

# *Technology Licensing Partners*

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## 1. Introduction

Technology licensing, where the appropriation and adaptation of technological advances takes a central role, has become increasingly important for the competitive strategy of firms in high technology industries. Especially, in the context of contemporary economic and business environments featuring rapid technology change, more aggressive competition through outsourcing and collaborating, networked corporate governance and strengthened intellectual property protection, licensing has arguably become a more visible type of strategic technological alliance between companies.

There is an extensive evidence of the increasing use of licensing agreements in technology-intensive industries. For instance, Degnan (1998) finds that US companies received \$66 billion in royalty income from unaffiliated entities in 1996. Anand and Khanna (2000) report that licensing accounts for about 20-33 percent of all inter-firm alliances, depending on the sector, in sectors such as chemicals, biotechnology, software, computers and electrical and non-electrical machinery. A study by Arora et al. (2001) also points that over 15,000 licensing transactions in technology occurred worldwide in the period 1985-1997 with a total value of over \$320 billion, implying an average of nearly 1,150 transactions worth \$25 billion per year. One frequently reads in the popular press that companies like Texas Instruments (TI) and International Business Machines (IBM) follow aggressive strategies of exploitation of their extensive technology patent portfolios through licensing.

Like many other types of strategic alliances, key questions in technology licensing include (a) why companies enter into licensing contracts and (b) whom do they choose as their licensing partners. As for the former question, theoretical appraisals in industrial economics have addressed several factors that may induce firms to license technology to others, such as entry deterrence (Gallini, 1984), additional revenues (Katz and Shapiro, 1985), enhancing demand (Shepard, 1987), and facilitating collusion (Lin, 1996). Arora and Fosfuri (2003) argue that competition among technology owners creates strategic incentives to license technology. Moreover, in high tech industries, large market leaders acquire technology in order to either maintain leadership in existing product generations or enter new product generations (Filson and Gretz, 2004). This suggests that companies

may license in to preserve a market position or acquire one. Scholars have explained technology licensing from the strategic management viewpoint as well. McDonald and Leahey (1985) deal with the advantages and disadvantages to both licensing-in and licensing-out that must be considered by business strategists. Wind and Mahajan (1988) look at licensing as a process of product development, whereas Cronin (1989) sees licensing as a means for obtaining income. In D'Aveni (1994), market structure and the nationality of the product market are key factors in determining strategies concerning timing of strategic moves. In a companion empirical paper, Kim and Vonortas (forthcoming) show that companies' licensing behavior is bounded by various firm and industry characteristics.

As for the latter question, Eswaran (1994) and Rockett (1990) demonstrate the inclination of incumbent firms' to avoid licensing their technology to potential entrants and the strategic incentive to license a weak rival to crowd the market and deter entry by a stronger competitor, thus "choosing the weak competition". However, with the exception of significant case study work, formal empirical analyses addressing the factors that might influence the choice of licensing partners are surprisingly rare.

This paper aims exactly at this void. It reports the results of an extensive empirical examination of the propensity of companies to engage in technology licensing agreements based on a large panel data set of observed licensing transactions involving US-traded companies in ten broadly defined industry sectors during the period 1990-1999. The examined companies are well established with documented patenting and financial history. The study complements the extant literature in two ways: (a) it covers a wider spectrum of industries that contribute significantly to observed technology licensing trends, including both manufacturing sectors and service sectors such as business services and software; and (b) it involves firm-level analysis using an extensive dataset that extends for a full decade.

We find strong evidence that two companies will tend to engage in licensing agreements the closer their technological profiles, the closer their market profiles, the more familiar they are with each other through prior such agreements, the higher their prior independent experience with licensing, and the stronger the intellectual property protection in the primary line of business of the licensor. Directly or indirectly, all these

factors determine the anticipated costs of licensing a piece of technology, including transaction costs (the costs of negotiating, monitoring, and enforcing contracts) as well as the costs related to technology transfer, learning, and eventual application. That is to say, the propensity of firms to collaborate through technology licensing depends on the economics of the whole “package” associated with such licensing. This compares with the message from most received theoretical literature in economics that has tended to focus on strategic behavior in technology licensing within a single industry.

The organization of the remaining sections is as follows. Section 2 presents the data and the empirical methodology. Section 3 discusses the empirical results. Finally, Section 4 concludes with a summary of the main results and managerial implications.

## **2. Empirical Analysis**

### **2.1.Data**

The data used in this analysis originate in the *Innovation Network Databank (INNET)* of the Center for International Science and Technology Policy at the George Washington University. *INNET* features longitudinal information on strategic alliances, US patents, and business performance for many thousands of companies since 1985. For this paper we have used the section on licensing agreements. The basic information on licensing agreements has been drawn from the SDC database of Thomson Financial which records all publicly announced alliance deals worldwide tracked down in the Security Exchange Commission filings in the United States, newswires, press, trade magazines, professional journals, and the like. SDC provides information on contract type (i.e. licensing agreement, marketing agreement, joint venture, joint development or production, etc.), content of the agreement, announcement date, identities of participant firms (primary SIC code, name, nation, parent companies, etc.), and the SIC classification of the alliance. The SDC also identifies different kinds of licensing agreements (exclusive, non-exclusive, cross-licensing) and the roles of the participants in them (licensor, licensee).

