Optimal Pricing Scheme in Technology Licensing: Empirical Evidence from the Pharmaceutical Industry

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Abstract

Drawing on agency theory and theory of innovation, this 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 licensed technology and 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; pricing scheme; pharmaceutical industry.

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1. INTRODUCTION

During the last two decades, markets for technology have grown in size and importance: technology licensing has become central to firms' R&D strategy. 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 1985-97, for a total market value of $320 billion. However, as recently outlined by an OECD survey (2004), accessing markets for technology entails some risks and costs to firms. One of the major obstacles is represented by transaction costs and fear of opportunism during contract negotiations (Fosfuri and Giarratana, 2010). Due to the inherent uncertainty of technology, contracts' incompleteness and information asymmetry hamper technology partnering. Hence, 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 and Singh, 1998; Roijakkers and Hagedoorn, 2006; Sampson, 2007; Hoetker and Mellewigt, 2009). Past literature has outlined the importance of designing incentive-compatible contracts in order to provide partners with mechanisms and incentives towards technology collaboration (Aghion and Tirole, 1994).

One of the crucial license contractual choice partners face when signing 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.

Theoretical literature on licensing formally demonstrates how different forms of payments deeply influence partners' conduct and commitments, mitigating issues deriving from opportunistic behavior (Kamien and Tauman, 1986; Gallini and Wright, 1990; Beggs, 1992; Bhattacharyya and Lafontaine, 1995; Bousquet, Cremer *et al.*, 1998; Choi, 2001). 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 receives a percentage of sales deriving from the licensee's technology commercialization. Finally, a two-part tariff comprises both a fixed and a variable part.

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 licensing optimal price scheme. The study aims to fill this gap in the literature by examining sources of adverse selection and moral hazard issues determining price structure in technology licensing contracts. Specifically, we investigate the following research question: which factors related to the licensed technology or to the parties to the transaction lead firms to choose between fixed versus variable payments as a compensation scheme?

The contribution of the study is twofold. Drawing on agency theory, we build a framework allowing to predict empirically what is the optimal payment scheme when asymmetric information and threats of opportunistic behavior put inter-firm technology transfer at risk. The article provides a detailed and comprehensive empirical analysis of potential sources of adverse selection and moral hazard issues affecting firms' choice of compensation scheme.

The study advances the relatively underdeveloped empirical research on technology licensing practices. Licensing price scheme has long been modelled in economic theory of innovation (Gallini and Winter, 1985; Gallini and Wright, 1990; Beggs, 1992; Bousquet, Cremer *et al.*, 1998; Choi, 2001); however, lack of adequate secondary data has been an obstacle to the validation of theoretical models. Firms value the terms of their licensing activity as strategic and therefore tend to avoid public disclosure. The few studies dealing with optimal payment structure are by Mendi (2005), Vishwasrao (2007) and Cebrian (2009). Cebrian (2009) analyses how license payment structure can be used to overcome issues of moral hazard behavior. A number of transaction-specific conditions and pair company-specific settings are matched to firms' choice between fixed payment, variable payment and two-part tariff. Mendi (2005) focuses on the impact of contract duration on license payment structure. Lastly, Vishwasrao (2007) considers industries, firms and contracts characteristics to explain the forms of payment. All the three studies, however, 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 in 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 features of the licensed technology, neglecting important sources of opportunistic behavior.

In turn, the present article represents the natural next-step in order to extend prior research on firms' licensing practices and the efficiency of markets for technology in allocating risks and resources among partners.

Research hypotheses are tested on a sample of 266 technology licensing agreements in the pharmaceutical industry over the period 1985-2004. We select as the research setting the pharmaceutical industry since it is a technology-intensive industry where uncertainty, asymmetric information and opportunistic behaviors 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. Finally, 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' features.

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.

2. THEORY

When transferring knowledge through arm's length market transactions, both the licensor and the licensee 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 set 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 and Tirole, 1994; Hart and 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 mitigate contractual hazards. 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 (Mendi, 2005; Cebrian, 2009).

