantee its technological leadership or to access financial and complementary assets to further develop and market a new technology (Lichtenthaler, 2008; Teece, 1986).

Despite its frequent recurrence, licensing an innovation at an embryonic stage of development implies a non-trivial technology transfer process. First, the exchanged knowledge is frequently characterized by high degrees of ambiguity: the linkages and interactions between the underlying elements composing the technology are not completely defined and the commercial applications of the technology are still unknown (Simonin, 1999). The further development of the licensed innovation is likely to require high levels of experimentation and tinkering and the licensee to be dependent on the licensor to fully understand and internalize the technology (Somaya et al., 2010). Second, licensing over an embryonic technology implies that knowledge transfer is highly dependent on tacit and context-specific information. Knowledge stickiness renders the transfer between partners costly and slow (Kogut & Zander, 1992; von Hippel, 1994). As outlined by von Hippel (1994), knowledge transfer might be hindered by the amount of information with non-zero transfer costs. The licensee has to draw upon a great deal of information with a non-zero transfer cost in order to advance the innovation development work. Consequently, the technology elicited in the contract, either in the form of patents or blueprints, is only one part of the transfer process. For the licensee to internalize the licensed innovation it is fundamental to interact with the licensor to access tacit and un-codified knowledge once the contract is signed.

Under such conditions, standard licensing is unlikely to be effective in maximizing the partners' joint value. The licensee has to rely on the licensor's competences to further develop the licensed innovation. Additionally, it might be difficult for partners to communicate and share sticky and contextual knowledge without appropriate coordination mechanisms and incentives. Finally, given the inherent uncertainty of R&D activity, partners are constrained in their ability to fully specify in the license contract the amount of information beyond patents and blueprints the licensor should provide to its partner.

We argue that when the licensed technology is at an early stage of development, the combination of licensing with an R&D collaboration is likely. Through its coordination mechanisms, the R&D partnership enhances the value partners can extract from their interaction. This type of combination eases the transfer of the tacit component, reinforces learning and guarantees access to licensor's skills, enabling the licensee to optimally internalize the exchanged technology.

We posit the following:

> *Hypothesis 1. When the licensed technology is at an early stage of development, partners will be more likely to choose a license combined with an R&D collaboration.*

3.3.1.2 Knowledge specificity

Some technologies, in order to be commercialized, need specific investments by the licensee either in terms of R&D, or manufacturing capabilities or marketing programs. For instance, the development and launch of a new drug requires on average capital investments for a total of $800 million (DiMasi et al., 2003). Due to technology requirements, regulatory norms and market-segment characteristics, part of these investments cannot be easily redeployed to other products.

Past studies have focused on the hazards deriving from transaction-specific skills and assets. Pisano (1989) highlights the difficulties firms face in writing complete contracts if R&D activity has to be undertaken and shows the use of equity links as a way to support exchange. Similarly Kim, Somaya and Vonortas (2010) show that when specific investments are to be undertaken by the licensee, the contract is likely to include exclusivity clauses and equity mechanisms in order to protect both licensor and the licensee. The licensee's minority equity participation creates a common ownership structure safeguarding both partners (Ahmadjian & Oxley, 2006; Deeds & Hill, 1999; Pisano, 1989).

We argue that, apart from transactional hazards, technology specificity renders stand-alone licensing ineffective for two main reasons. First, from the licensee's perspective, the undertaking of specific investments leads to the development of knowledge, skills and assets specific to the licensor's technology. These might be used to perform technologically similar projects in the future. It might be key for the licensee to guarantee access to similar future promising technologies of the licensor's technology base. Indeed, equity participation allows the licensee to exploit this long-term link to redeploy past investments in specific know-how and skills in future projects related to similar promising innovations of its partner's technology base.

Second, knowledge exchange through licensing does not guarantee an even distribution of information between partners. For instance, the licensor might possess more information about the commercial potential of the exchanged innovation than does the licensee. Therefore, by having a place on the board, the information flows is facilitated, providing the licensee with access to strategic information about the licensed technology.

We posit the following:

Hypothesis 2. When the licensed technology requires skills and asset-specific investments for its commercial exploitation, partners will be more likely to combine the license with a minority equity participation on the part of the licensee.

3.3.2 Dyad features

The adoption of the "transactional value" perspective highlights the high interdependence between the licensor and the licensee in technology exchange. Hence, in order to explain licensing combination, it is crucial to consider the attributes of the dyad and how they impact on firms' optimal combination choice. Specifically, three main characteristics are taken into account: the technological gap between partners, the licensee's unfamiliarity with the licensor's specific technology and the competence gap between licensor and licensee. The first and third constructs make it possible to distinguish between partners' diversity in terms of competences across technological domains as well as in terms of product and commercialization skills. Differently, the licensee's unfamiliarity with the licensor's technology captures whether the licensee lacks specific technical skills in order to receive and master its partner's knowledge.

3.3.2.1 Partners' technological diversity

In recent literature there is consensus on the importance of partners' technological profiles in determining the costs of technology transfer (van Wijk et al., 2008). If, on the one hand, differences in partners' knowledge bases are a source of knowledge creation; on the other, they represent a threat to partnering (Nooteboom, Vanhaverbeke, Duysters, Gilsing, & Vandenoord, 2007). The recombination of different resources might in fact lead to new innovation output. However, when the distance between partners is excessive, cooperation is inhibited due to the lack of a common technological base in which to ground resource recombination (Colombo, 2003). The skills gap impedes learning and knowledge integration.

In the licensing context, the partners' technological diversity has been shown to be a cost rather than an opportunity. For instance, Kim and Vonortas' (2006) empirical investigation highlights that the likelihood of two partners forming a license is negatively related to their technological distance. Different technology specializations increase the learning cost the licensee has to bear in order to master and implement the licensed technology. Due to its different set of competences in distant technological fields, the licensee is limited in its capability to receive the licensor's knowledge (Cassiman & Veuglers, 2006). Moreover, the licensor might be required to implement some modifications to the technology in order to render it transferable.

Under such conditions, we posit that licensing needs to be integrated with other forms of collaboration in order to make technology transfer effective. Specifically, since partners lack a common technological base, R&D collaboration might represent a viable solution. By favoring interaction and learning about the licensed project, it bridges the partners' complementary knowledge bases, enabling the licensee to develop the licensed technology effectively.

As argued before, the interaction through licensing with a partner mastering different technological fields might also represent an opportunity. Access to a different set of competences is a way for the recipient firm to diversify its knowledge base, enter new technological domains and add new combinations to its current knowledge endowment. Therefore, the licensee might be willing to access its partner's technological domains beyond the scope of the licensed innovation and establish a preferential link to future projects that might represent an important source of innovation. Indeed, we argue:

> *Hypothesis 3a. The higher the technological diversity between the licensor and the licensee, the more likely it is that the license will be combined with an R&D collaboration.*
>
> *Hypothesis 3b. The higher the technological diversity between the licensor and the licensee, the more likely it is that the license will be combined with a minority equity participation on the part of the licensee.*

3.3.2.2 Unfamiliarity with licensor's technology

Technology transferability is favoured by the possession of related skills by the recipient firm (Cassiman & Veuglers, 2006; Cohen & Levinthal, 1990). As argued by Simonin (1999: p. 601): "for a knowledge seeker, prior experience with a given knowledge base predetermines the level of familiarity and comfort with both information content and context, and thus favours the transferability of knowledge". In the context of licensing, we argue that the capability of the licensee to absorb and integrate the licensed innovation with its knowledge endowment is dependent on the familiarity it has with the licensor's technology (Mowery et al., 1996). Unlike technological diversity, which is related to partners' dissimilarities along a set of technological domains, familiarity is related to the licensor's specific technology and the licensee's awareness of it. On the one hand, a company that decides to in-license a patent, having cumulated prior knowledge about the licensor's technological base through patent citations, is likely to possess the relevant skills needed to exploit the acquired technology. In contrast, when a company decides to in-license a technology, valuing its relevance to R&D strategy but lacking any prior specific experience, it might lack the technical competences to fully exploit it. The codified descriptions provided by the licensed patents embody only a partial explanation on how to proceed further.

We argue that unfamiliarity with the licensor's technological base threatens technology transfer effectiveness. Accessing the market through standard licensing might be sup-optimal for both partners: the licensee is limited in its capability of experimenting with the licensor's technology, putting the successful commercialization of the licensed innovation at risk. Under such conditions, we posit that licensing is likely to be coupled with an R&D collaboration. The latter supports the former by favouring learning and knowledge accumulation. By collaborating with the licensor in further developing the licensed technology, the licensee can fill the deficiencies and cumulate relevant skills to those of the licensor, reinforcing its ability to assimilate and apply the licensed innovation.

Hypothesis 4: If the licensee is unfamiliar with the licensor's technology base, the more likely it is that the license contract is combined with an R&D collaboration.

3.3.2.3 Vertical licensing

The licensing literature distinguishes between horizontal and vertical licenses (Anand & Khanna, 2000). A vertical license occurs between two organizations that, at least under the parameters of the license contract, engage in relatively distinct sets of activities along the industry value chain. In vertical licensing, companies located in the upstream pole of the industry value chain out-license their technology to companies located in the downstream pole. For instance, in many industries technology-based firms are understood to be originators of technology, which is eventually brought to the marketplace by partners with extensive production, marketing and distribution capabilities (Stuart et al., 2007). Horizontal licenses, unlike vertical agreements, involve partners operating along the same phases of the industry value chain.

Notwithstanding partners' specialization and interdependence, we argue that in the case of a vertical license stand-alone licensing is a sup-optimal choice. As the partners are engaged in different sets of activities along the industry value chain, knowledge integration is non-trivial. In industries where vertical licensing is a common practice, licensors are usually specialized in the early stages of technology development. For instance, biotech firms are focused on target identification and lead optimization (Pisano, 2006). All such phases require insights from disciplines such as molecular biology, cell biology, functional biology, etc. Licensees, instead, are specialized in downstream development phases, where the relevant disciplines are toxicology, clinical development, regulatory affairs, production and marketing (Pisano, 2006). The successful commercialization of the licensed technology requires tight knowledge integration and a continuous exchange of information throughout the development process, since each technical choice has implications for the others.

Thereby, it is fundamental for the licensee to rely on the licensor's competences in order to internalize the technology. Coupling the license with R&D activity might indeed support knowledge integration, bridging partners' specializations. It increases the likelihood of successful commercialization of a new profitable product, allowing the licensee to master the licensed technology and understand upstream processes as well as the licensor to anticipate downstream problems and requirements. The R&D collaboration favours information exchange and enables partners to work interdependently.

Further, we argue that the joint value maximization could be further reached through a minority equity participation on the part of the licensee. Given the partners' heterogeneity in terms of R&D and product-market competences, partners might have a common interest in establishing a long-term link beyond the project collaboration. The licensee might have an interest in its partner's technological base as a future source of innovations, beyond the scope of the licensed project. From the licensor's perspective, the establishment of a long-term link with the partner might be optimal as well. The licensee's equity participation provides access to managerial skills, market-product knowledge as well as downstream complementary assets.

Hence, if licensor and licensee belong to different phases of the industry value chain, it is likely that stand-alone licensing will not be effective.

Hypothesis 5a. When partners belong to different stages of the industry value chain – the license is a vertical one – partners will be more likely to choose a license combined with a R&D collaboration.

Hypothesis 5b. When partners belong to different stages of the industry value chain – the license is a vertical one – partners will be more likely to *choose a license combined with a minority equity participation on the part of the licensee.*

3.4 METHODS[8]

3.4.1 Research setting

The research context of the study is the global biopharmaceutical industry over the period 1985-2004. The industry represents the ideal research setting in which to test the determinants of licensing combination because of its distributed innovation model, the centrality of inter-firm technology transfer and firms' strategic need for flexible contracts to manage different and concurrent partnerships. The industry accounts for a substantial share of inter-firm partnerships (Hagedoorn, 2002): since the mid-1970s it has experienced a growing pattern in the number of newly established R&D partnerships. This was especially true after the advent of biotechnology, which led to a radical change in the industry structure and the division of innovative labor (Arora & Gambardella, 1990). Due to the dispersion of knowledge among different actors and the rise of new technological areas, firms started to experiment with new forms of cooperation (Roijakkers & Hagedoorn, 2006). Firms are now engaged in a portfolio of flexible contract-based partnerships in order to access and acquire external specialized skills. Among the different forms, technology licensing accounts for the lion's share of technology exchanges (Anand & Khanna, 2000): small biotechnology companies out-license early stage compounds to large pharmaceutical companies conducting clinical trials, seeking market approval and finally manufacturing and commercializing new drugs (Stuart et al., 2007).

[8] Since the thesis builds on a single dataset, the "methods" sections of the three papers share common arguments and information relative to the choice of the research setting, the creation of the research sample, and variables' operationalization.

3.4.2 Data and sample

To test the research hypotheses, we compiled a dataset combining license data with firms' patent and market data. The license data are collected from Deloitte Recap Database. This database records a wide range of agreements in the global biopharmaceutical industry since 1985: mergers, license deals, settlement agreements, joint ventures, co-development agreements. A number of considerations led to building the research sample by drawing on Recap. First of all, it represents the most accurate and global information source on partnerships in the industry (Audretsch & Feldman, 2003; Schilling, 2009), making it possible to retrieve extensive and reliable data. It covers an extensive time period of analysis of about 30 years. Second, for each deal it provides copies of the material contracts filed per the requirements of the SEC and also provides some analysis of the contracts. The availability of original contracts allowed to collect detailed and objective information that other databases on alliances do not provide[9]. For instance, for each license agreement – whenever available – it provides access to additional contracts that were signed together with the license: R&D contracts, minority equity holding contracts, manufacturing agreements, marketing agreements, etc. Further, relative to the contract analysis, it provides information coded by industry experts. For instance, information relative to the development stage of the licensed technology is provided, as well as the therapeutic area of the deal, the type of investments planned by the acquiring party or the deal compensation scheme. Thus, the original contracts and their corresponding analyses provided a reliable and objective overview of each license partnership.

To build the research sample, the following criteria were applied in selecting the deal contracts from Recap: (i) the contract is a license agreement, (ii) the transaction

[9] For further information relative to alliance and license datasets, see Shilling (2008).

involves the transfer of "patent" or "technology", (iii) the original text of the contract is available. This led to an initial sample of 2018 licensing agreements. Next, only unilateral agreements were selected, excluding 378 cross-licensing deals. The exclusion of cross-licenses is due to the fact that they are usually negotiated when each of the two companies has patents that may read on the other's products or processes. They imply a bilateral technology exchange in order to guarantee both partners with freedom to operate in their internal innovative activity (Shapiro, 2001). Hence, the motives underlying their formation are different from those of a unilateral license (Colombo, 2003).

Finally, given the focus of the study on inter-firm partnerships, all licenses involving universities or governmental laboratories as technology partners were dropped. Although academic and governmental institutions are central actors in the market, we excluded them from the sample since unlike the private sector where profits and commercial success are the ultimate objective, university objectives are more diverse (Thursby, Jensen, & Thursby, 2001). For instance, the primary objectives of a technology transfer office from licensing usually comprise: attracting sponsored research funds, funding patent applications and generating royalties to fund internal academic research.

After the selection process, the research sample was composed of 815 license agreements.

Once the license data had been collected and coded, we matched the dataset with other information sources. The primary additional source of data was the National Bureau of Economic Research (NBER) dataset (Hall et al., 2001). By matching the names of both the licensor and licensee with assignees' names recorded in the NBER dataset, we could obtain the firms' patent portfolios and statistics related to their innovative activity. The further additional information sources were Biospace, Compustat and companies' websites. We matched the available information on the names of licensor and licensee with data on the firms' primary reference market – SIC codes – in order to detect whether partners were drug or biotech companies.

Due to missing values both in license and patent data, the final sample comprised 441 license agreements.