The most serious limitation of SDC is its bias towards US organizations, due to the data collection methodology (language, geography, ability to be equally inclusive around the globe). We have limited the analysis reported here to licensing agreements between companies traded in the United States during the past decade (1990-1999).

There were 10,069 entries referring to licensing agreements worldwide from January 1, 1990 to December 31, 1999 involving 20,840 participants, corresponding to 8,193 different organizations. This amount of data, however, was reduced extensively following a series of steps to clean the entries, positively identify the individual companies, collect longitudinal statistical information on their market performance, and link them to the patent database produced by the NBER. Data cleaning involved discarding entries that did not involve new deals. Standard & Poor's CompuStat (publicly traded companies in the United States) was used to cross-identify individual companies and extract financial information on each one. Given that the empirical analysis below requires the identification of a licensor and a licensee, we were obliged to eliminate agreements for which we could not identify at least two participants. This treatment and some additional cleaning of the data resulted in an initial set of 1,071 original licensing agreements with at least two identified participants (licensor and licensee). These agreements involved 2,295 participants, corresponding to 985 different companies.

We have concentrated our analysis on the ten most active industry sectors in this dataset, that is, the sectors accounting for the largest number of identified companies (total 786). We subsequently linked this sample to the NBER patent database to obtain the patenting histories of 552 companies for the period 1968-1999, also including all patent citations to each patent applied for in the examined time period. These 552 companies make up our final sample of licensors and licensees.<sup>1</sup>

Table 1 provides a full picture of the licensing deals underlying this empirical analysis. It breaks them down by sector (licensor main line of business) using 'point-to-point tabulation', counting deals between pairs of companies (a licensor and a licensee).

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<sup>1</sup> The loss of observations is due to data matching across three databases (alliances, patents, financial). It has important consequences since it limits the sample of organizations in terms of company nationality (US-traded firms are only considered), company size (very small firms with no well-documented patenting and financial history are dropped), and company technological capabilities (firms without patent applications during the examined time period are excluded). The composition of the sample does not seem to be biased in other ways.

That is to say, a license agreement is counted as many times as there are identified licensees.

[TABLE 1 ABOUT HERE]

Business services (SIC 73) and electronics (SIC 36) are shown to be the most active sellers of technology through licensing. They are trailed by chemicals and pharmaceuticals (SIC 28). Chemicals companies registered the highest (by far) share of exclusive licenses whereas electronics companies registered the highest share of cross-licensing, as expected on the basis of their IPR regimes (Grindley and Teece, 1997).

Tables 2 & 3 distribute the 552 licensor and licensee firms across the ten sectors.

[TABLES 2 & 3 ABOUT HERE]

This data sample was used to construct a panel in which the unit of observation is the unique firm  $i$ -firm  $j$  pair, or dyad. For each year, the dyad data is constructed as follows:  $f1\sim f2, f1\sim f3, \dots, f1\sim fn; f2\sim f1, f2\sim f3, \dots, f2\sim fn; fn-1\sim f1, fn-1\sim f2, \dots, fn-1\sim fn; fn\sim f1, fn\sim f2, \dots, fn\sim fn-1$ , where  $f1$ =firm 1, ...,  $fn$ =firm  $n$ . There are  $n \times n-1$  possible dyads in each year. Given our  $n=552$  firms, this translates to 304,152 dyads in each year or to 3,041,520 year-dyads across the time period 1990-1999.

## 2.2. Model Specification

We use a random effects probit model to estimate the probability that firm  $i$  will license its technology to firm  $j$  in a specific year  $t$ .<sup>2</sup> Let:

$$P_{ijt} = F [Z_t(i,j), Y_t(i), L_t(I), Y_t(j)]$$

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<sup>2</sup> Multinomial probit or ordered probit models were not used because there are very few instances where a firm licenses to another more than once in a particular year. Since all 552 firms were identified in the NBER patent database, we are fairly confident that a specific firm which did not license out in a given year had no incentive to do so rather than it had nothing to sell.

where

$P_{ijt}$  = probability that licensor firm  $i$  will license its technology to licensee firm  $j$  in year  $t$ .

$F$  = cumulative probability function.

$Z_t(i,j)$  = vector of variables describing the relationship between firms  $i$  and  $j$  in year  $t$ .

$Y_t(i)$  = vector of characteristics of licensor firm  $i$  in year  $t$ .

$L_t(I)$  = vector of market and technological characteristics of the primary industry  $I$  of the licensor firm  $i$  in year  $t$ .

$Y_t(j)$  = vector of characteristics of licensee firm  $j$  in year  $t$ .

$t = 1990, \dots, 1999$ .

### Dependent Variable

**LICENSE** $_{ijt}$  = 1 if firm  $i$  licenses one or more technologies to another firm  $j$  in year  $t$ ;  
= 0 otherwise.

### Independent Variables

(a) *Relationship between firms  $i$  and  $j$  in year  $t$ ,  $Z_t(i,j)$ .*

**TECHPROXIMITY** $_{ijt}$  = degree of similarity in the technological profile of licensor firm  $i$  and licensee firm  $j$  in year  $t$ .

