UNIVERSIDAD CARLOS III DE MADRID working papers

Working Paper 04-15
Business Economics Series 07
February 2004

Departamento de Economía de la Empresa
Universidad Carlos III de Madrid
Calle Madrid, 126
28903 Getafe (Spain)
Fax (34-91) 6249608

THE LICENSING DILEMMA:
UNDERSTANDING THE DETERMINANTS OF THE RATE OF LICENSING

Andrea Fosfuri*[1]

Abstract

Licensing entails a tradeoff: licensing payments net of transaction costs (revenue effect) have to be balanced against the lower price-cost margin and/or reduced market share that the increased competition (profit dissipation effect) from the licensee implies. We argue that the presence of multiple technology holders, who compete in the market for technology, changes such tradeoff and triggers a more aggressive licensing behavior. To test our theory we analyze technology licensing by large chemical firms during the period 1986-96. We find that the rate of licensing is initially increasing and then decreasing in the number of potential technology suppliers, negatively related to the licensor's market share and to the degree of product differentiation.

Key words: licensing, revenue effect, profit dissipation effect, chemical industry

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[*] I gratefully acknowledge financial support from the European Commission (HPSE-CT-2002-00146), the Instituto Flores de Lemus and the Spanish Ministry of Science and Technology (SEC2003-03797). I would like to thank Ashish Arora, Thomas Roende, Giovanni Valentini and seminar participants at the 2003 Annual Meeting of the Academy of Management (Seattle), University Pompeu Fabra (Barcelona) and Carnegie Mellon University (Pittsburgh) for comments and suggestions on a previous draft.

[1] Universidad Carlos III de Madrid, Department of Business Administration. C/ Madrid, 126.28903 Getafe (Madrid), Spain. Phone: + 34 91 6249351; Fax: + 34 91 6249607. E-mail: andrea.fosfuri@uc3m.es

1. INTRODUCTION

The last decade of the 20th century has witnessed an unprecedented growth in a variety of arrangements for the exchange of technologies or technological services (Rivette and Kline, 1999; Rigby and Zook, 2002). Certain technology-based sectors, including biopharmaceutics, software, semiconductors and telecommunications, have made the licensing of intellectual property a way of life (Arora, Fosfuri and Gambardella, 2001).

It is not surprising that small technology-based firms license. Lacking the downstream manufacturing and marketing capabilities, they have no other means to appropriate the rents from innovation. More surprising is that large established producers are actively promoting licensing-based strategy. Firms such as Union Carbide, Procter & Gamble, DuPont, Boeing, Hoechst, IBM, Texas Instruments, AT&T, and Phillips Petroleum are now explicitly considering licensing revenues as a part of the overall return from investing in technology (Rivette and Kline, 1999).[1] These firms are well established, have large market shares in the product markets, and are capable of exploiting the technology on their own. Interesting enough, many of such companies have created specific web pages to advertise and sell their technologies (Arora et al., 2001).

This paper examines the licensing strategies of large firms by focusing on some of the determinants of their rate of licensing. In particular, we aim at shedding light on the role played by competition in the market for technology to shape firms' licensing decisions. We argue that firms' rate of licensing can be explained by the interplay of two effects that licensing generates on the licensor's profits: the profit dissipation effect and the revenue effect. Indeed, licensing forces a trade-off: Licensing and royalty revenues net of transaction costs (the revenue effect) have to be balanced against the lower price-cost margin and/or reduced market share that the increased competition (the profit dissipation effect) from the licensee implies (Arora and Fosfuri, 2003). The presence of multiple technology holders, who compete in the market for technology, changes such tradeoff and triggers a more aggressive licensing behavior. We then focus on two other potentially important determinants of firms' rate of licensing: the licensor's market share in the product market, and the degree of product differentiation.

We test our theory on a sample of large chemical firms that possess technological competencies in a set of more than 100 chemical products. We look at their licensing strategies over the period 1986-1996. The chemical industry has a long tradition of technology licensing (Arora, 1997). This allows us to count on reliable data. In addition, as we highlight in the next section, there are often several technologies available from different licensors to produce the same chemical product, which helps us underscore the effect of competition in the market for technology. For instance, there is an established market for polyolefins production processes with about 25 different polyethylene technologies available and eight for polypropylene. Large established chemical producers like Dow Chemicals, BP-Amoco, Exxon-Mobil, Union Carbide, Univation and Basell, along with independent technology suppliers like Novolen and Engelhard, compete face to face in the licensing market (Tullo, 2003).