3.4.3 Measures

Dependent variable. According to our model, when signing a license, partners face two simultaneous choices: whether to combine the license with an R&D contract or not; whether to combine the license with a minority equity participation or not. In turn, the dependent variable is a bivariate one: it represents the probability of coupling the license with a R&D contract and the probability of coupling the license with a minority equity link on the part of the licensee.

Variables are coded from information provided in the license agreements and – wherever present – from R&D agreements and minority equity holding contracts related to the licenses. Other studies adopt a similar coding strategy for licensing-related variables (Anand & Khanna, 2000; Bessy & Brousseau, 1998a; Somaya et al., 2010).

Independent variables. Following the research hypotheses, we expect the *development stage* of the licensed technology to have an impact on the type of licensing combination. For each license deal, Recap provides a description of the licensed technology and its development phase. Drug development is a well-structured process, mainly consisting of three macro phases: discovery, clinical trials and regulatory approval (DiMasi et al., 2003). The discovery process ends with preclinical trials during which the compound undergoes laboratory and animal testing to assess safety and biological efficacy. After approval from the competent authorities for trials on humans, the candidate drug enters clinical trials. In order to capture the early stage nature of the licensed innovation, we coded a dummy variable – *early stage technology* – taking a value of 1 if the technology is licensed before preclinical trials; and 0, otherwise. During the coding process we relied on two industry experts to determine until which phase a compound could be classified as an early stage innovation.

In order to capture the degree of specificity of the licensed technology, two dummy variables were coded from the text of the license contracts: *R&D specific investments* and *marketing specific investments*. The former takes a value of 1 if the licensee is expected to undertake specialized R&D investments to evaluate, further develop and exploit the licensed technology. The latter captures whether technology specific investments in terms of market approval, advertising and marketing programs need to be set up to market the technology. As for the dependent variable, the variables were coded from information disclosed in the license or in the contracts coupled with it and cross-checking their reliability with the contract analyses provided by Recap. The focus is on specialized R&D and marketing investments, since their technology specificity is higher compared to those of other types of capital commitments such as manufacturing investments, which are more easily redeployable to other uses (Somaya et al., 2010).

Following previous studies (Branstetter & Sakakibara, 2002; Jaffe, 1986; Kim & Vonortas, 2006a; Sampson, 2007), we measure the diversity of partners' technological competences, namely *technological diversity*, by examining the extent to which partners patent in the same technological classes, i.e. patent classes. The choice of measuring partners' different technology specialization using patents is related to two main reasons. First, the industry appropriability regime is such that firms have incentives to protect their inventions through patents rather than recurring to other forms of protection (Cohen et al., 2000). Indeed, patents are good proxies of firms' knowledge bases (Griliches, 1990). Second, patents are categorized according to the underlying technology and not to the end product per se (Jaffe, 1986). Indeed, measuring technological diversity across patent classes makes it possible to understand the degree of dissimilarities between partners' knowledge bases. The variable is computed as follows:

$$\text{Technological diversity} = 1 - \frac{F_i F_j^{'}}{\sqrt{(F_i F_i^{'})(F_j F_j^{'})}} \text{ with } i \neq j$$

Vectors F_i and F_j are patents distributions across USPTO 3-digit patents classes of respectively licensee *i* and licensor *j* up to license year. The variable varies between 0 and 1, with value of 1 indicating the highest technological diversity between partners.

Unfamiliarity with the licensor's technology records whether the licensee is unfamiliar with the licensor's knowledge base. For constructing the variable we consider whether, before license year *t*, the licensee has cited the licensor's technology in its patents. The variable takes a value of 1 if the licensee has never cited the licensor's technology in its past patent applications; 0 otherwise. As it is well known in innovation literature, patent citations are a good indicator of firms' search process and inter-firm knowledge flows (Jaffe et al., 1993). Citations of the patents of firm A by the patents of firm B means that B is building on the technology of A and consequently that B is familiar with firm A's technology.

Vertical licensing is a dummy variable equal to 1 if partners belong to different phases of the industry value chain, i.e. if the licensor is a biotech company and the licensee is a drug company. The partners' industry classification was set according to SIC codes. The variable captures whether partners have different capabilities along the industry value chain. Traditionally, biotechnology firms are originators of technology, which is then brought to the marketplace by drug companies with extensive experience in managing the clinical trials and regulatory process (Rothaermel, 2001; Rothaermel & Deeds, 2004; Stuart et al., 2007).

Controls. In order to account for potential competing explanations of licensing combination, following prior literature we included a number of control variables.

Exclusive licensing is a dummy variable equal to 1 if the license contract is exclusive and 0 otherwise. The presence of exclusivity clauses has an influence on partners' cooperative behavior (Somaya et al., 2010), therefore we expect it to affect the choice of coupling the license with other contractual forms, acting as a substitute for equity investments.

We included a dummy to account for *international licensing*. Entering an international license is more challenging in terms of coordination and knowledge transfer, increasing the likelihood of coupling the license with R&D partnerships. The variable equals to 1 if the licensor and licensee are based in different regions, i.e. US, Europe and Japan; 0 otherwise.

For both licensor and licensee, the logarithmic transformation of total stock of patents applied for up to the license year is computed. The variables are proxies for *partners' inventive size*. According to prior literature, large and small firms leverage markets for technology differently. For instance, firms with large knowledge stocks usually out-license their patents to realize monetary benefits differently from small-scale companies that through technology licensing access downstream complementary assets and commercialize their inventions (Gans & Stern, 2003; Lichtenthaler, 2007a). Similarly, licensees with large knowledge stocks often access markets for knowledge with the goal of effectively exploiting their internal research activity and at the same time benefiting from their partners' technology specialization. They typically enter multiple concurrent forms of collaboration with their partner (Arora & Gambardella, 1990; Roijakkers & Hagedoorn, 2006). In turn, because of their impact on either the objectives or the ability to benefit from licensing, we expect partners' inventive size to influence the choice of licensing combination.

The variable *partners' past relationships* is defined as the number of prior licenses between the partners that were signed up to the license year. The variable proxies for the existence of informal and relational governance mechanisms based on reciprocity, trust, reputation and familiarity (Gulati, 1995a). We expect the presence of past ties to favour cooperation, reducing the partners' need to recur to licensing combination to support technology exchange.

Finally, a linear time trend variable, *time*, is included to control for possible growth in the number of agreements (Gulati, Lavie, & Singh, 2009; Hagedoorn et al., 2008) and in the gradual shift of firms' preferences between combined and stand-alone licenses.

3.4.4 Estimation strategy

Given the nature of the dependent variable, the empirical analysis is based on the estimates of a discrete choice model. When signing a license, partners face two simultaneous decisions: to couple the license with an R&D agreement, or not; to couple the license with a licensee's minority equity participation, or not. As mentioned before, following prior literature (Arora & Gambardella, 1990) we expect the two choices to be interrelated one another. Indeed, when estimating factors determining licensing combination, we need to take into account the relationship between R&D contracts and equity links and assess their potential joint incidence. A model making it possible to account for the joint incidence is the bivariate probit model (Cappellari & Jenkins, 2003). The general specification of the model is the following one:

$$y_1 = x_1^{'}\beta_1 + \varepsilon_1 \text{ where } y_1 = 1 \text{ if } y_1^* > 0\text{; 0 otherwise}$$
$$y_2 = x_2^{'}\beta_2 + \varepsilon_2 \text{ where } y_2 = 1 \text{ if } y_2^* > 0\text{; 0 otherwise}$$

$$E\left[\varepsilon_1 | x_1, x_2\right] = E\left[\varepsilon_2 | x_1, x_2\right] = 0$$

$$Var\left[\varepsilon_1 | x_1, x_2\right] = Var\left[\varepsilon | x_1, x_2\right] = 1$$

$$Cov\left[\varepsilon_1, \varepsilon_2 | x_1, x_2\right] = \rho$$

According to the model, error terms are distributed as a bivariate normal, each with zero average and variance-covariance matrix V, where V has values of 1 on the leading diagonal and correlations $\rho_{jk} = \rho_{kj}$ as off-diagonal elements (Greene, 2003).

It is important to recall that the correlation might reflect either jointness in the decision to couple the license with both R&D and equity contracts, or on the contrary, might reflect the presence of unobserved factors that affect both decisions. Therefore, model specification is fundamental to assess the relationship existing between the two simultaneous decisions. Omitting a variable influencing both the decision of coupling the license with an R&D agreement and the decision to couple the license with an equity contract would then be the cause of a correlation between the two. In order to account for unobserved heterogeneity caused by omitted variables, in model specification we draw on previous literature on both R&D partnerships and minority equity links in order to account for important factors being correlated with one or both decisions.

3.5 RESULTS

Before presenting the estimation results, it is worth describing some patterns in the data. The sample is composed of 441 license contracts. Of these: 51 percent are standard license agreements; 26 percent are license contracts combined with R&D agreements; 23 percent are license contracts coupled with minority equity contracts.

Table 6 provides an overview of the data and summary statistics.

Insert Table 6 about here

Approximately 65 percent of licenses are early stage and about 83 percent require investments in R&D activity for the successful commercialization of the licensed innovation. Additionally, about 90 percent of licenses are exclusive, 45 percent occur between partners belonging to different phases of the value chain, namely biotech and drug companies; finally, about 37 percent of licenses are international. As far the inventive size of licensors and licensees (measured in terms of patent stocks) is concerned, it is worth noting that on average licensee size is larger than licensor size, suggesting the well-established industry dynamic of small firms licensing their technologies to larger firms. Notwithstanding its focus on a single industry, the sample's descriptive statistics are similar to those of inter-industry data used in other studies (Annad and Khanna, 2000; Somaya et al., 2010).

Table 7 reports Pearson correlation coefficients. Correlation is low for most variables indicating that multicollinearity is not a problem in the analysis. Additionally, using STATA 10, variance inflated tolerance factors were calculated. All tolerance factors were close to one, indicating the absence of collinearity among variables.

Insert Table 7 about here

Table 8 reports the results of the bivariate probit analysis. In models 1-5 explanatory variables are step-wisely introduced. For the sake of simplicity, results discussion is based on the full model: model 5.

Insert Table 8 about here

Hypothesis 1 asserts that when the licensed technology is at an early stage of development, firms are likely to combine the license with an R&D agreement. In model 5, the coefficient of early stage licensing is positive and significant below the 5 percent level, supporting therefore hypothesis 1. The R&D agreement eases the transfer of sticky and contextual knowledge and guarantees licensor' support during technology exploitation.

Hypothesis 2 posits that it is likely that the license will be coupled with a minority equity participation on the part of the licensee if the licensed technology requires specific investments for its commercialization. Analyzing the equation relative to licensee's minority equity investment, we notice that estimated coefficients of the variable *R&D specific investment* are positive as expected but not significant at conventional levels. Instead, looking at the equation relative to R&D collaboration, the results show that technology-specific investments are related to R&D agreements rather than to equity links. We might conjecture that through an R&D contract, the licensee is better able to reduce sunk and technology-specific investments by securing access to licensor's research capabilities. As for the variable *marketing specific investment* in the equation relative to licensee's minority equity link, its coefficient is positive and significant below 1 percent level. The findings strongly support our idea that when the licensed technology is highly specific, it is likely to combine licensing with an equity link. In such a case the equity contract provides the licensee with access to its partner's technology base, thereby increasing the likelihood of redeploying specific skills and resources developed in commercializing the licensed innovation. In turn, hypothesis 2 is partially supported.

Hypothesis 3a conjectures that the higher the technological diversity between partners, the more likely they are to combine the license with an R&D collaboration. The hypothesis is weakly supported: the coefficient is positive but, in the full model, remains significant below the 10 percent level. Results weakly confirm the idea that the R&D collaboration bridges partners' knowledge bases, reinforcing the licensee's capability to master the licensed innovation. Hypothesis 3b, on the contrary, is not supported by results: technological diversity does not represent an opportunity to access and scout distant technological domains through an equity link.

Hypothesis 4 is supported. An inexperienced licensee is more likely to be reliant on the licensor's skills and know-how to exploit the licensed technology. Licensing needs to be supported with an R&D contract to guarantee the success of the transfer.

Results are supportive of Hypothesis 5a and 5b. In a vertical license, partners are more likely to combine licensing with both an R&D agreement and an equity participation. Issues of knowledge integration and access to complementary skills and resources lead firms to choose both an R&D collaboration and equity contract.

In analyzing the estimated correlation between the error terms we notice a positive sign, suggesting the existence of a complementary relationship between R&D agreement and licensee's equity contract. Notwithstanding the weak significance of the correlation coefficient, the result supports and enriches prior findings on the complementarity relation between R&D partnerships, providing evidence at the transaction level of analysis (Arora & Gambardella, 1990).

The results related to control variables are mixed. Under exclusive licensing, it is more likely that partners combine the license with an R&D agreement. Following Somaya, Kim and Vonortas' (2010) argument, the R&D collaboration might be a hostage the licensee provides to the licensor in exchange for exclusivity. Pertaining to partners' technology size, results confirm prior findings. Large licensors are likely to access the market through standard licensing. Such a strategy is a valuable tool to find markets for unexploited technologies and focus internal R&D activity (Gambardella et al., 2007). On the other hand, large licensees are more likely to leverage licensing to access proprietary knowledge and concurrently scout partners' technology base through equity links. Concerning partners' past ties, we surprisingly find that they do not have an effect on licensing combination choice. Finally, empirical evidence highlights the existence of a time trend in partners' license choice. The time coefficient is negative and significant in the case of R&D agreement, highlighting a shift in firms' preferences.

3.6 DISCUSSION AND CONCLUSIONS

In this study we departed from the traditional view of licensing as a spot market transaction for the exchange of proprietary knowledge and introduced the concept of licensing combination. Our work aimed at explaining the substantial heterogeneity in the ways firms access markets for knowledge through licensing, examining factors that drive partners to integrate a license contract with R&D partnerships. Drawing on licensing and R&D partnership literature and adopting the "transactional value" perspective, we identified two types of antecedents – knowledge and dyad features – to explain licensing combination and the role of R&D and equity contracts in supporting inter-organizational exchange.

Empirical results provided support for our theoretical predictions. As for the antecedents related to knowledge features, we find that both the development stage of the licensed technology as well as its specificity have an impact on firms' combination choice. The findings highlight the importance of R&D collaborations in supporting technology exchange, favouring the transfer of sticky and contextual knowledge and guaranteeing the licensee with access to licensor's skills and know-how. Interestingly, we find that when the exchanged knowledge is highly specific, the optimal combination is contingent on the type of specificity. If knowledge specificity is in terms of R&D investments, then partners choose to maximize their joint value by combining the license with an R&D collaboration. Instead, if specificity is not related to R&D activity, then minority equity participation by the licensee is the optimal mechanism to profit from licensing. Our findings show that a gap in partners' technological skills as well as market competences hinders licensing effectiveness. Considering technological skills, the results outline that either in the absence of a common knowledge set between partners or in case of the licensee's unfamiliarity with its partner's technology base, the exchange is to be supported through a collaboration in R&D. On the other hand, in the case of a competence gap due to companies' different specialization along the value chain, the partners' optimal choice is a combination of licensing with both R&D and equity contracts. In turn, empirical evidence supports our conjecture about the different role of R&D and equity contracts when combined with licensing.