The technological proximity between two firms  $i$  and  $j$  can be measured as their “distance” in “technology space”, approximated here by the degree of similarity in their patent portfolios, used as a proxy for technological profile (see Appendix for detailed definition). Firms with similar technological profiles will incur lower transaction costs in technology licensing because of similar capabilities (Gomes-Casseres, 1993). Similar specializations will also decrease the learning cost of new technology. For example, the transferred technology is easier to master by the licensee, requires fewer modifications by the licensor, and can be implemented faster. On the other hand, similarity in capabilities dampens the incentives of the licensor to go through with the transaction due to the

anticipation of increased competition. This typically results in the imposition of special clauses in terms of exploitation of the technology which may make it less attractive to the licensee. On the basis of cost considerations, the model predicts a positive sign for *TECHPROXIMITY<sub>ijt</sub>*. The competition consideration, however, works the opposite way.

*MARKETPROXIMITY<sub>ij</sub>* = 1 if firm *i* and firm *j* share the same primary industry;  
= 0 otherwise.

Prospective licensors are typically loath to license their technology to firms with similar market profile due to the high potential for creating strong competitors (Gomes-Casseres, 1993). On the other hand, firms operating in similar industries may be organized along similar lines, making the transfer less costly in terms of being familiar with markets, processes and supply chains. Moreover, higher business similarity between partners allows firms to scrutinize with greater confidence their partners' opportunistic behavior (Alchian and Demsetz, 1972; Merchant and Schendel, 2000). The market distance between firm *i* and firm *j* is approximated by comparing the firms' primary sectors (see Appendix). The expected sign for *MARKETPROXIMITY<sub>ij</sub>* is ambiguous.

*FAMILIARITY<sub>ijt</sub>* = The number of licenses granted by firm *i* to firm *j* up to period *t-1*.

Efficient technology transfer through arm's length transactions may fail due to the presence of uncertainty and opportunistic behavior (Arrow, 1962; Link and Tassej, 1987). Former studies suggest that previous partner experience is an important variable in overcoming such difficulties. For instance, previous partner experience is demonstrated as a key factor of lowering transaction costs in learning and transferring of knowledge (Kotabe, et al., 1996; Dyer and Singh, 1998; Kale, et al., 2000) and alliance formation processes (Doz, et al., 2000). Gulati (1995) also argues that trust formed through prior deals displaces a lot of the transaction costs. Prior interaction and experience in alliances affects not only the decision to enter an alliance but also the terms of the resulting agreements (e.g., Filson and Morales, forthcoming). Mayer and Argyres (2004) point out that repeated contracts with a partner over time serve as repositories of knowledge about how to efficiently work with each other. Overall, repeated contracts with the same licensing partner, through frequent communication in each partner for the other, will

build confidence, eliminate lots of uncertainty about partners, provide partners knowledge about better ways to collaborate, and will lower the transaction costs of the licensing agreement.<sup>3</sup> A positive sign for *FAMILIARITY<sub>ijt</sub>* is expected.

(b) *Characteristics of licensor firm i in year t, Y<sub>t</sub> (i)*

*SALES<sub>it</sub>* = sales of firm *i* in year *t*.

Sale figures have been used as proxy for firm size. Large companies will license out in order to better exploit their technology. They may also license as a result of strategic incentives created by both technology and market competition (e.g., to increase the reach of their technology and deter competitors). Smaller companies will often license to maintain the necessary cash flow. In certain industries such as pharmaceuticals the costs of fielding products is very high (clinical trial costs may run into the hundreds of millions of dollars). Relatively small firms (e.g., biotechnology companies) often cannot even attempt to market their inventions without assistance from larger established pharmaceutical companies.<sup>4</sup> It may be argued that small firms may be pressured to license technologies more frequently than larger companies. The expected sign for *SALES<sub>it</sub>* is ambiguous.

*SELEXPERIENCE<sub>it</sub>* = The number of licenses granted by firm *i* up to period *t-1*.

Seller (licensor) experience is used as yet another proxy for the transaction cost of licensing. Experience in gathering information about prospective licensees, negotiating, writing contracts and enforcing them will lower the cost of licensing for the seller. In addition, this variable controls for unobserved firm level factors since firms that have licensed before may be qualitatively different from those that never did. A positive sign for *SELEXPERIENCE<sub>it</sub>* is expected.

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<sup>3</sup> Another kind of familiarity may be technological, approximated by patent cross-citation between the two parties (Link and Scott, forthcoming). Similar implications apply.

<sup>4</sup> Research-oriented small firms often earn their profits through licensing arrangements with more established, incumbent firms, in commercializing a new technology (Gans and Stern 2000). However, such companies are excluded from our population as explained in section 2.1.

(c) *Characteristics of industry I in year t,  $L_t(I)$*

**$CONCENTRATION_{it}$**  = concentration of primary industry  $I$  of firm  $i$  in year  $t$ .

Low concentration implies that the firms already have many competitors (lower market power) in their primary product market (Caves, 1970). It will be less expensive for a licensor to create another licensee in a more competitive market relative to a more concentrated market, considering the negative rent dissipation effect of a prospective competitor on the licensor's profit. This argument makes licensing by firms in a less concentrated environment more likely. A negative sign for  **$CONCENTRATION_{it}$**  is expected across all types of licensing.