After controlling for different other sources of variation, our results suggest that firms license more actively their technology when there are competing technologies available in the market, when they have a tiny market share and when the downstream product is relatively homogenous.

This research contributes to several branches of the licensing literature. First, it develops a very simple, but powerful framework to analyze firms' licensing decisions. It goes behind the standard transaction costs theory used in the management literature to explain why licensing is chosen or not for a given transaction (Williamson, 1991; Teece, 1986; Teece, 1988). We follow here an approach that considers the impact of licensing on the whole value chain of the licensor rather than narrowly focusing on economizing on each single transaction. Needless to say that

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[1] The exact magnitude of the phenomenon is difficult to assess. Anecdotal evidence suggests that it already involves large sums of money. Both Dow Chemicals and DuPont, two firms with a long tradition of exploiting their technology in-house, are expected to have licensing revenues above $100 million per year. In 1998 IBM patent licensing revenues accounted for 10% of IBM's net profits. Union Carbide is reported to earn more than $300 million from its polyolefin licensing in a single year (Arora et al., 2001).

transaction costs considerations are still important in shaping firms' licensing strategy. Hence, our approach complements rather than substitutes the extant transaction costs theory.

Second, this paper adds to the economic literature that has investigated several strategic rationales behind firms' licensing decisions. For instance, licensing can be used strategically to control competition and limit entry. Gallini (1984) has argued that an incumbent firm may license its production technology to reduce the incentive of a potential entrant to develop its own, possibly better, technology. Alternatively, the incumbent firm might license a weak rival to crowd the market and deter entry by a stronger competitor (Rockett, 1990). Licensing can also be used to make performance or price commitments that otherwise would not be credible (Farrell and Gallini, 1988). In this paper we show that an important and yet little understood determinant of licensing is competition in the market for technology. This also suggests that the standard assumption made in the economic literature of a monopolist technology holder might sometimes be implausible.

Third, and most important, this work contributes to the relatively underdeveloped empirical research on licensing. This lacuna is understandable. In many industries licensing is a very recent phenomenon, so available data are scattered. In addition, firms tend to conceal information about licensing deals, which is typically considered strategic and not publicly disclosed.

Anand and Khanna (2000) provide one of the few econometric investigations of the rate of licensing. Their study is however aggregated at the level of the sector, and they do not attempt to explain inter-firm differences in the rate of licensing. Kim and Vonortas (2003), using a similar theoretical approach, investigate firms' characteristics that explain the probability that two companies engage in a licensing agreement. They do not look however at the interaction between licensing decisions and competition in the market for technology which is crucial in this paper. Recently, several scholars have directed their attention to the analysis of licensing practices by universities (Mowery and Shane, 2002). For, instance Sine, Shane and Di Gregorio (2003) have shown that the rate of licensing by universities is an increasing function of their prestige. However, university licensing decisions are much different from those made by large firms, if anything because universities do not have stakes in the product market.

Other empirical research on technology transfer has focused on the factors that determine the choices firms make between various organizational forms (e.g. Teece, 1986; Hill, 1992). For instance, Gans, Hsu and Stern (2002) study the determinants of commercialization strategy for start-up innovators. Within this tradition, the empirical literature has especially looked at the entry choice in foreign markets (e.g. Kogut and Singh, 1988; Hill, Hwang, and Kim, 1990). None of these studies looked at the factors underpinning firms' rate of licensing.

The rest of the paper is organized as follows. The next section briefly discusses licensing dynamics in three chemical products and motivates our interest in the role played by competition in the market for technology. Section 3 develops our theoretical framework to explain firms' rate of licensing and formulates some testable hypotheses. Section 4 describes the empirical methodology and our data. Section 5 discusses the results, whereas section 6 concludes the paper.

2. TECHNOLOGY LICENSING IN THE CHEMICAL INDUSTRY

Technology licensing in the chemical industry has a very long tradition. Cross-licensing agreements were already used at the beginning of the 20th century as a means to maintain market shares and deter entry in an international chemical market characterized by the presence of strong cartels (see, e.g., Spitz, 1988). It is, however, only after world war II that firms started to use licensing as a means to profit from innovation and a market for chemical technology begun to arise. Indeed, starting from the 1950s an increasing number of chemical processes became available for license (Arora, 1997). In this section, we briefly describe licensing dynamics in three chemical markets.[2] We aim to highlight the role played by competition in the technology market in shaping firms' licensing strategies.