Theoretically, the arguments and results of the study contribute to the literature on markets for technology and R&D partnerships. From the perspective of markets for ideas, we advance knowledge on the use of licensing to benefit from inter-firm partnering. Our study proposes a new conceptualization of licensing, well beyond the traditional view of a market-based transaction for the exchange of IP rights, enriching the recent literature on license optimal structuring (Bessy & Brousseau, 1998a; Brousseau, Coeurderoy, & Chaserant, 2007; Cebrian, 2009; Somaya et al., 2010). We provide evidence of different ways firms leverage licensing combination to maximize the benefits from accessing the market. Such identification is important in and of itself in the context of markets for technology, since it provides a micro detailed analysis of firms' licensing practices. However, it is also important since it highlights the centrality of tailoring *ad hoc* licensing agreements in order for firms to balance access to external resources with the acquisition and integration of skills into internal knowledge endowments. In many industries, technological convergence and vertical division of innovative labour have led firms to be part of networks of innovation (Powell et al., 1996). Firms are engaged in multiple and concurrent external ties. Thereby, given the importance of accessing external resources and optimally managing such relationships, it is key for firms to rely on flexible governance mechanisms guaranteeing a balance between resource access and resource accumulation. Thanks to our research design, we contribute to the understanding of different types of licensing combination, highlighting firms' cooperative use of markets for technology. On the base of our quantitative results as well as leveraging the in-depth insights of our qualitative review of licensing deals we propose four types of licensing combination: 1) Stand-alone licensing; 2) R&D licensing; 3) Equity licensing; 4) R&D and equity licensing.

The first type embodies the traditional view of licensing: a market exchange for proprietary knowledge. A relevant example in our dataset is provided by the license agreement between Aventis and Zymogenetics in the hematology therapeutic area. A large pharmaceutical company sold its patents to a biotech company that in the process of re-establishing itself as an independent company, aimed through the agreement to enlarge its project-portfolio and R&D pipeline. The second type of licensing combination represents the coupling of licensing with an R&D collaboration. This latter allows the licensee to access and optimally internalize the licensed technology and the licensor to secure the success of the transfer. Indeed, the license partnership between ICOS and Abbott in the oncology therapeutic area is an example of how partners exploited markets for ideas through an R&D collaboration to identify and optimize therapeutic agents small molecules in the field. The third type depicts the combination of licensing with minority equity participation by the licensee. This case represents the situation where the firms' partnering value is linked both to license-based resources as well as to company-based resources. For instance, due to the importance of Genelabs' knowledge in the infectious diseases therapeutic area to Glaxo's technology strategy, the parties entered an equity capital contract: Glaxo became a shareholder of Genelabs' equity capital. At the same time, Genelabs out-licensed its technology and patents to Glaxo in order for the latter to develop and commercialize a vaccine against the Hepatitis C virus. Finally, the last type of licensing combination represents a situation in which both R&D and equity links integrate the exchange to maximize partners' joint value. An example is the agreement between Neurogen and Merck, in which the latter paid $15 million as upfront fee to access Neurogen's patents and know-how. The partners integrated the license with an R&D agreement with the goal of pooling their competences to further develop an embryonic technology related to the treatment of pain (vanilloid receptor – VR1 –). Additionally, Merck purchased shares of Neurogen for about $15 million to monitor its partner's research activities in a growing therapeutic area such as the treatment of pain.

We further contribute to the literature by providing a dynamic view of licensing. Prior research has focused on the analysis of a focal firm's perspective, neglecting the fact that a technology exchange is the result of a bilateral negotiation between partners with different strategic and economic expectations. The adoption of the perspective of both licensor and licensee provides a complete framework to understand firms' choice in structuring technology exchange and more importantly highlights the cooperative nature of markets for ideas.

Finally, the study advances by a few steps the R&D partnership literature. Our contribution is twofold. Firstly, the analysis of licensing combination with R&D and equity contracts sheds further light on the so-called "hybrid" transaction forms lying along the market-hierarchy continuum. Prior studies have mainly focused on the market-hierarchy dichotomy, overlooking firms' common practices of structuring hybrid transactions to exchange technology. Our research design, by relying on original license agreements, allowed to deepen our understanding of hybrid transactions. The study's focus on licensing and the contingent factors leading firms to resort to R&D contracts and equity links provides with an explanation of the heterogeneity in license partnering forms. An R&D collaboration, through its coordination mechanisms, creates a common knowledge ground in which to base technology transfer. Instead, minority equity serves to access a broader set of resources and competences well beyond the licensed project, creating a long-term link between partners.

The paper also makes a contribution towards managerial practice. From a practitioner standpoint, the analysis of optimal licensing strategy to access markets for knowledge is of significant importance, given the economic and strategic stakes associated with it. As outlined by previous studies, accessing external knowledge is fruitful for firms' innovation strategy, positioning and time to market (Arora et al., 2001a; Chesbrough, 2003). Therefore, the analysis and proposed classification scheme provide managers with an understanding of the optimal combination strategy to leverage licensing contingent on technology and dyad specific factors.

We acknowledge a number of limitations of the study. While we were able to explain when licensing combination occurs and how firms couple the license contract, we did not relate firms' combination choice to any performance measure either at firm or project level. Future research could attempt to relate the choice of license combination to the research outcome of the partnership or differently to the innovative performance of the acquiring firm. This would clarify the link between license contract structuring and performance, a stream of research that as of today has received little attention.

The study provides a framework of analysis to understand firms' use of licensing to access and cumulate external resources and skills. Future research might extend our framework including into the analysis universities and governmental laboratories. As mentioned before, these play a key role in markets for ideas, as they are core sources of basic knowledge. Indeed, future work should start investigating how licensing is leveraged when universities and government institutions are involved as technology partners.

The findings support our research hypotheses; however, we must acknowledge that our focus on the biopharmaceutical industry raises questions about the generalizability of the study to other research settings. The industry has several unique features that differentiate it from other technology-intensive industries. Among the unique characteristics, we mention the following: a risky and long product development process, the presence of a regulatory approval process to access the market and the importance of scientific knowledge in R&D activity. Despite these unique attributes, we believe our results might be extended beyond this specific research setting since inter-firm cooperation through licensing is at the core of firms' strategy in other technology-intensive industries. For instance, in the electronics and information technology industries, the complexity of technologies and the complementarity of innovative inputs require intensive collaboration for technology transfer, inducing firms to combine licensing with other partnerships (Hagedoorn et al., 2008). Future research could assess the validity of our analysis by testing it in different industry settings.

Finally, we restricted our analysis to R&D and licensee's minority equity contracts neglecting the use of other forms of collaborations such as manufacturing or co-marketing agreements to integrate licensing. Although our choice made it possible to understand technology related factors influencing firms' use of licensing. However, we believe future research might benefit further by including other factors and consequently other forms of collaborations.

References

Aghion, P., & Tirole, J. 1994. On the Management of Innovation. ***Quarterly Journal of Economics***, 109(4): 1185-1207.

Ahmadjian, C., & Oxley, J. 2006. Using Hostages to Support Exchange: Dependence Balancing and Partial Equity Stakes in Japanese Automotive Supply Relationships. ***Journal of Law, Economics, and Organization***, 22(1): 213-233.

Anand, B., & Khanna, T. 2000. The structure of licensing contracts. ***Journal of Industrial Economics***, 48(1): 103-134.

Arora, A. 1996. Contracting for tacit knowledge: the provisions of technical services in technology licensing contracts. ***Journal of Development Economics***, 50(2): 233-256.

Arora, A. 2003. Licensing the market for technology. ***Journal of Economic Behavior & Organization***, 52(2): 277-295.

Arora, A., Fosfuri, A., & Gambardella, A. 2001. ***Markets for technology: The economics of innovation and corporate strategy***. Cambridge, Massachusetts: The MIT Press.

Arora, A., & Gambardella, A. 1990. Complementarity and external linkages: the strategies of the large firms in biotechnology. ***Journal of Industrial Economics***, 38(4): 361-379.

Arora, A., & Gambardella, A. 2010. Ideas for rent: an overview of markets for technology. ***Industrial and Corporate Change***, 19(3): 775-803.

Audretsch, D., & Feldman, M. 2003. Small-Firm Strategic Research Partnerships: The Case of Biotechnology. ***Technology Analysis & Strategic Management***, 15(2): 273-288.

Bessy, C., & Brousseau, E. 1998. Technology licensing contracts features and diversity. ***International Review of Law and Economics***, 18: 451-489.

Branstetter, L. G., & Sakakibara, M. 2002. When do research consortia work well and why? Evidence from Japanese panel data. ***The American Economic Review***, 92(1): 143-159.

Brousseau, E., Coeurderoy, R., & Chaserant, C. 2007. The governance of contracts: Empirical evidence on technology licensing agreements. ***Journal of Institutional and Theoretical Economics***: 205-235.

Cappellari, L., & Jenkins, S. 2003. Multivariate probit regression using simulated maximum likelihood. ***The Stata Journal***, 3: 221-222.

Cassiman, B., & Veuglers, R. 2006. In search of complementarity in innovation strategy: Internal R&D and external knowledge acquisition. ***Management Science***, 52(1): 68-82.

Cebrian, M. 2009. The structure of payments as a way to alleviate contractual hazards in international technology licensing. ***Industrial and Corporate Change***, 18(6): 1135-1160.

Chesbrough, H. 2003. ***Open Innovation: the new imperative for creating and profiting from technology***. Boston: Harvard Business School Press.

Choi, J. P. 2001. Technology transfer with moral hazard. ***International Journal of Industrial Organization***, 19: 249-266.

Cohen, W., Nelson, R., & Walsh, JP. 2000. Protecting their intellectual assets: appropiability conditions and why U.S. manufacturing firms patent or not. ***NBER Working Paper n. 7552***.

Cohen, W. M., & Levinthal, D. 1990. Absorptive capacity: A new perspective on learning and innovation. ***Administrative Science Quarterly***, 35(1): 128-152.

Colombo, M. G. 2003. Alliance form: a test of the contractual and competence perspectives. ***Strategic Management Journal***, 24(12): 1209-1229.

Deeds, D., & Hill, C. 1999. An examination of opportunistic action in research alliances: evidence from the biotechnology industry. ***Journal of Business Venturing***, 14(2): 141-163.

DiMasi, J. A., Hansen, R. W., & Grabowski, H. G. 2003. The price of innovation: new estimates of drug development costs. ***Journal of Health Economics***, 22(2): 151-185.

Fosfuri, A. 2006. The licensing dilemma: understanding the determinants of the rate of technology licensing. ***Strategic Management Journal***, 27(12): 1141-1158.

Gallini, N., & Wright, B. 1990. Technology transfer under asymmetric information. ***RAND Journal of Economics***, 21(1): 147-160.

Gambardella, A., Giuri, P., & Luzzi, A. 2007. The market for patents in Europe. ***Research Policy***, 36: 1163-1183.

Gans, J. S., & Stern, S. 2003. The product market and the market for ideas: commercialization strategies for technology entrepreneurs. ***Research Policy***, 32: 333-350.

Grant, R. M. 1996. Toward a knowledge-based theory of the firm. ***Strategic Management Journal***, 17(Special Issue: Knowledge and the firm): 109-122.

Greene, W. 2003. ***Econometric Analysis***. Upper Saddle River, New Jersey: Prentice Hall.

Griliches, Z. 1990. Patent statistics as economic indicators: A survey. ***Journal of Economic Literature***, 28(4): 1661-1707.

Gulati, R. 1995. Does familiarity breed trust? The implications of repeated ties for contractual choice in alliances. ***Academy of Management Journal***, 38(1): 85-112.

Gulati, R., Lavie, D., & Singh, H. 2009. The nature of partnering experience and the gains from alliances. ***Strategic Management Journal***, 30(11): 1213-1233.

Hagedoorn, J. 1993. Understanding the rationale of strategic technology partnering: interorganizational modes of cooperation and sectoral differences. ***Strategic Management Journal***, 14: 371-395.

Hagedoorn, J. 2002. Inter-firm R&D partnerships: an overview of major trends and patterns since 1960. ***Research Policy***, 31: 477-492.

Hagedoorn, J., Lorenz-Orlean, S., & van Kranenburg, H. 2008. Inter-firm technology transfer: partnership-embedded licensing or standard licensing agreements? ***Industrial and Corporate Change***, 18(3): 529-550.

Hagedoorn, J., & Hesen, G. 2007. Contract Law and the Governance of Inter-firm Partnerships- An analysis of different forms of partnering and their contractual implications. ***Journal of Management Studies***, 44(3): 342-365.

Hall, B., Jaffe, A., & Trajtenberg, M. 2001. The NBER patent citations data file: lessons, insights, and methodological tools. ***NBER Working Paper***, 8498.

Jaffe, A. 1986. Technological opportunity and spillovers of R&D: evidence from firms' patents, profits and market value. ***The American Economic Review***, 76(5): 984-1001.

Jaffe, A., Trajtenberg, M., & Henderson, R. 1993. Geographic localization of knowledge spillovers as evidenced by patent citations. ***The Quarterly Journal of Economics***, 108(3): 577-598.

Kim, Y., & Vonortas, N. 2006. Technology licensing partners. ***Journal of Economics and Business***, 58(4): 273-289.

Kogut, B. 1988. Joint ventures: theoretical and empirical perspectives. ***Strategic Management Journal***, 9: 319-332.

Kogut, B., & Zander, U. 1992. Knowledge of the firm, combinative capabilities, and the replication of technology. ***Organization Science***, 3(3): 383-397.

Laursen, K., Leone, M. I., & Torrisi, S. 2010. Technological exploration through licensing: new insights from the licensee's point of view. ***Industrial and Corporate Change***, 19(3): 871-897.

Lichtenthaler, U. 2007. Corporate technology out-licensing: Motives and scope. ***World Patent Information***, 29(2): 117-121.

Lichtenthaler, U. 2008. Leveraging technology assets in the presence of markets for knowledge. ***European Management Journal***.

Lichtenthaler, U., & Ernst, H. 2009. Technology licensing strategies: the interaction of process and content characteristics. ***Strategic Organization***, 7(2): 183-221.

Mowery, D. C., Oxley, J. E., & Silverman, B. S. 1996. Strategic alliances and interfirm knowledge transfer. ***Strategic Management Journal***, 17: 77-91.

Nooteboom, B., Vanhaverbeke, W., Duysters, G., Gilsing, V., & Vandenoord, A. 2007. Optimal cognitive distance and absorptive capacity. ***Research Policy***, 36(7): 1016-1034.

Oxley, J. 1989. Appropriability Hazards and Governance in Strategic Alliances: a transaction cost approach. ***Journal of Law Economics & Organization***, 13(2).

Palomeras, N. 2007. An analysis of pure-revenue technology licensing. ***Journal of Economics and Management Strategy***, 16(4): 971-994.

Pisano, G. 1989. Using Equity Participation to Support Exchange: Evidence from the Biotechnology Industry. ***Journal of Law Economics & Organization***, 5(1): 109-126.

Pisano, G. 2006. Can science be a business? Lessons from biotech. ***Harvard Business Review***, 84(10): 114-125.

Powell, W. W., Koput, K., & Smith-Doerr, L. 1996. Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology. ***Administrative Science Quarterly***, 41: 116-145.

Prencipe, A. 2000. Breadth and depth of technological capabilities in CoPS: the case of the aircraft engine control system. ***Research Policy***, 29: 895-911.

Reed, R., & Defilippi, R. J. 1990. Casual ambiguity, barriers to imitation, and sustainable competitive advantage. ***The Academy of Management Review***, 15(1): 88-102.

Roijakkers, N., & Hagedoorn, J. 2006. Inter-firm R&D partnering in pharmaceutical biotechnology since 1975: Trends, patterns, and networks. ***Research Policy***, 35(3): 431-446.