**$GROWTH_{it}$**  = growth rate of primary industry  $I$  of firm  $i$  in year  $t$ .

The higher the growth rate of industry output, ceteris paribus, the less an entrant's supply will depress industry price and output (Orr 1974). Accordingly, firms will have a better incentive to license in rapidly growing sectors since rent dissipation due to increased competition with new entrants will be minimized by high growth. A positive sign for  **$GROWTH_{it}$**  is expected.

**$INDUSTRY PATENT_{it}$**  = *Patent / R&D expenditures* of primary industry  $I$  of firm  $i$  in year  $t$  (propensity to patent).

If the patent intensity of the main line of business of the licensor is high, then there are more technologies that can be licensed out and we are more likely to observe licensing, other things equal. Put otherwise, the probability that the specific firm  $i$  will license technology out, and hence meet firm  $j$ , is higher. Patent intensity can be considered as an indicator of the strength of the intellectual property protection (IPR) regime in an industry. The stronger the IPR regime the better the ability of the licensor to capture a larger share of the rents generated from the licensed technology, ceteris paribus (Anand and Khanna, 2000). A weak IPR regime exacerbates the appropriability problem: users of the licensor's technology do not pay appropriately for it. Further, Merges (1998) argues that transaction costs of technology licensing are negatively related to the strength of patent protection. To counteract the licensee's incentive to shirk payment in the case of

weak IPR protection the licensor's costs for monitoring and enforcement will increase. The expected sign for *INDUSTRY PATENT<sub>It</sub>* is positive.

*COMPLEXITY<sub>I</sub>* = 1 if *I* is a complex product industry;  
= 0 otherwise.

Cohen et al. (2000, 2002) distinguish between “complex” and “discrete” product industries based on whether a new product incorporates numerous separately patentable elements or relatively few. For example, electronic products typically are comprised of a relatively large number of patentable elements, and thus characterized as complex. In contrast, new drugs or chemicals are comprised of a relatively discrete number of patentable elements (often a single formula) (Rycroft and Kash, 1999). As a result, simple technologies can be better protected through patents (strong IPR) whereas complex technologies may be easier to invent around (weak IPR). Following Cohen et al. (2002), we use SIC 35 as a crude cut-off point between complex product industries (35 and above) and simple product industries (below 35). As defined, simple product industries include ferrous and non-ferrous metals, chemicals, petrochemicals, drugs, food, tobacco, and so forth. Complex product industries include machinery, computers, electrical equipment, scientific instruments, and all kinds of services. Better IPR protection (easier enforceable, less expensive) raises the prospects of licensing. A negative sign for *COMPLEXITY<sub>I</sub>* is generally expected.

*GPT<sub>I</sub>* = 1 if industry *I* can be described as ICTs, biotechnology, or advanced materials;  
= 0 otherwise.

Information and communication technologies (ICTs), biotechnology, and advanced materials have “infrastructural” characteristics (general purpose technologies). They have penetrated throughout the economy during the past 2-3 decades and have thus dramatically altered the basic meaning of high technology. Rather than referring to the output of R&D-intensive industries, high tech is now argued to indicate a style of work applicable to just about any business (Branscomb and Florida 1998; Porter 1998). The penetration of these GPTs – information technology in particular – has gradually shifted the locus of high technology production from exclusively manufacturing to a

combination of manufacturing and service industries (Hauknes 1998; Leech, et al. 1998; OECD 2000). As a result of widespread use, we would expect these technologies to be licensed more widely than others. A positive sign of  $GPT_t$  is anticipated.

*(d) Characteristics of licensee firm  $j$  in year  $t$ ,  $Y_t(j)$*

$SALES_{jt}$  = sales of licensee firm  $j$  in year  $t$ .

Large firms typically have substantial production, marketing, and organizational capabilities. They thus present higher risks in terms of becoming strong competitors with the licensor once they get access to the technology. This clearly dampens the incentive to the licensor. On the other hand, there is evidence that a significant share of licensing takes place between relatively small licensors and much larger licensees (e.g., biotech, pharmaceuticals). The expected sign for  $SIZE_{jt}$  is ambiguous.

$BUYEXPERIENCE_{jt}$  = The number of licenses bought by firm  $j$  up to period  $t-1$ .

Licensee experience is used as another proxy for the transaction cost of licensing. Experience in gathering information about technologies and their proprietors, negotiating, writing contracts and enforcing them will lower the cost of licensing. A positive sign for  $BUYEXPERIENCE_{jt}$  is expected.

The Appendix provides additional detail regarding the construction of the more synthetic variables. Tables 4 and 5 provide descriptive statistics of the variables and the correlation matrix respectively.

[TABLES 4 & 5 ABOUT HERE]

### 3. Results

#### 3.1. Estimation

Table 6 presents the estimation results (marginal effects).<sup>5</sup> Three different models are presented with different sets of explanatory variables. Model 1 uses the variables indicating the relationship between firms  $i$  and  $j$  ( $Z_t(i,j)$ ). Model 2 adds the characteristics of firm  $i$  and industry  $I$  ( $Y_t(i)+L_t(I)$ ). Model 3 adds the characteristics of firm  $j$  ( $Y_t(j)$ ) (complete model).