Theoretical literature has long investigated optimal licensing payment schemes both in the presence of adverse selection and moral hazard issues (Kamien and Tauman, 1986; Gallini and Wright, 1990; Beggs, 1992; Choi, 2001). Economic models demonstrate that fixed payments are the efficient scheme (Gallini and Wright, 1990; Beggs, 1992; Choi, 2001). 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. 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's side implies the licensor being more informed than the licensee 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's 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 secure a share to revenues deriving from technology commercialization.

Theoretical literature analyses also issues of moral hazard and their impact on licensing 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 fixed fee only, cannot be implemented. The optimal licensing contract includes a royalty rate, which serves as a hostage to induce the licensor to exert costly effort.

Differently, if the likelihood of opportunistic behavior is on the licensee's side, the optimal payment scheme is a fixed payment. With a lump sum, the licensor does not need to monitor the licensee's effort toward technology commercialization and avoids the difficulty of verifying its output. Additionally, the presence of a fixed payment serves as incentive for the licensee to exert the optimal commitment towards technology commercialization since it can keep the upside potential of the rent for itself.

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 posed to identify sources of adverse selection and moral hazard determining optimal licensing price scheme. Drawing on prior research, potential sources of transactional hazards are divided into two main categories: sources deriving from features 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's technological size and licensor's, partners' technological diversity and past relationships.

3. RESEARCH HYPOTHESES

3.1 Features of the licensed technology

3.1.1 early stage licensing

In many industries ex-ante licensing is a common practice (Anand and Khanna, 2000): the licensed technology is at an embryonic stage of development and its potential applications or likely success are still uncertain. Under such circumstances, technology transfer is at risk, since the degree of uncertainty is higher and consequently the likelihood of partners' opportunistic behavior. Two main hazards threat 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 and costly.

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 in its 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 (Teece, 1986; Gallini and Wright, 1990). 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.

The other concern in early stage licensing is linked to the fact that 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 for technology commercialization. However, as noted by Oxley (1989), the licensor's 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 technology transfer.

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

> *Hypothesis 1* – All else 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.

3.1.2 Transfer of know-how

Technology licensing usually entails much more than the transfer of intellectual property rights (Leone and Reichstein, 2011). Technology elicited in the contract might not be enabling by itself. 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. In such cases, the licensee can benefit from establishing a channel of information with the licensor (Cohen *et al*., 2000). The licensee needs access to the licensor's skills and know-how to understand 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 for 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 (Choi, 2001; Cebrian, 2009). 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: it is in the licensor's interest to assist its partner in exploiting 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 be exposed to opportunism as well. Once the know-how is transferred, the licensee might change its priorities, for instance renegotiating or terminating the contract to avoid paying royalties. Additionally, the licensee might exert a suboptimal effort in commercializing the licensed technology, posing at risk the licensor's profits from its innovation. As a result, the optimal payment structure would comprise a fixed payment in order to guarantee the licensor certain returns from its innovation.

The above arguments lead to the following hypotheses:

Hypothesis 2a – All else 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 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.

3.1.3 Technology-specific investments

Some innovations, when licensed, are far from being marketable. They require investments either in terms of R&D, or manufacturing or marketing programs to reach the market. For instance, the commercialization of a new drug needs dedicated R&D programs in order to test and demonstrate the safety of the drug. Similarly, in order to successfully commercialize a new technology, marketing programs need to be set up, advertising investments to be allocated and the distribution network to be trained.

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 stated 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.

The contract must be incentive-compatible. The optimal payment scheme should refrain the licensor's opportunistic behavior and 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. On the one hand, the licensor has lower incentives to behave opportunistically since its profits are dependent on the licensee's success in commercializing the licensed technology. On the other hand, the licensee might optimally invest in specific assets since through variable payment it shares some of the risks with the licensor. Additionally, through royalty rate, the licensor might signal the high value of the licensed technology, inducing the licensee's optimal commitment towards the further development of the technology.

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

3.2 Features of the parties to the transaction

3.2.1 Partners' technological bases

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.

For what concerns the licensor's 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. Low quality inventions tend to be licensed, while drastic inventions tend to be exploited within the firm (Rockett, 1990). 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.