Rothaermel, F. T. 2001. Incumbent's advantage through exploiting complementary assets via interfirm cooperation. ***Strategic Management Journal***, 22(6-7): 687-699.
Rothaermel, F. T., & Deeds, D. L. 2004. Exploration and exploitation alliances in biotechnology: a system of new product development. ***Strategic Management Journal***, 25(3): 201-221.
Sampson, R. C. 2007. R&D alliances and firm performance: the impact of technological diversity and alliance organization on innovation. ***Academy of Management Journal***, 50(2): 364-386.
Schilling, M. A. 2009. Understanding the alliance data. ***Strategic Management Journal***, 30(3): 233-260.
Shapiro, C. 2001. Navigating the patent thicket: cross licenses, patent pools, and standard setting, ***Innovation policy and the economy***, Vol. Volume 1: MIT Press.
Simonin, B. 1999. Ambiguity and the process of knowledge transfer in strategic alliances. ***Strategic Management Journal***, 20(7): 595-623.
Somaya, D., Kim, Y., & Vonortas, N. S. 2010. Exclusivity in licensing alliances: using hostages to support technology commercialization. ***Strategic Management Journal***, 32(2): 159-186.
Stuart, T., Ozdemir, S., & Ding, W. 2007. Vertical alliance networks: The case of university–biotechnology–pharmaceutical alliance chains. ***Research Policy***, 36(4): 477-498.
Teece, D. J. 1986. Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. ***Research Policy***, 15: 285-305.
Thursby, J., Jensen, R., & Thursby, M. 2001. Objectives, characteristics and outcomes of university licensing: a survey of major U.S. universities. ***Journal of Technology Transfer***, 26(1): 59-72.
van Wijk, R., Jansen, J. J. P., & Lyles, M. A. 2008. Inter and intra-organizational knowledge transfer: a meta-analytic review and assessment of its antecedents and consequences. ***Journal of Management Studies***, 45(4): 830-853.
von Hippel, E. 1994. "Sticky information" and the locus of problem solving: implications for innovation. ***Management Science***, 40(4): 429-439.
Zajac, J., & Olsen, C. 1993. From transaction cost to transaction value analysis: implications for the study of interorganizational strategies. ***Journal of Management Studies***, 30(1): 131-145.

APPENDIX: MAIN TABLES

TABLE 6. Descriptive statistics

	Source	N	Mean	s.d.	Min	Max
Dependent variables						
R&D collaboration	Recap	441	0.26	0.44	0	1
Licensee's minority equity	Recap	441	0.23	0.42	0	1
Main independent variables						
Early stage technology	Recap	441	0.60	0.49	0	1
R&D investments	License	441	0.83	0.37	0	1
Marketing investments	License	441	0.82	0.39	0	1
Unfamiliarity with licensor's technology	NBER	441	0.97	0.14	0	1
Technological diversity	NBER	441	0.49	0.34	0	1
Vertical licensing	Compustat	441	0.46	0.50	0	1
Control variables						
Exclusive licensing	License	441	0.92	0.27	0	1
International licensing	License	441	0.38	0.49	0	1
Previous ties	Recap	441	1.10	0.36	1	3
Licensor's patent stock	NBER	441	296.93	1092.36	0	13257
Licensee's patent stock	NBER	441	550.59	1126.05	0	11086
Time		441	1995.84	4.62	1985	2004

TABLE 7. Correlation matrix

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1. R&D collaboration	1.00											
2. Licensee’s minority equity	**0.16**	1.00										
3. Early stage technology	**0.22**	0.07	1.00									
4. R&D investments	**0.10**	0.06	**0.15**	1.00								
5. Marketing investments	0.01	0.06	-0.09	-0.05	1.00							
6. Unfamiliarity with licensor's technology	0.09	0.04	0.01	0.06	-0.02	1.00						
7. Technological diversity	**0.14**	0.07	0.03	0.02	0.02	0.05	1.00					
8. Vertical licensing	**0.22**	**0.19**	0.07	0.00	-0.03	0.01	0.08	1.00				
9. Exclusive licensing	**0.15**	0.08	**-0.14**	0.05	**0.21**	0.08	0.01	**0.12**	1.00			
10. International licensing	-0.08	**-0.10**	0.03	**0.10**	0.08	-0.05	-0.06	0.08	0.04	1.00		
11. Past ties	-0.03	-0.06	0.03	0.00	-0.03	-0.05	**-0.14**	-0.09	0.01	-0.06	1.00	
12. Log(licensor's patent stock)	**-0.31**	**-0.15**	**-0.30**	-0.01	0.01	**-0.16**	**-0.20**	**-0.30**	**-0.14**	-0.01	**0.14**	1.00
13. Log(licensee's patent stock)	**0.16**	**0.23**	**0.11**	-0.01	-0.03	0.01	0.05	**0.43**	**0.11**	-0.06	-0.00	**-0.24**

Note: Correlation coefficients in bold are significant at a 5% level.

TABLE 8. Bivariate probit estimates: determinants of licensing combination with R&D and equity contracts

	Model 1		Model 2		Model 3		Model 4		Model 5	
	R&D	Equity	R&D	Equity	R&D	Equity	R&D	Equity	R&D	Equity
Main independent variables										
Early stage technology	**0.44***** (0.157)	0.13 (0.154)	**0.39**** (0.163)	0.11 (0.157)	**0.38**** (0.162)	0.11 (0.157)	**0.38**** (0.164)	0.11 (0.157)	**0.41**** (0.164)	0.11 (0.159)
R&D investments			**0.46**** (0.223)	0.21 (0.200)	**0.45**** (0.220)	0.20 (0.200)	**0.46**** (0.222)	0.20 (0.201)	**0.47**** (0.223)	0.23 (0.199)
Marketing investments			0.19 (0.580)	**4.03***** (0.208)	0.19 (0.626)	**4.02***** (0.203)	0.19 (0.621)	**4.36***** (0.199)	0.26 (0.550)	**4.40***** (0.231)
Technological diversity					**0.42**** (0.214)	0.11 (0.210)	**0.40*** (0.215)	0.11 (0.209)	**0.38*** (0.217)	0.09 (0.208)
Unfamiliarity licensor's tech							**4.57***** (0.253)	-0.01 (0.613)	**4.52***** (0.280)	-0.06 (0.600)
Vertical licensing									**0.43***** (0.161)	**0.34**** (0.161)
Control variables										
Exclusive licensing	1.40*** (0.455)	0.36 (0.304)	1.38*** (0.466)	0.26 (0.310)	1.46*** (0.465)	0.27 (0.308)	1.46*** (0.470)	0.27 (0.309)	**1.45***** (0.465)	0.23 (0.307)
International licensing	-0.17 (0.149)	-0.28* (0.148)	-0.19 (0.151)	-0.30** (0.150)	-0.16 (0.150)	-0.30** (0.150)	-0.14 (0.151)	-0.30** (0.150)	-0.20 (0.152)	**-0.35**** (0.149)
Log(licensor's patent stock)	-0.15*** (0.036)	-0.07** (0.032)	-0.15*** (0.036)	-0.07** (0.032)	-0.14*** (0.036)	-0.07** (0.032)	-0.13*** (0.037)	-0.07** (0.034)	**-0.12***** (0.038)	-0.06 (0.034)
Log(licensee's patent stock)	0.06** (0.028)	0.10*** (0.027)	0.06** (0.028)	0.10*** (0.027)	0.06** (0.028)	0.10*** (0.027)	0.06** (0.028)	0.10*** (0.027)	0.03 (0.030)	**0.08***** (0.030)
Past ties	-0.04 (0.257)	-0.29 (0.211)	-0.01 (0.248)	-0.27 (0.207)	0.03 (0.258)	-0.26 (0.210)	0.03 (0.263)	-0.26 (0.210)	0.07 (0.263)	-0.21 (0.211)
Time	-0.06*** (0.017)	0.02 (0.015)	-0.07*** (0.018)	0.02 (0.015)	-0.07*** (0.018)	0.02 (0.015)	-0.07*** (0.018)	0.02 (0.015)	**-0.07***** (0.019)	0.02 (0.015)
Rho R&D-Equity	**0.19*** (0.097)		**0.18*** (0.098)		**0.18*** (0.098)		**0.18*** (0.098)		**0.17*** (0.098)	
Observations	441	441	441	441	441	441	441	441	441	441
Log-likelihood	-422.96	-422.96	-418.91	-418.91	-416.96	-416.96	-415.57	-415.57	-410.11	-410.11

Note: Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1.
Constant terms omitted from the table.

4. OPTIMAL PRICING SCHEME IN TECHNOLOGY LICENSING: EMPIRICAL EVIDENCE FROM THE BIOPHARMACEUTICAL INDUSTRY

ABSTRACT

Drawing on agency theory and theory of innovation, the study empirically examines determinants of optimal pricing scheme in technology licensing. We posit that firms' choice between fixed versus variable payments is contingent on both attributes of the licensed technology as well as partners' features. The analysis relies on a dataset of 266 licensing contracts signed in the pharmaceutical industry between 1985 and 2004. Key findings suggest that royalty payments are associated to ex-ante licensing and to situations where the licensed innovation requires specific-capital investments by the licensee. Further, output-based payments are preferred to lump sums when the parties to the transaction have different technological competences. On the contrary, fixed payments are preferred when know-how by the licensor is transferred or when the licensee has a large knowledge stock. Finally, past relations between the licensor and the licensee mitigate risks of opportunistic behavior, leading firms to choose as optimal payment scheme a fixed compensation.

Keywords: technology licensing, lump-sum, output based payment, two-part tariff, moral hazard, adverse selection

4.1 INTRODUCTION

During the last two decades, markets for technology have grown in size and importance, especially in technology-based industries (Fosfuri & Giarratana, 2010). Athreye and Cantwell (2007) provide evidence of the increase in licensing receipts over the period 1980-2003. Arora *et al.* (2001) estimate over 15,000 technology licensing transactions took place worldwide in the period 1985-1997, for a total market value of $320 billion. The rising importance of technology licensing is related to its several implications for the diffusion of technology, the rate of economic utilization of patents, firms' research efforts, and product market competition (Arora & Gambardella, 2010; Gallini, 1984; Rockett, 1990a; Shepard, 1987). Despite its importance to firms' management of innovation, entering into license contracts in markets for ideas entails some risks and costs to firms (OECD, 2005). One of the major obstacles is represented by transaction costs and fear of opportunism during contract negotiations (Fosfuri & Giarratana, 2010). Due to the inherent uncertainty of technology, inter-firm licensing is hampered by contracts' incompleteness and information asymmetry. Past literature has outlined the importance of designing incentive-compatible contracts in order to provide partners with mechanisms and incentives towards technology collaboration (Aghion & Tirole, 1994). As noted by Somaya *et al.* (2010), the ultimate impact of licensing relationships is determined by how these agreements are structured. Differently structured technology partnerships might lead to very different performance outcomes in terms of partners' commitments, technology transfer and commercial success (Gulati & Singh, 1998; Hoetker & Mellewigt, 2009; Roijakkers & Hagedoorn, 2006; Sampson, 2007).

One of the crucial license contractual choice partners face when negotiating a contract is the price scheme of the transaction (Razgaitis, 2006). The licensor provides the licensee with the right to exploit a specific innovation, usually in form of patents or know-how, in exchange for compensation. Traditionally, three main compensation schemes are observed: fixed payments, variable payments and two-part tariffs. A fixed payment usually comes as an up-front fee the licensee pays to the licensor when signing the contract, or in form of milestone payments or minimum annual royalties. It is therefore a predefined amount of money the licensor receives in exchange for its technology. On the contrary, a variable payment is an output-based payment. The most traditional forms are sales-based royalties: the licensor accrues a percentage of sales deriving from the licensee's technology commercialization. Finally, a two-part tariff comprises both a fixed and a variable part. Theoretical literature on licensing formally demonstrates how different forms of payments deeply influence partners' conduct and commitment, mitigating issues deriving from opportunistic behavior either under adverse selection or moral hazard (Beggs, 1992; Bhattacharyya & Lafontaine, 1995; Bousquet, Cremer, Ivaldi, & Wolkowicz, 1998; Choi, 2001; Gallini & Wright, 1990; Kamien & Tauman, 1986).

Notwithstanding the centrality of licensing price scheme in mitigating partners' opportunistic behaviors in technology transfer, with few exceptions, little attention has been given to the factors generating such behaviors and consequently firms' choice of compensation scheme. The few empirical studies dealing with optimal payment structure are by Mendi (2005), Cebrian (2009) and Vishwasrao (2007). Despite their contributions to the literature, all the three studies present some limitations that render empirical results little informative and extendable to other contexts. Firstly, the two former studies base their empirical analyses on a sample of contracts between Spanish and foreign firms where the licensed technologies are at a mature stage of development, thereby issues of technological uncertainty and adverse selection are less of a concern. The latter study analyses a sample of license contracts entered by manufacturing firms in India. In such a case, license contracts represent technology flows from developed countries to less developed ones, where the licensed technologies are already applied to the licensor's country and the level of technological uncertainty is limited. As a result, issues of asymmetric information and contract incompleteness might be less crucial. Secondly, all the three papers consider a limited set of variables, especially for what concerns the attributes of the licensed technology, neglecting important sources of opportunistic behavior. In turn, the present article represents the natural next-step in order to extend empirical research on firms' licensing practices by examining sources of adverse selection and moral hazard determining price structure in technology licensing contracts. Specifically, we investigate firms' choice between fixed payments versus variable payments contingent on the attributes of the licensed technology and the features of the parties to the transaction.

The contribution of the study is twofold. Firstly, the study advances the relatively underdeveloped empirical research on technology licensing practices. Licensing price scheme has long been modelled in economic theory of innovation (Beggs, 1992; Bousquet et al., 1998; Choi, 2001; Gallini & Winter, 1985; Gallini & Wright, 1990). However, lack of adequate secondary data has been an obstacle to the validation of theoretical models and to the assessment of potential sources of opportunistic behavior. Building on agency theory, we develop a synthetic framework to predict empirically how fixed, variable payments or a combination of the two allow partners to cope with uncertainty, asymmetric information and contract incompleteness. Secondly, through its empirical analysis of sources of adverse selection and moral hazard, the article provides an overview of the efficiency of technology markets in allocating risks and resources among partners.

Research hypotheses are tested on a sample of 266 technology license agreements in the worldwide biopharmaceutical industry over the period 1985-2004. We select the biopharmaceutical industry as the research setting since it is a technology-intensive industry where uncertainty and asymmetric information pose serious threats to technology partnering (Vishwasrao, 2007). Additionally, technology licensing has a long tradition in the industry, allowing to gather reliable data and provide an overview of the patterns in the industry.

The research design relies on multiple sources of information: data on licensing are combined with data on firms' patenting activity and features of the technology exchanged through the license. This allows to include in the analysis a rich set of explanatory variables considering both technology and partners' attributes.

The article proceeds as follows. Sections 2 and 3 review previous theoretical and empirical contributions and formulate hypotheses. Section 4 describes the research design and methodology. Section 5 presents the main findings. The paper finalizes with a conclusion, drawing both policy and managerial implications.

4.2 LITERATURE REVIEW

When transferring knowledge through arm's length market transactions, both licensors and licensees face several hazards (Caves *et al.*, 1983). As pointed out by Arrow (1962), the intrinsic risky and tacit nature of knowledge renders contracts incomplete. The licensing literature traditionally recognizes three main contracting hazards that negatively impact on the effective functioning of markets for inventions. Firstly, asymmetric information between partners poses serious threats to knowledge transfer. Partners have different sets of information about the true value of the technology, the probability of success of the transfer and partner's capabilities both in technology transfer and commercialization (Shane, 2002). Secondly, key activities for the success of the transaction cannot sometimes be fully contracted and specified (Aghion & Tirole, 1994; Hart & Moore, 2008). For instance, it is difficult for partners to specify the optimal amount of know-how and expertise the licensor should transfer to the licensee; or, it is difficult to contract the optimal level of resources and commitment the licensee should invest for the successful technology commercialization. Finally, prescribed activities cannot always be adequately monitored and enforced (Arora, 1996; Macho-Stadler *et al.*, 1996). For instance, due to the inherent uncertainty of technology, it is difficult for the licensor to detect and monitor the true effort exerted by the licensee in technology commercialization; or, on the other side, it might be difficult for the licensee to monitor licensor's commitment towards technology transfer. Hence, when contracts are incomplete because of gaps in specification and partners' different sets of information, the possibility of moral hazard and adverse selection arise on both sides of the transaction (Oxley, 1989).