[TABLE 6 ABOUT HERE]

The estimation results are strong. Nine out of the twelve explanatory variables are statistically significant. Specifically, three of the four sets of explanatory variables are fully statistically significant, including those that describe the relationship between the contracting firms and the characteristics of each firm ( $Z_t(i,j)$ ,  $Y_t(i)$ ,  $Y_t(j)$ ). All three non-significant variables belong to the set describing the characteristics of the primary industry of the licensor ( $L_t(I)$ ). No signs reverse across models and the size of the coefficients remain relatively stable.

#### 3.2. Discussion

The statistically most important explanatory factors of the probability that two firms will engage in a technology agreement as a licensor and a licensee are found to relate to the relationship between the two companies and the characteristics of each company. All seven variables in these three sets are highly statistically significant (1%

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<sup>5</sup> The marginal effect of a variable measures the estimated change in the probability of observing licensing from firm  $i$  to firm  $j$  given a small change in the value of the variable. We use marginal effects of estimated variables to discuss the results in this paper, as coefficients of estimation lack a clear interpretation in limited dependent variable models. For further discussion see Greene (2000).

level). According to Table 6, companies engage in licensing agreements the closer they are in terms of both technological and market profiles and the more familiar they are with each other, that is, the larger their past interaction in terms of technology licensing ( $TECHPROXIMITY_{ijt}$ ,  $MARKETPROXIMITY_{ij}$ ,  $FAMILIARITY_{ijt}$ ). The estimated marginal effects (Model 3), for example, show that the increase in technology proximity between companies by one raises the likelihood of observing licensing between them by 78.8 percentage points.<sup>6</sup> Increasing market proximity by one increases the likelihood of occurring licensing by 28.7 percentage points. Each additional previous licensing experience between the two firms increases the probability of further licensing among them by 31.2 percentage points. The implication here is that the effect of lower anticipated costs associated with technology transfer (licensing transaction costs, learning and application costs) dominates the more strategic consideration of creating additional competition in one's own business area. Case study and anecdotal evidence has indicated for a long time that licensors try to avoid selling their latest technologies. Larger firms, at least, will typically sell one or two generations-old technologies (e.g., Caves, 1982). If so, the competition disincentive loses a lot of its power as an explanatory factor of licensing relative to cost factors.

The cost incentive for licensing is further reinforced by the significant and positive influence of prior experience with licensing agreements for both the licensor and the licensee ( $SELEXPERIENCE_{it}$ ,  $BUYEXPERIENCE_{jt}$ ). Company size also appears as a statistically significant factor ( $SALES_{it}$ ,  $SALES_{jt}$ ): the chances for two firms to meet in a licensing agreement increases with their size.

The explanatory power of the characteristics of the primary industry of the licensor was somewhat of a disappointment. Of the five variables in this set, two were statistically significant at the 10% level ( $INDUSTRY PATENT_{it}$  and  $CONCENTRATION_{it}$ ). An increase in industry patent intensity of a licensor by one raises the likelihood of observing licensing by an estimated 19.3 percentage points. The patent intensity in the main line of business of the licensor appears to be an important factor in determining the probability of two firms to meet in a licensing deal. As mentioned earlier,

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<sup>6</sup> To interpret the marginal effects of independent variables, we may consider increasing each variable by one standard deviation in Table 4.

patent intensity can be considered as a proxy for the strength of intellectual property protection as perceived by the company. If the link between patent intensity and the strength of IPR protection in an industry is strong – as has indeed been emphasized in the literature (Anand and Khanna, 2000; Levin et al., 1987) – then, this result further reinforces our cost findings above: the strength of patent protection lowers the transaction cost of technology licensing, thus raising the incentive to sell technology, enhancing the set of candidate technologies for sale, and raising the probability that two firms meet in licensing deals.

Lower concentration levels in the licensor's primary sector, on the other hand, are associated with higher probabilities that two firms meet in a licensing agreement. To the extent that larger numbers of competitors can be associated with more technological homogeneity, this result supports the prediction of extant theory that more technological homogeneity among technology owners will raise the incentives of each one of them to license out technology (also in Arora and Fosfuri, 2003).

Finally, the rate of growth of the primary sector of the licensor ( $GROWTH_{it}$ ), the degree of technological complexity in that sector ( $COMPLEXITY_t$ , indicating the extent of technology appropriability by the licensor), and the classification of that sector into the general-purpose technology category ( $GPT_t$ ) did not produce statistically significant results. Still, two of the three estimated coefficients come with the anticipated signs, indicating that the higher the growth rate and the reference to a general-purpose technology increase incentives to license and the probability that two firms to meet in the market for technology.

We suspect that these three variables did not work as well as expected because we were obliged to use the primary industry of the licensor to capture industry-level effects on the incentives of two firms to enter a licensing agreement. The first best would have been to use the industry in which the specific licensed technology can be classified in. While this information was available to us, the reason for choosing the primary industry of the firm is that our econometric methodology juxtaposes the dyads which were observed with those which were not: we obviously did not have the industrial classification for non-consummated licensing deals. Considering that the license may be given in a field different from the licensor's primary sector, however, the estimated

coefficients may lack the necessary explanatory power. We could think of no obvious solution to this problem.