However, differently from other studies, we take into consideration firms' technological sizes, namely licensor's and licensee's 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 licensed technology commercialization, large licensees might prefer lump sum payments over royalty rates in order to retain benefits from their sales (Sakakibara, 2010). Secondly, licensees with greater 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 distorting the optimal payment scheme with an output-based payment. 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 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 equal, the larger the licensor's technological base, the more likely the license payment structure will comprise a lump sum payment only.

3.2.2 Partners' technological diversity

Partners' technological diversity represents another source of uncertainty, generating serious hazards (Colombo, 2003; Kim and Vonortas, 2006). When partners have skills and competences in different and distant technological domains, technology transfer through licensing is a non-trivial process.

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). Through an output-based payment, the licensor might extract the licensee's private information about product markets (Mendi, 2005).

The licensee might also be exposed to adverse selection issues if the partners' knowledge bases differ. Given its different set of competences in distant technological fields, the licensee is limited in its ability to assess the value of licensor's technology and the potential profitability. Consequently, the licensor might use royalty payments to signal the high value of its innovation and induce the licensee to optimally commit to technology commercialization.

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

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

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 transactions 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 and Vonortas 2006). Such 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 a lower risk of opportunistic behavior, partners do not need to introduce payment distortions. Trust between partners and familiarity with the licensor's technology replace other contractual hostages such as variable payments.

> *Hypothesis 6* – All else 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. DATA AND METHODOLOGY

4.1 Data and sample

The research hypotheses are tested on a dataset based on the coding of 1830 license agreements in the pharmaceutical industry worldwide over the time period 1985-2004. License data were retrieved from Deloitte Dealbuilder Database.

A number of considerations led to build the research sample drawing on Dealbuilder. Firstly, Dealbuilder 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: 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; the type of activities the licensee is expected to undertake to commercialize the licensed technology.

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

From Dealbuilder 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 1830 licensing agreements. Next, only unilateral agreements were selected, excluding a large number of cross-licensing agreements. This choice is due to the fact that firms signing a crosslicense agreement face different contractual hazards compared to those of a standard license (Colombo, 2003). 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 classify whether they were biotech or drug companies. By the end of this process, the research sample comprised 266 license agreements.

4.2 Measures

4.2.1 Dependent variable

The dependent variable is the *type of payment structure* chosen by partners. When signing a license, partners have three choices in terms of payment scheme: 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 payment structure is scheduled on both fixed and output-based payments.

4.2.2 Independent variables

Early stage technology: For each license, Dealbuilder 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. 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 for determining 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 such a clause is included in the license, it implies that the technology disclosed through patents and blueprints is not enabling by itself. The licensee is dependent on the licensor's skills and resources to exploit the licensed technology.

Technology specificity is a dichotomous variable taking value of 1 if the licensee is expected to undertake R&D specific investments to evaluate and further develop the licensed technology. As for the dependent variable, even in this case the variable is coded from information disclosed in the license contract. The focus on R&D investments is due to the fact that such capital commitments are highly technology-specific, differently from other types of investments such as manufacturing ones, which are more easily redeployable.

In line with previous studies (Kim and Vonortas, 2006; Sakakibara, 2010), *partners' technological bases* 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. Due to the tight appropriability regime of the industry, firms capture the value from innovation through patents rather than recurring to other forms of protection such as secrecy (Cohen *et al.*, 2000).

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*.

Following prior research (Kim and 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, 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:

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

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 prior 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, 1995).

4.2.3 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 might impact on optimal 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 and 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. Partners' risk aversion rather than moral hazard or adverse selection might determine partners' choice of compensation scheme.

We included a dummy to account for *international licensing*. Entering 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. The licensor's experience in terms of looking for potential partners, writing contracts, transferring the technology lowers the cost of licensing, thereby reducing the magnitude of transactional hazards.

Similarly, the variable – *licensee's past relations* – measures the number of licensed 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* and *others.*

Year dummies are included to control for time effects (Hagedoorn *et al.*, 2008; Gulati *et al*., 2009).

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.