Past studies on licensing practices have outlined the importance of specific contractual clauses and financial incentives in order for firms to design incentive-compatible license agreements and favour technology cooperation. Somaya *et al.* (2010) provide empirical evidence relative to the importance of exclusivity provisions to align partners' incentives to cooperation. Exclusivity is used as a contractual hostage to safeguard licensee's investments in complementary assets and to enable contracting over early stage technologies. Arora (1996), studying data on the acquisition of technology by Indian chemical firms, finds that bundling know-how with other complementary inputs is a way to avoid opportunistic behavior by both parties and render technology transfer over tacit knowledge effective. Finally and most importantly, previous authors have shed light on the centrality of payment structure in providing partners with the economic incentives towards technology collaboration (Cebrian, 2009; Mendi, 2005). Relative to this last point, theoretical literature has long investigated optimal license payment schemes both in the presence of adverse selection and moral hazard (Beggs, 1992; Choi, 2001; Gallini & Wright, 1990; Kamien & Tauman, 1986). Economic models demonstrate that fixed payments are the efficient scheme (Beggs, 1992; Choi, 2001; Gallini & Wright, 1990). Any variable payment introduces a distortion on the licensee's output decision, determining a non Pareto-efficient equilibrium. As noted by Choi (2001), royalty rate artificially changes the licensee's effective marginal cost, inducing an inefficient production decision. In practice, however, licensing contracts are predominantly royalty-based (Choi, 2001). This discrepancy between theory and empirical evidence is due to information problems. Contract incompleteness and asymmetric information between partners prevent markets for inventions from attaining a first best outcome. We argue that the settlement of fixed or output-based payments or both can be a means of screening among potential partners, aligning partners' incentives to cooperation, and finally monitoring each partner's effort, mitigating the risk of opportunistic behaviors.

Under adverse selection, partners have different sets of information. Adverse selection from the licensor' side implies the licensor being more informed than its partner on the true value of the licensed innovation. Gallini and Wright (1990) show that under such conditions, the optimal payment structure is a two-part tariff. The licensor uses royalty payments to signal the high value of its technology. The model predicts a separating equilibrium where the compensation scheme for innovations with relatively low value is a fixed fee; whereas, for high-value innovations the compensation scheme comprises both a fixed and a variable fee.

Differently, asymmetric information on the licensee' side is linked to two main factors. The first is related to the licensee's technical capabilities in technology commercialization. When signing the contract, the licensor does not know licensee's type, whether high or low. Hence, payment schemes can be used to reach a separating equilibrium between high and low types. A low type will be reluctant to pay a fixed fee only; on the contrary, a high type will prefer a fixed payment since, due to its greater technological capabilities, it can keep the upside potential of the rent to itself (Mendi, 2005; Sakakibara, 2010). The second factor is related to the licensee's better knowledge of the market potential of the licensed technology. If the licensee has a better knowledge of market opportunities, it might be difficult for the licensor to ascertain the true market potential of the innovation and determine the size of the lump sum (Beggs, 1992). Hence, the licensor might use variable payments to extract information from the licensee about product markets and secure a share of revenues deriving from technology commercialization.

Theoretical literature also analyses issues of moral hazard and their impact on license payment schemes. Moral hazard rises when key activities for the success of the transaction cannot be fully contracted and specified. This leaves space for opportunistic behavior by one or both parties (Cebrian, 2009). For instance, partners shirk on the provision of inputs to the technology transfer since the ability to verify their provision is low (Arora, 1996). Choi (2001) demonstrates that if the effectiveness of technology transfer depends on the effort provided by the licensor and this effort is not verifiable, then the first-best outcome, namely a fixed fee only, cannot be implemented. The optimal licensing contract includes a royalty rate, which serves as a hostage to induce the licensor's costly effort.

Differently, if the likelihood of opportunistic behavior is on the licensee' side, the optimal payment scheme is a fixed payment. With a lump sum, the licensor does not need to monitor its partner's effort toward technology commercialization and avoids the difficulty of verifying its output (Cebrian, 2009).

Section 3 formulates a set of hypotheses on the impact of potential sources of both adverse selection and moral hazard on partners' choice of scheduled payments. As outlined before, optimal pricing scheme has been a subject of a long tradition of scholarship. However, little attention has been devoted to identify sources of adverse selection and moral hazard determining optimal compensation scheme. According to the licensing literature, the optimal structure of a license depends on the type of technology exchanged, the partners involved and the contracting environment (Anand & Khanna, 2000; Gans & Stern, 2003). Following this stream of research, in assessing the potential sources of uncertainty and asymmetric information, we consider the two former antecedents: sources deriving from the attributes of the licensed technology and sources related to the parties to the transaction. The former category includes the following elements: development stage of the licensed technology, transfer of know-how and technology specific investments to market the licensed innovation. The latter takes into account of: licensee and licensor's technological size, partners' technological diversity and past relationships. We do not analyze in our framework the contracting environment due to our focus on a single research setting, namely the biopharmaceutical industry.

4.3 RESEARCH HYPOTHESES

4.3.1 Attributes of the licensed technology

4.3.1.1 Early stage licensing

In many industries ex-ante licensing is a common practice (Anand & Khanna, 2000): the licensed technology is at an embryonic stage of development and its potential applications or likely success are still uncertain. Under these circumstances, technology transfer is at risk, since the degree of uncertainty is higher and consequently the likelihood of partners' opportunistic behavior (Somaya et al., 2010). More specifically, we argue that two main hazards threaten the successful outcome of the transaction: the licensor's private information relative to the true value of the licensed technology and the presence of inputs that are not contractible, costly, and difficult to monitor.

The uncertainty inherent the potential applications and profitability of the licensed technology makes it difficult for the licensee to ascertain the underlying value of the technology. Being the technology still a prospective one, the linkages and interactions among the elements composing it are not completely defined (Simonin, 1999), limiting the licensee's capability of evaluating the licensed technology. Additionally, knowledge about an embryonic technology is usually tacit and contextual (von Hippel, 1994): the licensor is expected to have superior knowledge about the licensed innovation. As a result of asymmetric information, the licensee would be reluctant to make irreversible commitments towards technology commercialization, without some assurance of the invention's profitability (Gallini & Wright, 1990; Teece, 1986). Consequently, we argue that an output-based payment might serve the licensor to signal the high value of the licensed innovation and overcome the information asymmetry. By linking its future stream of profits to the successful commercialization of the technology, the licensor provides the licensee with a signal of the value of its innovation.

The other concern in early stage licensing is related to the inherent difficulty for partners both to specify and monitor key activities to technology transfer. Knowledge about embryonic technologies usually requires more experimentation and tinkering by the recipient firm (Somaya *et al.*, 2010). The licensee may depend to a greater extent on the licensor's assistance to technology commercialization. However, as noted by Oxley (1989), the licensor' support is hardly contractible, exposing the licensee to licensor's opportunism. Building on Choi (2001), we argue that an output-based payment is likely to be included in order to induce the licensor to exert optimal effort in assisting the licensee in exploiting the licensed innovation.

Instead, adopting the licensor's perspective, we argue that a lump sum is likely to be implemented. Being the technology still a prospective one, the licensor faces high degrees of ambiguity and uncertainty relative to its partner's effort and commitment towards the further development of the licensed innovation. Due to the difficulty in monitoring licensee's effort towards the commercialization of the technology, the optimal payment scheme might comprise a lump sum in order for the licensor to accrue a secure amount of profits from the sale of the innovation.

As a result of contractual hazards deriving from high uncertainty, knowledge tacitness and contract incompleteness, we hypothesize the following:

Hypothesis 1a. All else being equal, if the licensed technology is at an early stage of development, it will be more likely that the license payment scheme comprises an output-based payment in cases of fear of opportunism by the licensor.

Hypothesis 1b. All else being equal, if the licensed technology is at an early stage of development, it will be more likely that the license payment scheme comprises a lump sum payment in cases of fear of opportunism by the licensee.

4.3.1.2 Transfer of know-how

Technology licensing usually entails much more than the transfer of intellectual property rights (Leone & Reichstein, forthcoming). Frequently, the knowledge described in the licensed patents and blueprints might provide only partial explanations to the licensee on how to further proceed in exploiting the licensed innovation (Arora & Gambardella, 1994). Hence, the licensee can benefit from the establishment a channel of information with the licensor to access skills and context-specific know-how in order to understand and efficiently master the licensed technology.

Due to contract incompleteness, however, it is difficult for partners to specify all the knowledge to be transferred and more importantly to contract the amount of effort the licensor should exert in training the licensee (Arora, 1996). Under such circumstances, conflict between partners may emerge unless the contract is designed to be incentive-compatible. The licensor, after signing the contract, might not disclose the required know-how to enable the licensee to exploit the licensed innovation; or it might exert a sub-optimal effort in technology transfer hampering the licensee's receptive capability. A way to induce the licensor's optimal effort is to implement a payment scheme based on royalty rate (Cebrian, 2009; Choi, 2001; Macho-Stadler, Martinez-Guiral, & Perez-Castrillo, 1996). An output-based mechanism serves as hostage to incentive the licensor's costly effort. The licensor's profits are now dependent on the licensee's success in technology commercialization. Indeed, it is in the licensor's interest to assist its partner in understanding and mastering the licensed technology.

The adoption of the licensor's perspective, however, leads to a different argument to the one previously put forward. When transferring its know-how, the licensor might also be exposed to opportunism due to the paradox of knowledge disclosure. Disclosure in fact increases the buyer's intrinsic evaluation of the innovation and its capability of using it, however it weakens the inventor's bargaining power (Arrow, 1962; Gans & Stern, 2003). Once the know-how is transferred, the licensee might change its priorities, for instance renegotiating or terminating the contract to avoid paying royalties. As a result, the optimal payment structure would comprise a fixed payment in order to safeguard the licensor from licensee's opportunism and guarantee it returns from the innovation.

The above arguments lead to the following hypotheses:

Hypothesis 2a. All else being equal, if the licensed technology entails the transfer of tacit know-how, it will be more likely that the license payment scheme comprises an output-based payment in cases of fear of opportunism by the licensor.

Hypothesis 2b. All else being equal, if the licensed technology entails the transfer of tacit know-how, it will be more likely that the license payment scheme comprises a lump sum payment in cases of fear of opportunism by the licensee.

4.3.1.3 Technology-specific investments

In several technology-intensive industries, innovations, when licensed, are far from being marketable. For instance, it is a common practice in the pharmaceutical industry to exchange molecules that are in the very early stages of the drug development process and for which no proof of concept or prototype exist at the time of licensing (Stuart et al., 2007). These innovations require specific investments either in terms of R&D, or manufacturing or marketing programs by the acquiring part in order to reach the market. For instance, the commercialization of a new drug requires dedicated R&D programs in order to test and demonstrate the safety of the drug (Pisano, 2006). Similarly, in order to successfully commercialize a new technology, *ad hoc* marketing programs need to be set up, advertising investments to be allocated and the distribution network to be trained (Ceccagnoli et al., 2010). All such capital commitments are highly specific to the licensed technology, making them difficult to be redeployed to other uses and exposing the licensee to hold-up issues (Williamson, 1981). After the licensee invests, the licensor could change its priorities, renegotiate the contract, or expand its choice of partners, leaving the licensee with technology-specific investments that have limited alternate uses (Somaya *et al.*, 2010). As noted by Teece (1986), under these circumstances a licensee would unlikely commit to these investments or if it did, a sub-optimal amount of resources would be allocated.

Hence, we argue that if the licensed innovation requires specific-capital commitments by the licensee, the contract must be incentive-compatible. On the one hand, the optimal payment scheme should refrain the licensor's opportunistic behavior and on the other side it should induce the licensee to optimally invest in specific and non-redeployable assets. Hence, a payment scheme comprising a royalty rate would induce both partners to collaborate. Under a royalty payment scheme, the licensor has lower incentives to behave opportunistically since its profits are dependent on the licensee' success in commercializing the licensed technology. Differently, the licensee has the incentives to optimally invest in technology-specific assets since through the variable payment it shares some of the risks with the licensor and it receives a signal by its partner about the potential profitability of the innovation (Mendi, 2005).

Hypothesis 3. All else being equal, if specific investments are needed for the commercialization of the licensed technology, it will be more likely that the license payment scheme comprises an output-based payment.

4.3.2 Attributes of the parties to the transaction

4.3.2.1 Partners' technological bases

The licensing literature points out that the size of firms taking part to the transaction plays a role in payment scheme choice. Firms' size is traditionally related to capital constraints, risk aversion and adverse selection arguments (Mendi, 2005; Vishwasrao, 2007). A large licensee may not be as risk averse and may be willing to pay a fixed fee only; differently, a small firm, having lower financial resources, might prefer an output-based royalty in order to share technology risks with the licensor (Mendi, 2005). For what concerns the licensor' size, theoretical research suggests that the extent of market position support given by an invention influences inventor's decision regarding whether to exploit the patent internally or license it (Rockett, 1990b). Low quality inventions tend to be licensed, while drastic inventions tend to be exploited within the firm. Additionally, empirical evidence highlights that adverse selection is more pronounced for large firms (Gambardella *et al.*, 2007): they might prefer lump sum payments due to the low value of the licensed inventions.

Unlike past studies, we take into consideration firms' technological sizes, namely licensor's and licensee' stock of technologies. We argue that firms' technological capabilities influence optimal payment structure in two respects. Firstly, being confident of their technological capabilities and consequently of the potential success of the commercialization of the licensed technology, large licensees might prefer lump sum payments over royalty rates in order to retain benefits from their sales (Sakakibara, 2010). Secondly, licensees with larger technological capabilities are less concerned with adverse selection issues: they are more able to assess the market potentials of the licensed technology (Beggs, 1992). Hence, they might prefer lump sum payments to keep the upside potential of the rent to themselves.

Differently, adopting large licensors' perspective, due to their large knowledge bases, they are more able to distinguish between low and high type licensees, with no need of recurring to output-based payments. Additionally, having large technical bases, they can better evaluate potential market applications of the licensed innovation. As a result, they can properly specify the amount of lump sum in the contract.

We posit the following:

Hypothesis 4a. All else being equal, the larger the licensee's technological base, the more likely the license payment structure will comprise a lump sum payment only.

Hypothesis 4b. All else being equal, the larger the licensor's technological base, the more likely the license payment structure will comprise a lump sum payment only.

4.3.2.2 Partners' technological diversity

Past literature points out that when partners have skills and competences in different and distant technological domains, technology transfer through licensing is a non-trivial process (Colombo, 2003; Kim & Vonortas, 2006a). The technological gap between partners represents a source of uncertainty and asymmetric information, generating serious contractual hazards. More specifically, due to their different technological specialization, both partners are exposed to transactional hazards. From the licensor's perspective, selling its technology to a partner with different technical capabilities might expose it to adverse selection issues. The licensee might possess more information about potential product markets of the licensed technology, making it difficult for the licensor to evaluate *a priori* the fixed amount of its compensation (Beggs, 1992). Being the licensor less informed relative to the commercial applications of its technology in distant markets, it might underestimate the commercial potential of the innovation and consequently its compensation. The licensee might also be exposed to adverse selection issues. Given its different set of competences in distant technological fields, the licensee is limited in its ability to assess the underlying value of licensor's technology.

Consequently, we argue that both for the licensor as well as the licensee, the introduction of an output-based payment is a way to overcome information asymmetry and extract information either relative to the licensed innovation or to the potential commercial applications of the technology. The licensor might use royalty payments to signal the high value of its innovation and induce the licensee to optimally commit to technology commercialization. Differently, through an output-based payment, the licensor might extract the licensee's private information about potential product markets.

We posit that output-based payments are likely to be observed in licenses where partners have distant knowledge bases.