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[2] These three short case studies have been constructed using information assembled from a variety of sources, most notably specialized chemical journals, business press, and the Internet.

Acrylic acid. Acrylic acid is one of the most widespread chemical compounds, key input of many products we use in our everyday life.[3] Acrylic acid was first prepared in 1843, however it was not produced commercially until the late 1920s, and only in the early 1950s started to have a major use. Several processes – acetylene-based, acrylonitrile hydrolysis, ketene process, ethylene cyanohydrin process, have been employed to produce acrylic acid before the actually standard technology, based on propylene oxidation, was developed by the Japanese chemical firm Nippon Shokubai in the 70s. Till the mid 80s Nippon Shokubai licensed its technology, which was also available through another Japanese firm, Mitsubishi Chemicals. Other technology holders, like the German giant BASF, were much more restrictive in offering their technology to potential licensees. Recently, as all the potential licensors are also producers and have strong interest in maintaining market stability, the attitude toward licensing even of the early licensors, Nippon Shokubai and Mitsubishi Chemicals, has become very conservative. A kind of tacit collusion in the market for technology seems to be in place nowadays. Firms avoid direct competition in the licensing business, which is likely to be destructive for all players. Most of the licensing is directed to markets with strong growth potential that could not be reached otherwise. Although pressure towards an aggressive licensing behavior exists because of the potential competition in the market for technology, all licensors are also big producers that hold symmetric stakes in the acrylic acid market and that would suffer almost equally the consequences of a licensing war.

Ethylene glycol. Ethylene glycol is a clear, colorless, odorless, viscous liquid with a sweet taste, that can produce dramatic toxicity. It is found most commonly in antifreeze, automotive cooling systems, and hydraulic brake fluids. In an industrial setting it is used as a solvent or as the raw material for a variety of processes.

Ethylene glycol was first prepared in 1856, but it is only around the 1920s that the American firm Union Carbide started its commercial production. The currently dominant technology for producing ethylene

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[3] Approximately two thirds of the acrylic acid manufactured in the US is used to produce acrylic esters that, when polymerized, are ingredients in paints, coatings, textiles, adhesives, plastics, and many other applications. The remaining one third of the acrylic acid is used to produce polyacrylic acid, or cross-

oxide through the direct oxidation of ethylene was developed by a French firm at the beginning of the 1930s and subsequently perfected by Union Carbide. At the end of the 1940s other two companies developed alternative technologies for the production of ethylene glycol based on the oxidation of ethylene, the engineering firm Scientific Design and the chemical giant Shell. Other firms like Dow Chemicals and DuPont used different technologies that have been later abandoned either because economically unviable or because of environmental concerns.

Union Carbide, which is the largest producer in the world used its own process captively and did not license it out. Scientific Design, who did not have a stake in the final market for ethylene glycol, licensed its process aggressively, and have now the largest share of built capacity. The other major player, Shell, both used and licensed its own process. Recently, Union Carbide too has started to license its technology although very selectively. It is important to emphasize here the role played by a firm, source of the technology, but not an active producer of the final product. Scientific Design was not inhibited in its licensing efforts by concerns over its production position and potential competition from new players. This has sparked a more proactive licensing behavior by the other two major players that would have been otherwise much more concerned about the potential threat created to their market shares. As a consequence, the industry structure of the ethylene glycol market is highly fragmented with many players and strong competition in any region of the world.

Metallocene. Metallocenes (more accurately, “single site catalysts”) are a new type of catalyst system for polymers that provide much greater control over molecular size and architecture than previously possible. Hence, the physical properties of the plastic can be tailored more finely. Key applications for metallocene-based polymers include pharmaceutical and medical packaging, capacitor films, flexible food packaging, optical parts and lenses, and toner binder resins.

The technology is still new and diffusing. Metallocene technology has been commercialized in polyethylene, but it is still in its early stages in polypropylene. Integrating the new catalyst with an

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linked polyacrylic acid compounds, which have been successfully used in the manufacture of hygienic products, detergents, and waste water treatment chemicals.

established process technology has been a major technical challenge in the development of the technology. Demand for global polyethylene in the year 2010 is estimated to be about 83 million tons, of which metallocenes represent about 17 million tons, or about 20%.