5. RESULTS

Table 1 provides an overview of the data and some descriptive statistics. The sample comprises 266 license agreements. Around 78% of the licenses schedule a payment scheme based on a two-part tariff; 12% a fixed payment only and 10% an output-based payment only. For what concerns the type of technology transferred from the licensor to the licensee, about 41% of licenses are at an early stage of development and 71% include the provision of know-how by the licensor. Approximately 84% of the licenses require specific R&D 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, suggesting the well-established industry dynamic of small firms licensing their technologies to larger firms. About 93% of licenses are exclusive and 60% have a worldwide geographic scope. About 48% 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% of licenses are international ones: partners are based in different countries.

*** INSERT TABLE 1 ABOUT HERE ***

Table 2 reports Pearson correlation coefficients of the variables included in the analysis. Correlations among variables are below the threshold level of 0.5-0.6, suggesting that multicollinearity is not an issue. 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 2 ABOUT HERE ***

The results of the multinomial logistic regression are reported in Table 3. 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 3 ABOUT HERE ***

Hypothesis 1 suggests that when the licensed technology is at an early stage of development, the more likely the optimal compensation scheme is based on an output-based payment. 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 wells 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, Hypothesis 1 is supported.

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 payment in order to guarantee the licensor a certain 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 in order 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 the licensee 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 the licensee's and licensor's technological capabilities on the probability of choosing fixed payments versus royalty ones or two-part tariff schemes. Empirical evidence support 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 greater 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 (Gulati and Singh, 1998; Mendi, 2005; Kim and Vonortas, 2006; Cebrian, 2009), past relations between partners increase costs of opportunistic behavior and decrease costs of transferring knowledge, thereby substituting for royalty rates.

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.

6. DISCUSSION AND CONCLUSIONS

Theory on innovation has long argued the risks firms are exposed to when accessing markets for technology. Particularly, transaction costs are identified as the main obstacles to the effective functioning of markets. 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, introducing some distortions in the compensation scheme. Through our study we analyses potential sources of both adverse selection and moral hazard issues and examine their impact on license price scheme.

The empirical results confirm our theoretical predictions. Both the features of the licensed technology and of the parties to the transaction affect the compensation scheme chosen when transferring knowledge. 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. Additionally, 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 the licensor and the licensee are important sources of uncertainty and asymmetric information. The higher 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 distortion 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.

Secondly and most importantly, our paper provides an empirical assessment of the potential factors threatening the effective functioning of markets for technology. Such a 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 generate opportunistic behaviors. 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 in technology trade, easing access to markets and facilitating the structuring of license deals. On the basis of our analysis we suggest that the focus should be on mechanisms aiming at enlarging the size of such markets and increasing the recurrence of firms to technology sourcing. In doing so, partners' reputation would become an important antecedent to market access, thereby reducing information asymmetry and reinforcing market efficiency. 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 where potential licensors seek potential licensees and vice versa. The presence of such platforms might lower the magnitude of asymmetric information and the costs of accessing the market.

The analysis presents some limitations, which also suggest some promising lines for future research. Despite the richness of information of the dataset, its focus is on a single industry. In turn the extension and generalizability of the results might be at risk. Future research might provide a confirmation and extension of our results if applied to other industrial settings.

Further, the study focuses its attention on the choice between fixed and variable payments, neglecting the possibility for partners to complement the payment scheme with other forms such as equity participation. Further research is needed in order to understand the conditions under which the parties to the transaction recur to such a form of payment in addition to the one considered in our study.

References

Aghion, P. and Tirole, J. (1994) On the Management of Innovation, *Quarterly Journal of Economics*, 109, 1185-207.

Anand, B. and Khanna, T. (2000) The structure of licensing contracts, *Journal of Industrial Economics*, 48, 103-34.

Arora, A. (1996) Contracting for tacit knowledge: the provisions of technical services in technology licensing contracts, *Journal of Development Economics,* 50, 233-56.

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

Beggs, A. W. (1992) The licensing of patents under asymmetric information, *International Journal of Industrial Organization*, 10, 171-91.

Bhattacharyya, S. and Lafontaine, F. (1995) Double-sided moral hazard and the nature of share contracts, *RAND Journal of Economics*, 26, 761-81.

Bousquet, A., Cremer, M., Ivaldi, M. and Wolkowicz, M. (1998) Risk sharing in licensing, *International Journal of Industrial Organization*, 16, 535-54.