Hypothesis 5. All else being equal, the larger the technological diversity between the licensor and the licensee, the more likely the license payment scheme will comprise an output-based payment.

4.3.2.3 Partners' past relationships

In recent years, numerous researchers have criticized the treatment of each transaction between firms as an independent event. Gulati (1995) argues that this assumption is particularly inappropriate when firms repeatedly enter into partnerships with each other. Ongoing interactions render partners' behavior predictable: firms learn about each other, reducing space for opportunistic behavior and lowering transaction costs in learning and transferring knowledge. Through past relations, partners gain higher knowledge of each others' technical capabilities, behavior and managerial style (Kim & Vonortas, 2006a). This growing knowledge reduces partners' asymmetric information and eases monitoring activity. Additionally, partners' previous experience eases the complexity of knowledge transfer and lowers the licensee's dependency on the licensor' support and know-how (Arora, 1996; Cebrian, 2009). Through previous experience, the licensee becomes familiar with the licensor's technology, reducing transaction costs in knowledge transfer.

As a result of lower degrees of asymmetric information, partners do not need to introduce any variable payment as a means of inducing technology collaboration.

Hypothesis 6. All else being equal, the higher the number of past relationships between partners, the more likely the license payment scheme will comprise a lump sum payment only.

4.4 DATA AND METHODS[10]

4.4.1 Data and sample

The research hypotheses are tested on a dataset based on the coding of 2018 license agreements in the worldwide biopharmaceutical industry over the time period 1985-2004. License data were collected from Deloitte Recap Database. A number of considerations led to build the research sample drawing on Recap. Firstly, Recap provides access to original license agreements, allowing to directly code information disclosed in the contracts. From the text of the contracts we retrieved a detailed set of information that other databases do not provide (Schilling, 2009): the compensation the parties agree upon; the stage of development of the licensed technology; the inclusion in the contract of specific clauses such as technology-furnish clauses, grant-back clauses, exclusivity on future innovations; and the type of activities the licensee is expected to undertake to commercialize the licensed technology. Additionally, Recap covers a technology-intensive industry over a time period of about 25 years. The pharmaceutical industry represents the ideal research setting where to test the determinants of license payment structure. In such an industry, the size of market for knowledge has been constantly increasing, leading to a vertical division of labor across different specialized firms (Arora *et al.*, 2001). Small biotechnology companies are specialized in generating innovations. They usually license out new compounds to large pharmaceutical companies that, due to their superior resources in technology commercialization, bring licensed innovations to market (Stuart et al., 2007). Albeit the increasing size of the market, information problems threat market's effective functioning. Large part of licensed innovations are at an early stage of development; the high technology-intensity of the product development process increases the

[10] Since the thesis builds on a single dataset, the "methods" sections of the three papers share common arguments and information relative to the choice of the research setting, the creation of the research sample, and variables' operationalization.

uncertainty partners face in technology exchange; finally, part of the inputs required for technology transfer are non contractible (Pisano, 2006). Hence, studying optimal payment structure in this research setting provides a rich overview of the type and magnitude of hazards firms face when accessing markets for technology.

From Recap we extracted contracts satisfying the following criteria: (i) the contract is a license, (ii) the transaction involves the transfer of patents, (iii) the original text of the contract is available. The initial sample comprised 2018 licenses. Next, only unilateral agreements were selected, excluding cross-license agreements. This choice is due to the fact that firms forming a cross-license partnership face different contractual hazards compared to those of a standard license (Oxley, 1997). Finally, given our interest in inter-firm licensing, all licenses involving universities or governmental research agencies were dropped from the sample. After this selection, we ended up with 945 license agreements. Next, license data were combined with patent data, using the National Bureau of Economic Research dataset (Hall *et al.*, 2001). By matching the names of the licensor and the licensee with assignees' names recorded in the NBER dataset, firms' patent portfolios and statistics related to their innovative activity were computed. Finally, for each licensor and licensee, the corresponding SIC codes were retrieved from Compustat to record their primary market. By the end of this process, the research sample comprised 266 license agreements.

4.4.2 Measures

Dependent variable The dependent variable is the *type of payment structure* chosen by partners. When choosing the license compensation scheme, partners have three choices: fixed payment only, variable payment only and two-part tariff.

Therefore, the dependent variable is a multi-categorical variable. According to the adopted coding, the category *fixed payment only* comprises: up-front fees, milestone payments and minimum annual royalties. The second category, namely *variable payment only*, comprises: royalties on net sales, royalties on gross sales and licensee's profit shares. Finally, the third category *two-part tariff* comprises those contracts where the payment structure is scheduled on both fixed and output-based payments[11].

Independent variables *Early stage technology*: For each license contract, Recap provides a description of the licensed technology and its development phase. Drug development is a well-structured process, consisting of three macro phases: discovery, clinical trials and regulatory approval (DiMasi et al., 2003). The discovery process ends with pre-clinical trials during which the compound undergoes laboratory and animal testing to assess safety and biological efficacy of the molecule. After approval for trials in humans, the candidate drug enters clinical trials. If the results of the trials show that the benefits of the drug outweigh the risks, the drug is submitted to the competent authorities for market approval.

For capturing the early stage nature of the licensed innovation, a dummy variable – *early stage technology* – was coded. It takes value of 1 if the technology is licensed before the first phase of clinical trials; and 0, otherwise. For coding the variable, we relied on two industry experts in order to determine until which phase a compound could be considered at an early stage of the development.

Transfer of know-how is a dichotomous variable expressing whether the agreement includes a technology-furnish clause. With such a clause, the licensor commits to transferring know-how and competences to the licensee, providing it with technical assistance. When this type of clause is included in the license, it implies that

[11] We adopted a coding strategy similar to the one proposed by Cebrian (2008).

the technology disclosed through patents and blueprints is not enabling by itself. The licensee is dependent on the licensor' skills and resources to exploit the licensed technology[12].

Technology specificity is a dichotomous variable taking value of 1 if the licensee is expected to undertake specific investments to evaluate, further develop, and market the licensed technology. As for the dependent variable, even in this case the variable is coded from information disclosed in the license contract. More specifically, we focused on two types of capital commitments by the licensee: investments in R&D and marketing activities. Unlike manufacturing investments, R&D and marketing investments are highly technology-specific and can be rarely redeployed to other uses (Pisano, 1989; Somaya et al., 2010), allowing to capture the specificity of the licensed technology. It is important to remind that the variable proxies whether the licensed innovation requires specific capital commitments by the licensee in order to reach the market. Hence, it captures a different attribute of the technology underlying the contract compared to the one proxied through the variable early stage technology.

In line with previous studies in innovation literature (Ahuja & Katila, 2001; Jaffe et al., 1993), *partners' technological bases* are proxied through firms' patent portfolios. Specifically, they are respectively defined as the logarithm of the number of patents the licensor has applied for up to the license year and the logarithm of the number of patents the licensee has applied for up to the license year. These variables capture the size of each partner's knowledge base. The choice of using patents to proxy partners' technological sizes relies on the fact that patents are representative of firms' knowledge bases in the pharmaceutical industry (Cohen et al., 2000). Due to the tight appropriability regime of the industry, firms capture the value from

[12] Bessy and Brousseau (1998) and Cebrian (2009) provide further evidence on the use of technology furnish clauses and other types of contractual clauses in license contracts.

innovation through patents rather than recurring to other forms of protection such as secrecy.

The diversity of partners technological capabilities, namely *technological diversity*, is measured by examining the extent to which partners patent in the same technological classes. Technological diversity captures partners' dissimilarities in terms of technological capabilities across a set of different technological fields, namely patent classes. The choice of using patent classes to measure partners' technological profiles derives from the fact that patents are categorized according to underlying technology and not end product *per se* (Griliches, 1990; Hall et al., 2001). Following prior research (Kim & Vonortas, 2006; Sampson, 2007), in order to construct the variable, we generate each partner's technological portfolio by measuring the distribution of its patents across US patent classes[13], up to the license year. A multidimensional vector, $F_i=(F_{i1}, F_{i2}, \ldots F_{is})$, reports the distribution across patents classes, where F_{is} represents the number of patents assigned to partner firm i in patent class s. Technological diversity is then computed as follows:

$$\text{Technological diversity} = 1 - \frac{F_i F_j^{'}}{\sqrt{(F_i F_i^{'})(F_j F_j^{'})}} \quad \text{with } i \neq j$$

The variable varies between 0 and 1, with value 1 indicating the highest technological diversity between partners.

The variable – *partners' past relationships* – is defined as the number of licenses between partners that were signed prior to the license year. This variable proxies the existence of informal and relational governance between partners, based on reciprocity, trust, and reputation (Gulati, 1995a). In order to avoid bias from sample selection and missing values, in constructing the variable we did not restrain to the

[13] We considered USPTO patent classes at 3 digits level.

final sample of 266 license contracts. We created the variable by counting the number of past ties between partners in the initial sample of 2018 license contracts.

Controls *Exclusive licensing* takes value of 1 if the license is exclusive and 0 otherwise. Under an exclusive license, the licensor agrees to work with only one commercialization partner. The presence of an exclusivity clause in the contract influences partners' cooperative behavior (Somaya *et al.*, 2010), hence it expect to influence partners' choice of payment scheme.

Geographic scope is a dummy variable equals to 1 if the licensee is provided with a worldwide right to sell and commercialize the licensed technology. Geographic scope restrictions might serve to reduce and manage transactional hazards (Oxley & Sampson, 2004). For instance, Somaya *et al.* (2010) note that geographic restrictions are used in order to protect the licensor from licensee's opportunism. As a consequence, we expect the presence of geographic restrictions to impact partners' optimal choice of price scheme.

Vertical licensing is a dichotomous variable taking value 1 if partners belong to different phases of the industry value chain, namely the licensor is a biotech company while the licensee is a drug company. The variable captures whether partners have different capabilities along the industry value chain. Biotechnology firms are usually originators of technology, which is then brought to the marketplace by drug companies with extensive experience in managing the clinical trials and regulatory process (Rothaermel, 2001; Rothaermel and Deeds, 2004; Stuart *et al.*, 2007). A vertical license might have a different effect on payment scheme compared to a horizontal one. We expect partners' risk aversion rather than moral hazard or adverse selection to determine partners' choice of compensation scheme.

We included a dummy to account for *international licensing*. Forming an international license might require higher costs in terms of coordinating and monitoring activities. The variable is equal to 1 if partners are based in different regions, namely the US, Europe and Japan; 0 otherwise.

The variable – *licensor's past relations* – measures the number of licenses granted by firm *i* up to the license year. We expect the licensor's experience in terms of looking for potential partners, writing contracts, transferring the technology to lower the cost of licensing, thereby reducing the magnitude of transactional hazards.

Similarly, the variable – *licensee's past relations* – measures the number of licenses acquired by firm *i* up to the license year. Similarly to the case of the licensor, the licensee's past experience in searching for potential technologies and partners, writing contracts and integrating and commercializing technology lowers the transaction costs of licensing.

We also considered the potential differences in terms of knowledge complexity and tacitness among different therapeutic areas of the industry. Different degree of complexity and knowledge codification might differently impact the magnitude of transaction hazards the parties are exposed to. A set of dummy variables accounting for different therapeutic areas is specified: *cancer*, *infectious*, *central nervous system*, *cardiovascular* and *others.*

Year dummies are included to control for time effects.

4.4.3 Econometric model

The dependent variable is a multi-categorical variable. According to the coding adopted to specify it, three alternative categories are considered: fixed payment only, variable payment only and two-part tariff. Since the variable categories have no natural ordering, we model the probability that a particular license falls into one of the three categories employing a multinomial logistic approach. In order to ease results interpretation, the reference category is: fixed payment only. Accordingly, the regression estimates two parameters for each explanatory variable. The first (β_{i1}) describes how the explanatory variable X_i influences the probability of adopting a royalty-based payment compared to the baseline category, namely fixed payment only. The second parameter (β_{i2}) expresses the impact X_i has on the probability of choosing a two-part tariff compared to a lump sum payment only. For instance, a positive β_{i1} suggests that all else equal, a higher X_i is associated with a higher probability of choosing a royalty-based payment only. We also estimate a model where the reference category is two-part tariff, in order to obtain the comparison between two-part tariff and royalty-based payments.

4.5 RESULTS

Table 9 provides an overview of the data and some descriptive statistics. The sample comprises 266 license agreements. Around 78 percent of the licenses schedule a payment scheme based on a two-part tariff; 12 percent a fixed payment only and 10 percent an output-based payment only. For what concerns the type of technology transferred from the licensor to the licensee, about 41 percent of licenses are at an early stage of development and 71 percent include the provision of know-how by the licensor. Approximately 84 percent of the licenses require specific R&D and/or marketing investments by the licensee in order to commercialize the licensed technology. For what concerns the inventive size of the licensor and the licensee – measured in terms of patent stocks – it is to observe that on average the licensee's size is larger than the licensor's. About 93 percent of licenses are exclusive and 60 percent have a worldwide geographic scope. About 48 percent of licenses are between firms operating at different levels of the industry value chain: namely the licensor is a biotech company while the licensee is a drug company. Finally, about 38 percent of licenses are international ones: partners are based in different countries.

Insert table 9 about here

Table 10 reports Pearson correlation coefficients of the variables included in the analysis. Correlations among variables are low, suggesting that multicollinearity is not an issue in the analysis. It is worth observing that the correlation coefficient between the variables *early stage technology* and *technology specificity* is low and not significant, confirming our conjecture that they proxy two different constructs: the former captures the uncertainty and tacitness of the licensed knowledge; the latter captures the specificity of the licensed technology in order to be commercialized by the licensee.

Insert table 10 about here

The results of the multinomial logistic regression are reported in Table 11. The first column – Model 1 – reports the estimation results for the baseline model where just control variables enter the regression. In models 2-7, explanatory variables are step-wisely introduced and the reference category is lump sum payment. Model 8 takes as reference category two-part tariff, in order to compare the likelihood of choosing a two-part tariff compared to a royalty-based payment. For the sake of clarity, results are discussed focusing on models 7 and 8.

Insert table 11 about here

Hypothesis 1a and 1b suggest that when the licensed technology is at an early stage of development, the optimal compensation scheme comprises an output-based payment in case of fear of opportunism by the licensor and a lump sum in case risks of opportunism are on the licensee' side. In table 3, the coefficient for early stage technology is positive and significant below the 5 percent level. We find that royalties are more likely to be chosen than fixed payments as well as two-part tariff schemes. Uncertainty about the value of the licensed technology and the need of licensor's support in technology commercialization render lump sum payment an inefficient price scheme to technology transfer. In turn, results provide evidence in favour of Hypothesis 1a.

Pertaining to Hypothesis 2a and 2b, we test two ideas. On the one side, Hypothesis 2a conjectures that the provision of know-how by the licensor is likely to be associated to a payment scheme comprising an output-based payment in order to induce it to optimally commit to technology transfer. On the other side, Hypothesis 2b proposes the idea that the risk of licensee's opportunism after the know-how has been transferred is likely to induce partners to choose a lump sum in order to guarantee the licensor a return on the licensed innovation. Results support Hypothesis 2b: fixed payments only are more likely to be introduced if the contract includes the transfer of know-how. Such a result contrasts the predictions of theoretical models (Choi, 2001), according to which royalties are to be introduced to induce the licensor's costly effort. However, it is in line with empirical evidence provided by Cebrian (2009), according to which the risk of licensee's opportunism after the know-how is transferred leads partners to choose fixed payments only. Such a discrepancy between theory and empirical evidence might be due to partners' bargaining power. More specifically, if the licensor's bargaining power is higher than the licensee's, the licensor might refuse to provide its partner with the technology in exchange for a variable payment in order to avoid licensee's opportunistic behavior.