#### 4. Conclusion

This study has investigated the determinants of technology licensing using an extensive panel data set of licensing transactions during the period 1990-1999 involving many hundreds of companies traded in the United States. The incentives to engage in licensing agreements are explained by sets of variables reflecting the relationship between licensor and licensee, the characteristics of each of these firms, and the characteristics of the primary industry of the licensor.

The most important explanatory factors of the probability that two companies will meet in a technology licensing agreement relate to the relationship between them and to the characteristics of each. Companies will tend to engage in licensing agreements:

- (a) the closer their technological profiles;
- (b) the closer their market profiles;
- (c) the more familiar they are with each other through prior agreements;
- (d) the higher their prior independent experience with licensing; and,
- (e) the stronger the intellectual property protection in the primary line of business of the licensor.

All these factors affect the cost of the licensing transaction. While the theoretical models in industrial economics have tended to concentrate on strategic, competition-related factors operating on within-industry licensing, this analysis shows that cost factors tend to weigh in heavily in explaining licensing behavior when inter-sectoral agreements are also involved in the mix. Our results do not question the validity of the theoretical argument: companies indeed loath to create new competition. They, however, tend to fend against that danger by refusing to sell their latest technology.<sup>7</sup> That problem aside, cost considerations take over in deciding whether to license at all and who to license.<sup>8</sup>

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<sup>7</sup> There is evidence that licensing typically involves one or two generations-old technology for that reason exactly (Caves 1982, 1996).

<sup>8</sup> A quarter of a century later, the pioneering results of Teece (1977) regarding the importance of costs in the transfer of technology by large firms still hold.

The managerial implications are important. It is now well understood that companies try to mitigate transaction and learning costs related to knowledge transfer and utilization when considering strategic alliances and networks (Gulati, 1998). For instance, they prefer to align with partners whom they know either directly from prior interactions or indirectly through information that they receive from existing partners. Our analysis confirms that licensing contracts are not exceptional. Firms are more likely to engage in a licensing agreement when they have prior licensing experience with each other. In addition, firms will tend to prefer more experienced partners to less experienced ones. They pay attention to the intellectual property regime. Finally, firms tend to license their technology to others with similar business and technological profiles.

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## Appendix: Variable Definition

**TECHPROXIMITY<sub>ijt</sub>**. We borrow from Jaffe (1986) and Branstetter and Sakakibara (2002) to calculate the technological proximity of two firms as an angle between the firms' patent class portfolios. Let  $V_{it}$  be firm  $i$ 's technology (patent) profile vector at year  $t$  ( $1969 \leq t \leq 1999$ ).  $V_{it}$  is an  $\mathbf{R}^m$  column vector, where  $m=36$  and the number of  $m$  comes from the technology categories determined by Hall et al. (2001) on the basis of USPTO patent classes.  $V_{it}(k)$ , the  $k^{\text{th}}$  element of  $V_{it}$  contains the cumulative number of patents granted to firm  $i$  in the  $k^{\text{th}}$  technology category from 1969 to the year prior to  $t$  (year  $t-1$ ).  $V_{it}$  is then calculated as follows:

$$V_{it} = (1 - \rho) V_{i(t-1)} + K_{it} ,$$

where  $\rho = 0.15$  is the depreciation rate,  $K_{it}$  is  $\mathbf{R}^m$  column vector whose  $k^{\text{th}}$  element represents the number of patents firm  $i$  obtained at year  $t$  that belong to the  $k^{\text{th}}$  technology category. The initial value of  $V_{it}$  for year 1968 is assumed to be zero. Thus, the technological proximity between firm  $i$  and firm  $j$  at year  $t$  is defined as the inner product,

$$\frac{V_{it} \cdot V_{jt}}{|V_{it}| \cdot |V_{jt}|} ,$$

where  $|V_{it}| = \left[ V_{it}(1) \cdot V_{it}(1) + V_{it}(2) \cdot V_{it}(2) + \dots + V_{it}(k) \cdot V_{it}(k) \right]^{1/2}$ ,  $V_{it}(k)$  is the value for  $k^{\text{th}}$  row of  $V_{it}$ .

**TECHPROXIMITY<sub>ijt</sub>**  $\in [0,1]$  Higher values represent more similar technology portfolios.

**MARKETPROXIMITY<sub>ij</sub>**. We compare firms' primary SIC codes only at the 2-digit SIC level. The SDC database provides this information. It is time invariant and calculated only once at the end of the examined period assuming that companies' main lines of businesses do not change frequently. Richards and Carolis (2003) use the same definition for this variable.

**FAMILIARITY<sub>ijt</sub>**, **SELEXPERIENCE<sub>it</sub>**, **BUYEXPERIENCE<sub>jt</sub>**. For these variables, we examined all licensing deals reported in SDC database since 1985.

***SALES<sub>it</sub>***, ***SALES<sub>jt</sub>*** The sales amount for each firm is extracted from CompuStat (millions of dollars).