Caves, R., Crookell, H. and Killing, P. (1983) The imperfect market for technology licenses, *Oxford Bulletin of Economics & Statistics*, 45, 249-67.

Cebrian, M. (2009). The structure of payments as a way to alleviate contractual hazards in international technology licensing, *Industrial and Corporate Change*, 18, 1135-60.

Cohen, W. M., Nelson, R. and Walsh, J. P. (2000) Protecting their intellectual assets: appropriability conditions and why U.S. manufacturing firms patent or not, Working paper no. 7522, NBER, Cambridge, MA.

Choi, J. P. (2001) Technology transfer with moral hazard, *International Journal of Industrial Organization*, 19, 249-66.

Colombo, M. G. (2003) Alliance form: a test of the contractual and competence perspectives, *Strategic Management Journal*, 24, 1209-29.

Fosfuri, A. and Giarratana, M. S. (2010) Introduction: Trading under the Buttonwood--a foreword to the markets for technology and ideas, *Industrial and Corporate Change*, 19, 767-73.

Gallini, N. and Winter, R. (1985) Licensing in the theory of innovation, *RAND Journal of Economics*, 16, 514-26.

Gallini, N. and Wright, B. (1990) Technology transfer under asymmetric information, *RAND Journal of Economics*, 21, 147-60.

Gambardella, A., Giuri, P. and Luzzi, A. (2007) The market for patents in Europe, *Research Policy*, 36, 1163-83.

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

Gulati, R., Lavie, D. and Singh, H. (2009) The nature of partnering experience and the gains from alliances, *Strategic Management Journal,* 30, 1213-33.

Gulati, R. and Singh, H. (1998) The architecture of cooperation: Managing coordination costs and appropriation concerns in strategic alliances, *Administrative Science Quarterly*, 43, 781-814.

Hagedoorn, J., Lorenz-Orlean, S. and van Kranenburg, H. (2008) Inter-firm technology transfer: partnership-embedded licensing or standard licensing agreements?, *Industrial and Corporate Change*, 18, 529-50.

Hall, B., Jaffe, A. and Trajtenberg, M. (2001) The NBER patent citations data file: lessons, insights, and methodological tools, Working Paper no. 8498, NBER, Cambridge, MA.

Hart, O. and Moore, J. (2008) Contracts as reference points, *The quarterly journal of economics*, 123, 1-48.

Hoetker, G. and Mellewigt, T. (2009) Choice and performance of governance mechanisms: matching alliance governance to asset type, *Strategic Management Journal,* 30,1025-44.

Kamien, M. I. and Tauman, Y. (1986) Fees versus royalties and the private value of a patent, *Quarterly Journal of Economics*, 101, 471-91.

Kim, Y. and Vonortas, N. (2006) Technology licensing partners, *Journal of Economics and Business*, 58, 273-89.

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

Macho-Stadler, I., Martinez-Guiral, X. and Perez-Castrillo, D. (1996) The role of information in licensing contract design, *Research Policy*, 25, 43-57.

Mendi, P. (2005) The structure of payments in technology transfer contracts: evidence from Spain, *Journal of Economics and Management Strategy*, 14, 403-29.

OECD (2004) Patents and innovation: Trends and policy challenges, OECD, Paris.

Oxley, J. (1989) Appropriability Hazards and Governance in Strategic Alliances: a transaction cost approach, *Journal of Law Economics & Organization,* 13, 387-407.

Oxley, J. E. and Sampson, R. C. (2004) The scope and governance of international R&D alliances, *Strategic Management Journal,* 25, 723-49.

Pisano, G. (2006) Can science be a business? Lessons from biotech, *Harvard Business Review*, 84, 114-25.

Razgaitis, R. (2006) U.S./Canadian Licensing in 2005 - Survey Results, *Les Nouvelles*, 233-45.

Rockett, K. (1990) The quality of licensed technology, *International Journal of Industrial Organization*, 8, 559-74.

Roijakkers, N. and Hagedoorn, J. (2006) Inter-firm R&D partnering in pharmaceutical biotechnology since 1975: Trends, patterns, and networks, *Research Policy*, 35, 431-46.

Rothaermel, F. T. (2001) Incumbent's advantage through exploiting complementary assets via interfirm cooperation, *Strategic Management Journal*, 22, 687-99.