Hypothesis 3 states that if the licensee has to undertake technology-specific capital commitments, it is more likely that the optimal payment scheme comprises an output-based payment. In model 8, two-part tariff is preferred to royalty payment only. In model 7, the sign of the coefficient comparing the probability of choosing between lump sum versus royalty payment suggests that the former is preferred to the latter; however, the coefficient is not significant at conventional level. Hence, results do not lend strong support to Hypothesis 3.

Hypotheses 4a and 4b test the influence of respectively licensee and licensor's technological capabilities on the probability of choosing a fixed payment versus royalties or two-part tariff schemes. Empirical evidence supports Hypothesis 4a only: the larger the licensee's technical base, the more likely the optimal payment scheme is based on a fixed payment only. The findings are in line with previous research (Cebrian, 2009; Sakakibara, 2010): licensees with larger technological capabilities can better assess the market potential of the licensed technology. Hence, they prefer lump sum payments to keep the upside potential of the rent to themselves.

In Hypothesis 5 we test the effect of partners' technological diversity on firms' choice between fixed and variable payments. The coefficient of technological diversity associated to royalty payment is positive and significant as expected either when compared to lump sum payment as well as to two-part tariff. If partners have different technological competences and master distant technological domains, an output-based payment is chosen in order to mitigate issues of adverse selection and asymmetric information on both sides of the exchange.

Finally, Hypothesis 6 analyses the impact of partners' past relations, asserting that past relations reduce partners' incentives to behave opportunistically, leading firms to choose fixed payment as a pricing scheme. Results lend support to our hypothesis: the coefficient associated to two-part tariff compared to fixed payment is negative and below 5 percent significance. In turn, in line with previous research (Cebrian, 2009; Kim & Vonortas, 2006; Mendi, 2005), past relations between partners increase costs of opportunistic behavior and decrease costs of transferring knowledge, thereby substituting for royalty rates.

Figure 3 depicts the comparison of odds ratios for the main explanatory variables. The comparison of odds ratios eases results interpretation and allows to better understand partners' preferences for the three forms of payment. If a two-part tariff scheme is an intermediate choice between lump sum and royalty payments, then we would expect that for any given change in the explanatory variables, the degree to which two-part tariff is chosen with greater odds would be intermediate compared to the degrees of the other two forms. Indeed, except in the case of technology specificity, results confirm our conjecture. A two part-tariff balances technology collaboration. On the one hand, the fixed part secures to the licensor a share of the profits from its innovation. On the other hand, the variable part serves to the licensee as a means of protection from its partner's opportunism.

Concerning the control variables, all models show that a license comprising a worldwide geographic scope is more likely related to a two-part tariff payment scheme. Following previous research (Somaya *et al.*, 2010), we might relate this finding to the licensor's willingness to take part to the licensee' profits deriving from technology commercialization.

Insert figure 3 about here

4.6 DISCUSSION AND CONCLUSIONS

Past managerial and industrial economic literature has long argued the risks firms are exposed to when accessing markets for technology (Caves, Crookell, & Killing, 1983; Fosfuri & Giarratana, 2010; Teece, 1986). Particularly, transaction costs are identified as the main obstacles to the effective functioning of markets (Razgaitis, 2006). Threats of opportunism by both parties to the transaction lead either to the failure of reaching an agreement or to sub-optimal equilibrium in terms of allocation of risks and resources between partners. As a consequence, parties need to structure incentive-compatible contracts in order to cope with uncertainty, asymmetric information and contract incompleteness. Through our study we analyse potential sources of both adverse selection and moral hazard and examine their impact on license price scheme.

The empirical results show that both the attributes of the licensed technology and of the parties to the transaction affect the license compensation scheme. We find that when the licensed innovation is at an embryonic stage of development, the optimal price scheme is linked to an output-based compensation. The first best solution – fixed payment – is not implemented because of technological uncertainty and knowledge tacitness. Differently, if the licensed innovation requires the transfer of know-how for its further exploitation, the optimal pricing scheme is based on fixed payments. Knowledge irreversibility increases the risk of licensee's opportunism after the licensor transfers its tacit expertise. Interestingly, we find that dissimilarities in terms of technological competences between licensor and licensee are important sources of uncertainty and asymmetric information. The larger the technological distance between partners, the less likely are parties to choose a fixed payment. Additionally, results outline the influence of the licensee's patent stock on pricing scheme. The larger the patent stock of the licensee, the more likely firms need not to introduce any variable payment in the contract. The licensee's technical capabilities allow to overcome issues of asymmetric information on the quality of the licensed innovation and its market potential. Finally, in line with previous studies, we find that partners' past relations increase the costs of opportunistic behavior, rendering trust and reputation effective.

Two contributions of the study are particularly worth emphasizing. Firstly, the research provides an empirical overview of optimal pricing scheme in technology licensing. In turn, it offers a valuable contribution to economic theory on licensing in assessing the empirical validity of theoretical models and explicitly analyzing sources of adverse selection and moral hazard in inter-firm technology transfer. The analysis provides an overview of how different price schemes allow technology partners to cope with uncertainty, asymmetric information and contract incompleteness.

Secondly, the paper provides an empirical assessment of the potential factors threatening the effective functioning of markets for technology and their future growth. This contribution is particularly valuable in light of the increasing centrality of technology licensing to firms' R&D strategy. Our study draws licensing managers' attention to examine factors linked both to the licensed technology and partner to the transaction, which might hinder technology collaboration. It offers a frame of reference for analyzing the potential obstacles associated to each transaction and choosing the optimal payment structure with regard to such risks.

For what concerns policy implications, the study highlights the incidence of uncertainty and asymmetric information on the effective functioning of markets for ideas. Policy makers should focus on reducing obstacles to technology trade, easing access to markets and facilitating the structuring of license deals. On the basis of our analysis, we suggest that mechanisms aiming to enlarge the size of these markets and increasing the recurrence of firms to technology sourcing might be effective to cope with information issues. In doing so, partners' reputation would become an important antecedent to market access, thereby reducing information asymmetry. Additionally, further attention should be posed on increasing transparency in the market. Firms face high search costs, which are lately reflected in the pricing of the license. Policy makers should support firms' partnering search, for instance supporting the development and rise of technology platforms and technology brokers. The presence of intermediary institutions might ease the license deal structuring and minimize risks deriving from contract incompleteness and information asymmetry. Indeed, intermediary institutions would preserve the bargaining power of both partners but would ease technology exchange and cooperation by reducing the information differentials between partners.

The study presents some limitations, which also suggest some promising lines for future research. Due to the focus on inter-firm technology transfer, we restrained our attention to license agreements between firms. This choice made it possible to provide a detailed and robust analysis of firms' preferences of price scheme. However, it brought to the exclusion from the study of key institutions of markets for ideas, namely universities and governmental agencies. We hope that future research will extend the analysis to university-firm license contracts, by providing an assessment of the determinants of license price scheme when a public institution is involved in the transaction. Further, the study focused on technology and firms' attributes to investigate optimal price scheme. Future studies could expand the analysis to environmental conditions and their effect on firms' choice of price scheme. Finally, the study did not relate firms' choice of price scheme to the performance of license contract either in terms of contract duration or commercialization success. Hence, from the analysis we cannot infer any conclusion about the impact of different price structure on license partnership success. We hope that future research will investigate such a relationship.

References

Aghion, P., & Tirole, J. 1994. On the Management of Innovation. ***Quarterly Journal of Economics***, 109(4): 1185-1207.

Ahuja, G., & Katila, R. 2001. Technological acquisitions and the innovation performance of acquiring firms: a longitudinal study. ***Strategic Management Journal***, 22: 197-220.

Anand, B., & Khanna, T. 2000. The structure of licensing contracts. ***Journal of Industrial Economics***, 48(1): 103-134.

Arora, A. 1996. Contracting for tacit knowledge: the provisions of technical services in technology licensing contracts. ***Journal of Development Economics***, 50(2): 233-256.

Arora, A., Fosfuri, A., & Gambardella, A. 2001. ***Markets for technology: The economics of innovation and corporate strategy***. Cambridge, Massachusetts: The MIT Press.

Arora, A., & Gambardella, A. 1994. The changing technology of technological change: general and abstract knowledge and the division of innovative labor. ***Research Policy***, 23(5): 523-532.

Arora, A., & Gambardella, A. 2010. Ideas for rent: an overview of markets for technology. ***Industrial and Corporate Change***, 19(3): 775-803.

Arrow, K. J. 1962. Economic Welfare and the allocation of resources for invention, ***The rate and direction of inventive activity***: 609-625. Princeton: Princeton University Press.

Athreye, S., & Cantwell, J. 2007. Creating competition?Globalisation and the emergence of new technology producers. ***Research Policy***, 36(2): 209-226.

Beggs, A. W. 1992. The licensing of patents under asymmetric information. ***International Journal of Industrial Organization***, 10(2): 171-191.

Bhattacharyya, S., & Lafontaine, F. 1995. Double-sided moral hazard and the nature of share contracts. ***RAND Journal of Economics***, 26(4): 761-781.

Bousquet, A., Cremer, M., Ivaldi, M., & Wolkowicz, M. 1998. Risk sharing in licensing. ***International Journal of Industrial Organization***, 16: 535-554.

Branstetter, L. G., & Sakakibara, M. 2002. When do research consortia work well and why? Evidence from Japanese panel data. ***The American Economic Review***, 92(1): 143-159.

Caves, R., Crookell, H., & Killing, P. 1983. The imperfect market for technology licenses. ***Oxford Bulletin of Economics & Statistics***, 45(3): 249-267.

Cebrian, M. 2009. The structure of payments as a way to alleviate contractual hazards in international technology licensing. ***Industrial and Corporate Change***, 18(6): 1135-1160.

Ceccagnoli, M., Graham, S. J. H., Higgins, M. J., & Lee, J. 2010. Productivity and the role of complementary assets in firms' demand for technology innovations. ***Industrial and Corporate Change***, 19(3): 839-869.

Choi, J. P. 2001. Technology transfer with moral hazard. ***International Journal of Industrial Organization***, 19: 249-266.

Cohen, W., Nelson, R., & Walsh JP. 2000. Protecting their intellectual assets: appropiability conditions and why U.S. manufacturing firms patent or not. ***NBER Working Paper n. 7552***.

Colombo, M. G. 2003. Alliance form: a test of the contractual and competence perspectives. ***Strategic Management Journal***, 24(12): 1209-1229.
DiMasi, J. A., Hansen, R. W., & Grabowski, H. G. 2003. The price of innovation: new estimates of drug development costs. ***Journal of Health Economics***, 22(2): 151-185.
Fosfuri, A., & Giarratana, M. S. 2010. Introduction: Trading under the Buttonwood--a foreword to the markets for technology and ideas. ***Industrial and Corporate Change***, 19(3): 767-773.
Gallini, N. 1984. Deterrance by market sharing: A strategic incentive for licensing. ***The American Economic Review***, 74(5): 931-941.
Gallini, N., & Winter, R. 1985. Licensing in the theory of innovation. ***RAND Journal of Economics***, 16(4): 514-526.
Gallini, N., & Wright, B. 1990. Technology transfer under asymmetric information. ***RAND Journal of Economics***, 21(1): 147-160.
Gambardella, A., Giuri, P., & Luzzi, A. 2007. The market for patents in Europe. ***Research Policy***, 36: 1163-1183.
Griliches, Z. 1990. Patent statistics as economic indicators: A survey. ***Journal of Economic Literature***, 28(4): 1661-1707.
Gulati, R. 1995. Does familiarity breed trust? The implications of repeated ties for contractual choice in alliances. ***Academy of Management Journal***, 38(1): 85-112.
Gulati, R., & Singh, H. 1998. The architecture of cooperation: Managing coordination costs and appropriation concerns in strategic alliances. ***Administrative Science Quarterly***, 43: 781-814.
Hall, B., Jaffe, A., & Trajtenberg, M. 2001. The NBER patent citations data file: lessons, insights, and methodological tools. ***NBER Working Paper***, 8498.
Hart, O., & Moore, J. 2008. Contracts as reference points. ***The quarterly journal of economics***, 123(1): 1-48.
Hoetker, G., & Mellewigt, T. 2009. Choice and performance of governance mechanisms: matching alliance governance to asset type. ***Strategic Management Journal***, 30(10): 1025-1044.
Jaffe, A., Trajtenberg, M., & Henderson, R. 1993. Geographic localization of knowledge spillovers as evidenced by patent citations. ***The Quarterly Journal of Economics***, 108(3): 577-598.
Kamien, M. I., & Tauman, Y. 1986. Fees versus royalties and the private value of a patent. ***Quarterly Journal of Economics***, 101(3): 471-491.
Kim, Y., & Vonortas, N. 2006a. Technology licensing partners. ***Journal of Economics and Business***, 58(4): 273-289.
Leone, M. I., & Reichstein, T. forthcoming. Licensing-in fosters rapid invention! The effect of the grant-back clause and technological unfamiliarity. ***Strategic Management Journal***.
Macho-Stadler, I., Martinez-Guiral, X., & Perez-Castrillo, D. 1996. The role of information in licensing contract design. ***Research Policy***, 25(1): 43-57.
Mendi, P. 2005. The structure of payments in technology transfer contracts: evidence from Spain. ***Journal of Economics and Management Strategy***, 14(2): 403-429.
OECD. 2005. Intellectual property as an economic asset: Key issues in valuation and exploitation. Paris: OECD.

Oxley. 1997. Appropriability Hazards and Governance in Strategic Alliances: a transaction cost approach. ***Journal of Law Economics & Organization***, 13(2).

Oxley, J. E., & Sampson, R. C. 2004. The scope and governance of international R&D alliances. ***Strategic Management Journal***, 25(89): 723-749.

Palomeras, N. 2007. An analysis of pure-revenue technology licensing. ***Journal of Economics and Management Strategy***, 16(4): 971-994.

Pisano, G. 1989. Using Equity Participation to Support Exchange: Evidence from the Biotechnology Industry. ***Journal of Law Economics & Organization***, 5(1): 109-126.

Pisano, G. 2006. Can science be a business? Lessons from biotech. ***Harvard Business Review***, 84(10): 114-125.

Razgaitis, R. 2006. U.S./Canadian Licensing in 2005 - Survey Results. ***Les Nouvelles***: 233-245.

Rockett, K. 1990a. Choosing the competition and patent licensing. ***RAND Journal of Economics***, 21(161-171).

Rockett, K. 1990b. The quality of licensed technology. ***International Journal of Industrial Organization***, 8: 559-574.

Roijakkers, N., & Hagedoorn, J. 2006. Inter-firm R&D partnering in pharmaceutical biotechnology since 1975: Trends, patterns, and networks. ***Research Policy***, 35(3): 431-446.

Rothaermel, F. T. 2001. Incumbent's advantage through exploiting complementary assets via interfirm cooperation. ***Strategic Management Journal***, 22(6-7): 687-699.

Rothaermel, F. T., & Deeds, D. L. 2004. Exploration and exploitation alliances in biotechnology: a system of new product development. ***Strategic Management Journal***, 25(3): 201-221.

Sakakibara, M. 2010. An empirical analysis of pricing in patent licensing contracts. ***Industrial and Corporate Change***, 19(3): 927-945.

Sampson, R. 2007. R&D alliances and firm performance: the impact of technological diversity and alliance organization on innovation. ***Academy of Management Journal***, 50(2): 364-386.

Schilling, M. A. 2009. Understanding the alliance data. ***Strategic Management Journal***, 30(3): 233-260.

Shane, S. 2002. Selling university technology: patterns from MIT. ***Management Science***, 48: 122-137.

Shepard, A. 1987. Licensing to enhance demand for new technologies. ***RAND Journal of Economics***, 18(3): 360-368.

Simonin, B. 1999. Ambiguity and the process of knowledge transfer in strategic alliances. ***Strategic Management Journal***, 20(7): 595-623.

Somaya, D., Kim, Y., & Vonortas, N. S. 2010. Exclusivity in licensing alliances: using hostages to support technology commercialization. ***Strategic Management Journal***, 32(2): 159-186.