***CONCENTRATION<sub>It</sub>***. The 4-firm concentration ratio is used (U.S. Census Bureau, 1992). Concentration ratios were unavailable for SIC 1-19. Small numbers of companies in those sectors were dropped.

***GROWTH<sub>It</sub>***. Percent change of GDP,  $\left( \frac{GDP_t - GDP_{t-1}}{GDP_{t-1}} \right) \times 100$ , where GDP is Real Gross

Domestic Product by two digit industry in 1996 dollars (billions) (Bureau of Economic Analysis).

***INDUSTRY PATENT<sub>It</sub>***. Total number of patents registered by firms in industry I divided by total R&D expenditures in that industry. Both numbers are constructed by aggregating over firms in CompuStat (net of firm's own patents and R&D).

***GPT<sub>I</sub>***. The database CorpTech (Corporate Technologies, 1999) classifies industries by functional sector (e.g., energy, biotechnology, advanced materials) as well as by SIC and maps one into the other. We use these classifications.

**Table 1.** Total Number of Licenses Sold in Sample, by Industry, 1990-1999<sup>a</sup>

<i>Industry<sup>b</sup></i>	<i>All Licenses<sup>c</sup></i>	<i>Non-exclusive Licenses</i>	<i>Exclusive Licenses</i>	<i>Cross-Licenses</i>
SIC 20	9	8	1	1
SIC 28	158	128	30	18
SIC 35	151	147	4	35
SIC 36	182	171	11	49
SIC 37	16	14	2	3
SIC 38	64	53	11	9
SIC 48	12	10	2	2
SIC 73	222	214	8	19
SIC 80	9	9	0	0
SIC 87	27	21	6	1
<b>Total</b>	<b>850</b>	<b>775</b>	<b>75</b>	<b>137</b>

<sup>a</sup> Point-to-point tabulation. A license from one firm to another is counted as one deal. A license of one firm to two others is counted as two deals. A license of one firm to three others is counted as three deals. And so forth.

<sup>b</sup> SIC 20=Food; SIC 28=Chemicals; SIC 35=Industrial Machinery & Equipment; SIC 36=Electronic & Other Electronic Equipment; SIC 37=Transport; SIC 38=Instruments & Related Products; SIC 48=Communications; SIC 73=Business Services; SIC 80= Health Services; SIC 87=Engineering and Management Services;

<sup>c</sup> Includes non-exclusive, exclusive, and cross-licenses.

**Table 2.** Frequency Distribution of Licensor Firms In Sample, By Sector, 1990-1999

<i>Industry</i> <sup>a</sup>	<i>Sold technology</i> <sup>b</sup>	<i>Did not sell technology</i>	<i>Total</i>
SIC 20	9	3	12
SIC 28	103	20	123
SIC 35	51	22	73
SIC 36	72	35	107
SIC 37	12	10	22
SIC 38	49	21	70
SIC 48	8	3	11
SIC 73	72	21	93
SIC 80	5	3	8
SIC 87	21	12	33
<i>Total</i>	402 firms	150 firms	552 firms

<sup>a</sup> SIC 20=Food; SIC 28=Chemicals; SIC 35=Industrial Machinery & Equipment; SIC 36=Electronic & Other Electronic Equipment; SIC 37=Transport; SIC 38=Instruments & Related Products; SIC 48=Communications; SIC 73=Business Services; SIC 80= Health Services; SIC 87=Engineering and Management Services;

<sup>b</sup> Includes non-exclusive, exclusive, and cross-licenses.

**Table 3.** Frequency Distribution of Licensee Firms In Sample, By Sector, 1990-1999

<i>Industry</i> <sup>a</sup>	<i>Bought technology</i> <sup>b</sup>	<i>Did not buy technology</i>	<i>Total</i>
SIC 20	7	5	12
SIC 28	66	57	123
SIC 35	53	20	73
SIC 36	73	34	107
SIC 37	18	4	22
SIC 38	41	29	70
SIC 48	8	3	11
SIC 73	56	37	93
SIC 80	5	3	8
SIC 87	12	21	33
<i>Total</i>	339 firms	213 firms	552 firms

<sup>a</sup> SIC 20=Food; SIC 28=Chemicals; SIC 35=Industrial Machinery & Equipment; SIC 36=Electronic & Other Electronic Equipment; SIC 37=Transport; SIC 38=Instruments & Related Products; SIC 48=Communications; SIC 73=Business Services; SIC 80= Health Services; SIC 87=Engineering and Management Services;

<sup>b</sup> Includes non-exclusive, exclusive, and cross-licenses.