Dow Chemicals and Exxon, the leaders in metallocene technology for polyethylene, are also leading producers of polyethylene. Both are also leading technology suppliers, licensing their technology on a worldwide basis in cooperation with other prominent firms (BP Chemicals and Union Carbide, respectively) who possess important complementary technologies, notably gas phase process technology for polyethylene.[4]

Beside these two main groups, other firms are also very active in the market for polymers and have invested heavily to develop their own metallocene technology. Although still followers, companies like BASF, Hoechst, Mitsui Toatsu, Fina, Nova and DuPont are reported to have already announced their intention to pursue an active licensing strategy as soon as they will perfect their technology. A strong licensing war seems to be the most likely scenario in the market of metallocene catalysts, where there are at least half a dozen potential sources of the technology.

3. THEORY DEVELOPMENT AND HYPOTHESES

A licensing contract is the less integrated, more market-based alternative available to firms for profiting from their innovation. Indeed, licensing positions itself at the extreme of a continuum of governance structures ranging from a market mechanism to hierarchy, i.e. in-house exploitation of the innovation (Williamson, 1991).

The standard framework to analyze licensing decisions is provided by the transaction costs theory. This approach suggests that, absent significant contracting hazards, an arm’s length contract such as licensing

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[4] In 1997, Exxon and Union Carbide created the joint-venture, Univation Technologies, with the aim to license polyethylene process technology. Exxon provided its Exxpol metallocene catalyst technology and Union Carbide provided its Unipol single reactor gas phase technology and expertise in the technology licensing business. Dow negotiated a joint development with BP shortly before the creation of Univation. Dow provided its metallocene catalyst technology (Insite system), whereas BP offered its gas phase technology as well as its licensing expertise.

would be the most direct way to capture the profit from the intellectual asset (such as a process or an idea) a firm holds. However, writing and executing a reliable contract for the use of technology requires adequate specification of property rights, monitoring and enforcement of contractual terms – any of which may be problematic. Teece (1988) identifies three major sources of transaction costs in technology transfer. First, it is hard to provide detailed specifications about the characteristics of the technology at the beginning of the transaction, implying that contracts are largely incomplete and potentially leave either party open to opportunistic behavior by the other. Second, most of the times the transfer of technology forces the licensee to develop tight interactions with the technology supplier. The interplay of relationships may generate sunk costs, which can give rise to switching costs and "lock-in" problems. Finally, releasing pre-contract information to potential buyers may require the company to share valuable proprietary information, and increases the risk that competitors will discover its R&D plans (see, also, Oxley, 1997). Indeed, Gans et al. (2002) find that start-ups prefer market-based means for profiting from innovation when there are mechanisms that help reduce transaction costs.[5]

One of the weaknesses of the transaction costs theory in analyzing licensing decisions is its narrow focus around isolated transactions (Williamson, 1999: page 1102). Each transaction is treated as an independent item, bearing almost no relationship with previous or future transactions, and with the rest of the firm's activity (Argyres and Liebeskind, 1999; Nickerson, Hamilton and Wada, 2001). If interaction effects are missed or if holistic consequences are glossed over, transaction costs theory would suggest that licensing is chosen when the transaction costs of using a market-based mechanism for profiting from innovation are sufficiently small (Teece, 1988). However, a licensing agreement might not take place, in spite of very low transaction costs, if it does not fit within the firm's overall strategy. In other words, although the transaction is per se profitable, it might have negative effects on other sources of rents that outweigh the net profits from the transaction. To sharp this argument further, consider the following

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[5] A related, but different, impediment to market-based exploitation of technological competencies is due to the nature of technological knowledge (Cohen and Levinthal, 1990; Kogut and Zander, 1992). Applying knowledge or technology developed in a specific context for a specific use, to another context and use, is rarely simple or straightforward (von Hippel, 1994).

simple example: a monopolist in a given product market has got the option to license out its technology (likely the source of its competitive advantage) to one or more potential licensees. Even in a Coasian world with zero transaction costs, the firm would not typically find a licensing agreement overall profitable. Indeed, the presence of another producer (the licensee) in the market would certainly put some pressure on the price that will fall below the monopoly level. Unless other reasons are brought in, the firm would never be able to earn greater profits under licensing than under no licensing, regardless the actual level of transaction costs. Per se the transaction might be well profitable, but striking the deal would imply less profits in other parts of the value chain. It is the net balance that matters for deciding whether to license or not. This argument suggests that, rather than focusing on economizing at the level of single transactions, it is advisable to consider the effects of technology licensing on the whole value chain (i.e. economizing at the level of the firm): technology management cannot be performed in isolation from other value creating activities, such as production or distribution.