Stuart, T., Ozdemir, S., & Ding, W. 2007. Vertical alliance networks: The case of university–biotechnology–pharmaceutical alliance chains. ***Research Policy***, 36(4): 477-498.

Teece, D. J. 1986. Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. ***Research Policy***, 15: 285-305.

Vishwasrao, S. 2007. Royalties vs. fees: How do firms pay for foreign technology? ***International Journal of Industrial Organization***, 25(4): 741-759.

von Hippel, E. 1994. "Sticky information" and the locus of problem solving: implications for innovation. ***Management Science***, 40(4): 429-439.

Williamson, O. 1981. The Economics of Organization: the Transaction Cost Approach. ***The American Journal of Sociology***, 87(3): 548-577.

APPENDIX: Tables and figures

TABLE 9. Summary statistics

	Source	N	Mean	s.d.	Min	Max
Main independent variables						
Early stage technology	Recap	266	0.41	0.49	0.0	1
Know-how	License	266	0.71	0.46	0.0	1
Technology specificity	License	266	0.84	0.37	0.0	1
Licensor's patent stock	NBER	266	355.97	1132.76	0.0	10948
Licensee's patent stock	NBER	266	938.51	1822.21	0.0	15433
Technological diversity	NBER	266	0.50	0.34	0.0	1
Past relations	Recap	266	1.06	0.28	1.0	3
Control variables						
Exclusive license	License	266	0.93	0.25	0.0	1
Geographic scope	License	266	0.60	0.49	0.0	1
Vertical license	Compustat	266	0.48	0.50	0.0	1
International license	License	266	0.38	0.49	0.0	1
Licensor's past relations	Recap	266	1.86	1.68	1.0	13
Licensee's past relations	Recap	266	1.97	1.72	1.0	11
Cancer area	Recap	266	0.23	0.42	0.0	1
Infectious area	Recap	266	0.16	0.37	0.0	1
Time		266	1995.16	4.12	1985	2004

TABLE 10. Correlation Matrix

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
1. Early stage technology	1.00														
2. Know-how	-0.08	1.00													
3. Technology specificity	0.06	0.05	1.00												
4. Log(licensor's patent stock)	**-0.33**	-0.09	0.07	1.00											
5. Log(licensee's patent stock)	0.11	0.04	-0.10	**-0.27**	1.00										
6. Technological diversity	**0.14**	0.04	0.03	**-0.22**	0.02	1.00									
7. Past relations	**0.15**	-0.01	-0.02	0.05	0.09	**-0.13**	1.00								
8. Exclusive license	**-0.20**	0.06	0.04	-0.08	0.06	-0.00	-0.10	1.00							
9. Geographic scope	**0.32**	-0.02	**0.16**	0.02	**0.17**	0.10	**0.15**	-0.01	1.00						
10. Vertical license	0.05	0.09	-0.01	**-0.24**	**0.47**	0.05	-0.04	0.05	0.06	1.00					
11. International license	-0.04	0.03	**0.13**	-0.02	-0.01	-0.05	-0.00	-0.01	**-0.13**	**0.14**	1.00				
12. Licensor's past relations	-0.07	-0.04	**0.13**	**0.36**	-0.03	-0.06	**0.24**	0.00	0.11	**-0.16**	**-0.12**	1.00			
13. Licensee's past relations	0.01	-0.03	0.09	**0.23**	**0.18**	-0.06	**0.15**	0.05	**0.22**	0.01	-0.09	**0.60**	1.00		
14. Cancer area	-0.07	-0.02	0.05	0.10	0.01	0.04	-0.05	-0.03	-0.04	-0.01	-0.03	0.02	-0.05	1.00	
15. Infectious area	0.05	0.01	-0.03	-0.07	-0.01	-0.04	0.02	-0.00	0.01	0.01	-0.01	0.00	0.03	**-0.24**	1.00
16. Other areas	0.03	-0.00	-0.07	-0.02	0.04	0.06	0.11	0.06	-0.05	-0.04	-0.01	0.05	0.06	**-0.43**	**-0.35**

Correlation coefficients in bold are significant at a 5% level.

TABLE 11. Multinomial logit estimates: firms' preferences among fixed, output-based payments and two-part tariffs

	Model 1		Model 2		Model 3		Model 4	
Reference Category	Lump Sum		Lump Sum		Lump Sum		Lump Sum	
	Royalty	2-part tariff	Royalty	2-part tariff	Royalty	2-part tariff	Royalty	2-part tariff
Main independent variables								
EARLY STAGE TECHNOLOGY			1.96** (0.764)	0.98* (0.543)	1.97** (0.769)	0.95* (0.545)	2.24*** (0.836)	0.87 (0.549)
KNOW-HOW					-1.17* (0.622)	-0.40 (0.462)	-1.14* (0.649)	-0.49 (0.472)
TECHNOLOGY SPECIFICITY							-0.96 (0.860)	0.90 (0.664)
Log(LICENSOR'S PATENTS)								
Log(LICENSEE'S PATENTS)								
TECHNOLOGICAL DIVERSITY								
PAST RELATIONS								
Control variables								
EXCLUSIVE LICENSE	-0.25 (0.929)	0.36 (0.787)	0.27 (1.035)	0.66 (0.878)	0.68 (1.054)	0.77 (0.889)	1.03 (1.139)	0.58 (0.941)
GEOGRAPHIC SCOPE	1.21* (0.655)	1.10** (0.459)	0.51 (0.714)	0.86* (0.485)	0.55 (0.720)	0.94* (0.479)	0.51 (0.777)	0.84 (0.509)
VERTICAL LICENSE	0.37 (0.635)	0.69 (0.467)	0.29 (0.650)	0.64 (0.478)	0.42 (0.654)	0.66 (0.475)	0.30 (0.686)	0.68 (0.495)
INTERNATIONAL LICENSE	-0.85 (0.667)	-0.38 (0.427)	-0.83 (0.701)	-0.34 (0.435)	-0.83 (0.712)	-0.35 (0.437)	-0.41 (0.762)	-0.43 (0.443)
LICENSOR'S PAST RELATIONS	-0.53 (0.374)	-0.14 (0.178)	-0.53 (0.406)	-0.12 (0.173)	-0.48 (0.422)	-0.09 (0.180)	-0.44 (0.393)	-0.13 (0.182)
LICENSEE'S PAST RELATIONS	0.29 (0.225)	0.01 (0.172)	0.31 (0.248)	-0.01 (0.168)	0.27 (0.252)	-0.03 (0.180)	0.33 (0.256)	-0.01 (0.181)
THERAPEUTIC AREA DUMMIES	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
YEAR DUMMIES	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	266	266	266	266	266	266	266	266
Log-likelihood	-143.60	-143.60	-139.87	-139.87	-138.21	-138.21	-132.54	-132.54

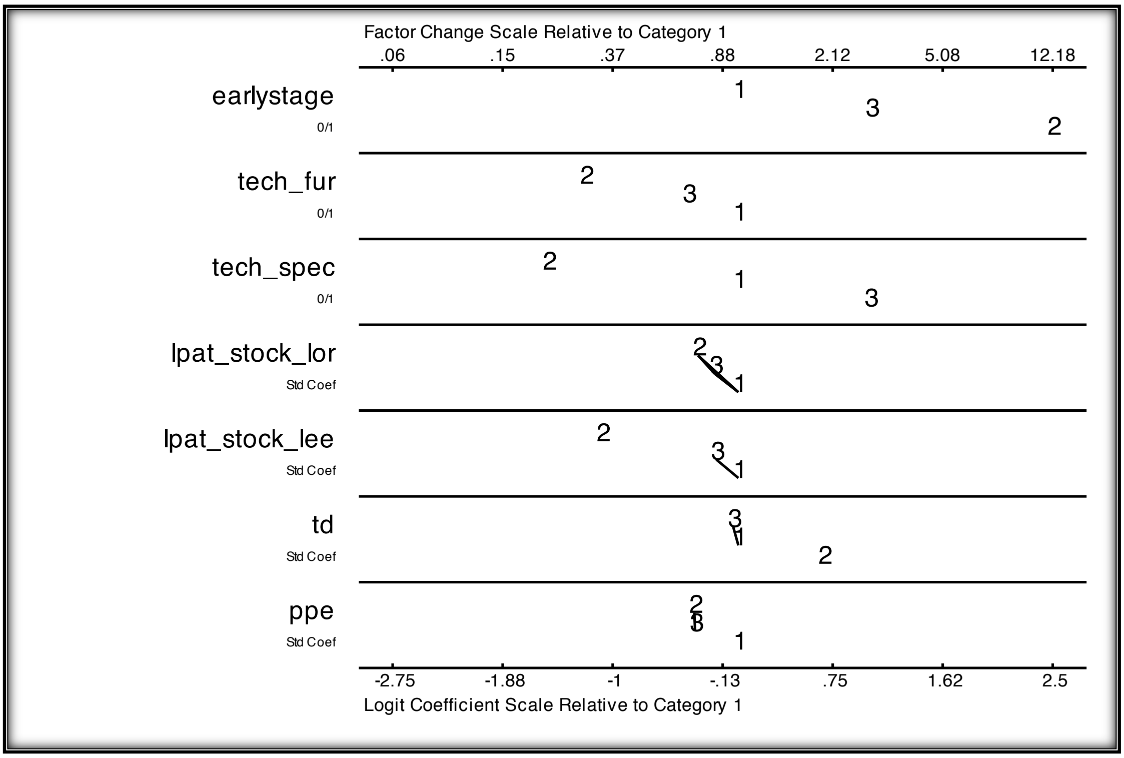
Note: Robust standard errors in parentheses.
Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

TABLE 3. Continued

	Model 5		Model 6		Model 7		Model 8	
Reference Category	Lump Sum		Lump Sum		Lump Sum		2-part tariff	
	Royalty	2-part tariff	Royalty	2-part tariff	Royalty	2-part tariff	Lump Sum	Royalty
Main independent variables								
EARLY STAGE TECHNOLOGY	2.11** (0.917)	0.84 (0.619)	2.26** (0.886)	0.82 (0.625)	2.50*** (0.920)	1.05 (0.679)	-1.05 (0.679)	1.45** (0.641)
KNOW-HOW	-1.17* (0.658)	-0.46 (0.474)	-1.31** (0.663)	-0.49 (0.488)	-1.22* (0.694)	-0.40 (0.491)	0.40 (0.491)	-0.82 (0.518)
TECHNOLOGY SPECIFICITY	-1.21 (0.952)	0.95 (0.706)	-1.61 (0.989)	0.95 (0.712)	-1.51 (1.011)	1.05 (0.730)	-1.05 (0.730)	-2.56*** (0.718)
Log(LICENSOR'S PATENTS)	-0.25 (0.217)	-0.13 (0.147)	-0.18 (0.221)	-0.12 (0.146)	-0.15 (0.231)	-0.09 (0.148)	0.09 (0.148)	-0.06 (0.190)
Log(LICENSEE'S PATENTS)	-0.41*** (0.156)	-0.10 (0.098)	-0.43*** (0.156)	-0.10 (0.096)	-0.39*** (0.150)	-0.06 (0.093)	0.06 (0.093)	-0.33*** (0.121)
TECHNOLOGICAL DIVERSITY			2.26** (1.146)	0.14 (0.648)	1.99* (1.115)	-0.12 (0.655)	0.12 (0.655)	2.11** (0.963)
PAST RELATIONS					-1.24 (1.417)	-1.22** (0.568)	1.22** (0.568)	-0.02 (1.377)
Control variables								
EXCLUSIVE LICENSE	1.12 (1.295)	0.77 (0.920)	1.69 (1.229)	0.75 (0.895)	1.90 (1.169)	0.97 (0.817)	-0.97 (0.817)	0.93 (0.880)
GEOGRAPHIC SCOPE	1.04 (0.798)	0.96* (0.552)	0.69 (0.767)	0.95* (0.549)	0.87 (0.801)	1.16* (0.595)	-1.16* (0.595)	-0.28 (0.589)
VERTICAL LICENSE	1.23 (0.774)	0.82 (0.555)	1.25 (0.793)	0.81 (0.556)	1.28* (0.771)	0.85 (0.543)	-0.85 (0.543)	0.43 (0.602)
INTERNATIONAL LICENSE	-0.60 (0.794)	-0.49 (0.462)	-0.53 (0.741)	-0.52 (0.460)	-0.41 (0.740)	-0.39 (0.474)	0.39 (0.474)	-0.03 (0.598)
LICENSOR'S PAST RELATIONS	-0.38 (0.388)	-0.11 (0.182)	-0.46 (0.325)	-0.12 (0.188)	-0.37 (0.340)	-0.03 (0.201)	0.03 (0.201)	-0.35 (0.281)
LICENSEE'S PAST RELATIONS	0.46* (0.265)	0.02 (0.178)	0.55** (0.258)	0.03 (0.182)	0.46* (0.266)	-0.06 (0.194)	0.06 (0.194)	0.52*** (0.193)
THERAPEUTIC AREA DUMMIES	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
YEAR DUMMIES	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	266	266	266	266	266	266	266	266
Log-likelihood	-127.94	-127.94	-124.63	-124.63	-122.97	-122.97	-122.97	-122.97

Note: Robust standard errors in parentheses.
Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

FIGURE 3. Plot of odds ratios



Note: 1: "lump sum"; 2: "output-based payments"; 3:"two-part tariff".

Studente: GIULIA TROMBINI

Matricola: 955546

Dottorato: DOTTORATO IN ECONOMIA AZIENDALE

Ciclo: XXIV CICLO

Titolo della tesi: TECHNOLOGY LICENSING IN MARKETS FOR IDEAS: EMPIRICAL EVIDENCE FROM THE BIOPHARMACEUTICAL INDUSTRY

Thesis abstract

While past research has advanced our understanding of the reasons leading firms to access markets for ideas and helped frame phenomena such as the division of innovative labour and the rise of technology specialist firms (Arora et al., 2001; Gans & Stern, 2003), less is known on the functioning of markets relative to license formation and contract structuring. Notwithstanding the importance of investigating what drives two partners to enter into a license partnership and how license contracts are to be structured, few empirical studies have attempted to tackle these research questions (Kim & Vonortas, 2006; Anand & Khanna, 2000; Bessy & Brousseau, 1998). Hence, this dissertation aims at providing a micro-level analysis of firms' licensing practices. In order to fill the gap in the literature, the study shifts the level of analysis from that of a focal firm, usually adopted by past literature to that of the dyad. The research setting selected for the study is the global biopharmaceutical industry over the period 1985-2004.

Abstract della tesi

Fino ad oggi, la letteratura sui mercati per la tecnologia ha focalizzato il proprio interesse di ricerca sulle ragioni che portano le imprese ad accedere a questi mercati e ad utilizzare gli accordi di licenza come strumento di gestione dell'innovazione. Se da un lato i risultati di questo filone di ricerca hanno permesso di comprendere fenomeni emergenti come la divisione verticale del lavoro innovativo e la nascita di piccole aziende cosidette "technology specialists" (Arora et al., 2001; Gans & Stern, 2003), dall'altro lato aspetti come la formazione di accordi di licenza e la struttura contrattuale di quest'ultimi non sono stati ancora analizzati. Lo scopo del presente lavoro, quindi, è quello di avanzare l'attuale stato dell'arte andando a fornire un'analisi empirica degli accordi di licenza per lo scambio di tecnologia tra imprese. In particolare, la tesi indaga i fattori che portano due aziende a siglare un accordo di licenza e le diverse forme contrattuali che quest'ultime scelgono al fine di massimizzare i benefici derivanti dall'accordo di licenza. Tali fenomeni vengono analizzati da un punto di vista empirico nel contesto dell'industria biofarmaceutica mondiale durante un arco temporale di vent'anni (1985-2004).

Firma dello studente

____