**Table 4.** Descriptive Statistics of Variables

<i>Variable</i>	<i>Mean</i>	<i>Std. dev</i>	<i>Min</i>	<i>Max</i>
<i>LICENSE<sub>ijt</sub></i>	.0003092	.0175825	0	1
<i>TECHPROXIMITY<sub>ijt</sub></i>	.1397481	.2472855	0	1
<i>MARKETPROXIMITY<sub>ij</sub></i>	.0400298	.1960291	0	1
<i>FAMILIARITY<sub>ijt</sub></i>	.0016639	.043537	0	4
<i>SALES<sub>it</sub></i>	4690.829	15033.41	0	174694
<i>SELEXPERIENCE<sub>it</sub></i>	1.481982	3.584917	0	51
<i>CONCENTRATION<sub>It</sub></i>	33.14979	15.94718	3.9	69.4
<i>GROWTH<sub>It</sub></i>	5.330143	5.555488	-7.78342	15.54192
<i>INDUSTRY PATENT<sub>It</sub></i>	.2397743	.1184148	.0386	.6134
<i>COMPLEXITY<sub>I</sub></i>	.7553365	.4298876	0	1
<i>GPT<sub>I</sub></i>	.5731234	.4946242	0	1
<i>SALES<sub>jt</sub></i>	4690.829	15033.41	0	174694
<i>BUYEXPERIENCE<sub>jt</sub></i>	1.308961	3.471092	0	53

**Table 5.** Correlation Matrix

<i>Variables</i>	<i>1.</i>	<i>2.</i>	<i>3.</i>	<i>4.</i>	<i>5.</i>	<i>6.</i>	<i>7.</i>	<i>8.</i>
<i>1.LICENSE<sub>ijt</sub></i>	-							
<i>2.TECHPROXIMITY<sub>ijt</sub></i>	.028	-						
<i>3.MARKEPROXIMITY<sub>ij</sub></i>	.017	.274	-					
<i>4.FAMILIARITY<sub>ijt</sub></i>	.041	.068	.037	-				
<i>5.SALES<sub>it</sub></i>	.009	.051	-.035	.023	-			
<i>6.SELEXPERIENCE<sub>it</sub></i>	.027	.074	.014	.099	.241	-		
<i>7.CONCENTRATION<sub>It</sub></i>	-.004	.043	-.048	-.006	.247	-.025	-	
<i>8.GROWTH<sub>It</sub></i>	.001	.022	.036	-.003	.001	-.003	.004	-
<i>9.INDUSTRY PATENT<sub>It</sub></i>	.001	-.039	-.054	-.001	-.002	-.002	.0003	.25
<i>10.COMPLEXITY<sub>I</sub></i>	.003	-.027	-.033	.007	-.036	.037	.2003	.002
<i>11.GPT<sub>I</sub></i>	.002	-.044	.052	-.0004	-.001	.011	-.008	-.188
<i>12.SALES<sub>jt</sub></i>	.014	.051	-.035	.038	-.002	-.002	-.0008	.013
<i>13.BUYEXPERIENCE<sub>ijt</sub></i>	.027	.083	.014	.1003	-.003	.014	-.013	-.036

	<i>9.</i>	<i>10.</i>	<i>11.</i>	<i>12.</i>	<i>13.</i>
<i>9.</i>	-				
<i>10.</i>	.001	-			
<i>11.</i>	-.249	-.0002	-		
<i>12.</i>	.107	-.0001	.107	-	
<i>13.</i>	-.029	-.0003	.005	.383	-

**Table 6.** Random-Effects Probit Estimates of the Likelihood of Firm *i* Licensing to Firm *j* (Marginal Effects at Mean Values)

<i>LICENSE<sub>ijt</sub></i>	<i>Model 1</i>	<i>Model 2</i>	<i>Model 3</i>
<i>TECHPROXIMITY<sub>ijt</sub></i>	.828*** (.035)	.804*** (.038)	.788*** (.04)
<i>MARKETPROXIMITY<sub>ij</sub></i>	.262*** (.034)	.274*** (.036)	.287*** (.038)
<i>FAMILIARITY<sub>ijt</sub></i>	.752*** (.049)	.529*** (.052)	.312*** (.055)
<i>SALES<sub>it</sub></i>	—	2.34e-06*** (6.71e-07)	2.38e-06*** (6.89e-07)
<i>SELEXPERIENCE<sub>it</sub></i>	—	.021*** (.002)	.022*** (.002)
<i>CONCENTRATION<sub>It</sub></i>	—	-.162* (.086)	-.158* (.089)
<i>GROWTH<sub>It</sub></i>	—	.002 (.002)	.002 (.002)
<i>INDUSTRY PATENT<sub>It</sub></i>	—	.061* (.035)	.193* (.108)
<i>COMPLEXITY<sub>I</sub></i>	—	.014 (.121)	.024 (.036)
<i>GPT<sub>I</sub></i>	—	.011 (.028)	.004 (.029)
<i>SALES<sub>jt</sub></i>	—	—	3.90e-06*** (5.69e-07)
<i>BUYEXPERIENCE<sub>jt</sub></i>	—	—	.019*** (.002)
<b>N</b>	3041520	3041520	3041520
<b>Log likelihood</b>	-4486.95	-4209.09	-3948.61

Notes: 1. \*\*\*significant at the 1% level; \*significant at the 10% level;  
2. Standard errors are in parentheses. In the typical regression model,  $y = xb + e$ , it is assumed that  $x$  and  $e$  are identical and independently distributed (i.i.d). In dyad analysis the problem of statistical nonindependence might occur when firms are repeated across different dyads. Robust standard errors were also used to adjust dyads for clustering on firms in these calculations. The results were similar to those reported here.