Rothaermel, F. T. and Deeds, D. L. (2004) Exploration and exploitation alliances in biotechnology: a system of new product development, *Strategic Management Journal*, 25, 201-21.

Sakakibara, M. (2010) An empirical analysis of pricing in patent licensing contracts, *Industrial and Corporate Change*, 19, 927-45.

Sampson, R. (2007) R&D alliances and firm performance: the impact of technological diversity and alliance organization on innovation, *Academy of Management Journal,* 50, 364-86.

Shane, S. (2002) Selling university technology: patterns from MIT, *Management Science,* 48, 122-37.

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

Somaya, D., Kim, Y. and Vonortas, N. (2010) Exclusivity in licensing alliances: using hostages to support technology commercialization, *Strategic Management Journal*, 32, 159-86.

Stuart, T., Ozdemir, S. and Ding, W. (2007) Vertical alliance networks: The case of university–biotechnology–pharmaceutical alliance chains, *Research Policy*, 36, 477-98.

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, 741-59.

Von Hippel, E. (1994) Sticky information and the locus of problem solving: implications for innovation, *Management Science*, 40, 429-39.

Williamson, O. (1981) The Economics of Organization: the Transaction Cost Approach, *The American Journal of Sociology*, 87, 548-77.

TABLES

Table 1. Summary statistics

	N	Mean	s.d.	Min	Max
Early stage technology	266	0.41	0.49	0.0	1
Know-how	266	0.71	0.46	0.0	1
Technology specificity	266	0.84	0.37	0.0	1
Licensor's patent stock	266	355.97	1132.76	0.0	10948
Licensee's patent stock	266	938.51	1822.21	0.0	15433
Technological diversity	266	0.50	0.34	0.0	1
Past relations	266	1.06	0.28	1.0	3
Exclusive license	266	0.93	0.25	0.0	1
Geographic scope	266	0.60	0.49	0.0	1
Vertical license	266	0.48	0.50	0.0	1
International license	266	0.38	0.49	0.0	1
Licensor's past relations	266	1.86	1.68	1.0	13
Licensee's past relations	266	1.97	1.72	1.0	11
Cancer area	266	0.23	0.42	0.0	1
Infectious area	266	0.16	0.37	0.0	1
Time	266	1995.16	4.12	1985.0	2004

Table 2. 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 3. Multinomial logit estimates

	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
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)
Licensor's patent stock								
Licensee's patent stock								
Technological diversity								
Past relations								
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)
Cancer area	-1.61* (0.898)	-0.58 (0.609)	-1.88* (0.987)	-0.64 (0.643)	-1.77* (0.981)	-0.59 (0.633)	-1.85* (0.972)	-0.74 (0.672)
Infectious area	-0.09 (1.124)	0.50 (0.870)	-0.24 (1.118)	0.37 (0.886)	-0.21 (1.112)	0.39 (0.868)	-0.57 (1.138)	0.26 (0.894)
Other areas	-0.62 (0.732)	-0.61 (0.546)	-0.92 (0.780)	-0.74 (0.588)	-0.89 (0.795)	-0.73 (0.568)	-1.34 (0.830)	-0.79 (0.601)
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.
Year dummy variable-coefficients are included in the regressions, however they are not reported in the table.

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
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)
Licensor's patent stock	-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)
Licensee's patent stock	-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)
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)
Cancer area	-1.47 (1.048)	-0.61 (0.649)	-2.20** (1.124)	-0.62 (0.649)	-2.10* (1.156)	-0.55 (0.627)	0.55 (0.627)	-1.55 (1.036)
Infectious area	-0.40 (1.134)	0.32 (0.866)	-0.71 (1.126)	0.30 (0.864)	-0.42 (1.156)	0.60 (0.886)	-0.60 (0.886)	-1.02 (0.802)
Other areas	-1.06 (0.855)	-0.71 (0.580)	-1.66* (0.908)	-0.71 (0.575)	-1.43 (0.941)	-0.48 (0.583)	0.48 (0.583)	-0.95 (0.791)
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.
Year dummy variable-coefficients are included in the regressions, however they are not reported in the table.