REVENUE EFFECT VERSUS PROFIT DISSIPATION EFFECT

We develop here a framework that accounts for these subtleties, and will allow us to explain firms' rate of licensing. Our approach does not substitute the extant transaction costs theory, but rather complement it. Indeed, we still argue that, other things held constant, smaller transaction costs stimulate licensing. Following Arora and Fosfuri (2003), we posit that licensing decisions are the result of the interplay of two effects that licensing generates on the licensor's profits: the profit dissipation effect and the revenue effect. The revenue effect is nothing but the present value of the flows of rents accruing to the licensor in the form of licensing payments net of all possible transaction costs that bear on the seller of the technology. Hence, if BP licenses its Innovene Gas Phase polyethylene process technology to Mitsui for an upfront installment of \$50 million and an annual royalty fee estimated around \$15 million/year, absent any transaction costs, the revenue effect amounts to \$$(50+\sum_{t=1}^{T}\frac{15}{(1+r)^t})$ million, where r is the interest rate and T is the (expected) length of the licensing contract. It is the revenue effect that firms look for when they strike a licensing deal. Indeed, in the words of Dow's vice-president*"...by both licensing and using the technology we could generate more cash..."*. The revenue effect is positively related to the (gross) profits the licensee can extract from the licensed technology, is negatively related to the amount of transaction costs and positively related to the bargaining power of the licensor. Hence, as predicted by the transaction costs theory, other things held constant, larger transaction costs imply a smaller revenue effect and, in turn, make licensing a less attractive strategy (Teece, 1986). Needless to say that the (gross) profits earned by the licensee, transaction costs, and the bargaining power are function of other variables. For instance, the licensor's bargaining power increases with the strength of intellectual property rights protection and with the number of suitable licensees.

The profit dissipation effect is the reduction in the licensor's profits (i.e. all other profits, but the payments from the licensing agreement) that might occur as a consequence of an additional firm competing in the product market. Additional competition in the downstream market can both reduce the price-cost margin and erode market share. As a result, a licensor, who also competes in the product market, might encounter a reduction in the profits it collects from directly producing and commercializing the final good. Although the licensor has many different strategies to limit the extent of this latter effect (for instance, the contract might impose quantity restrictions or exclusive territories, or unit royalties might be set such as to control the licensee's output), an entrant is nevertheless a potential threat to the licensor. To make the argument clearer, consider the simple example discussed above. Assume that BP is a major player in the European market for polyethylene with $1 billon net present value profits. By licensing its Innovene process technology to Mitsui, BP allows the entry of a new competitor in the European market (assume, for simplicity, that Mitsui would not enter the European market without a license from BP). Additional competition trims BP net present value profits in the European market for polyethylene to $900 million. Hence, the profit dissipation effect of licensing amounts to $100 million. The profit dissipation effect depends on several factors: primarily among them, the magnitude of the competitive pressure exerted by a new player in the downstream market.

The danger of increased competition in the licensor's own market is echoed by industry players and often reported as the main reason for not licensing out. *"...For our main chemical products, such as epoxy and polyketones, we just don't want to license them out because it would threaten our market"* (a Shell's spokesperson).

It is the careful comparison between the profit dissipation effect and the revenue effect that explains whether a firm is licensing or not, and, if it does, how much it is licensing.

THE ROLE OF COMPETITION IN THE MARKET FOR TECHNOLOGY

To begin with let us consider a situation in which the profit dissipation effect dominates the revenue effect. As we discussed above this is typically the case of a monopolist in the product market. Absent any threat in the market for technology (i.e. absent any other source for the technology) the firm would optimally decide not to license. We are implicitly assuming here that the demand for the final product is stable and that the incumbent monopolist has already made the necessary investment to satisfy such demand. Now suppose that another firm has got the technology to produce the final product and can potentially license it to an entrant. For the sake of simplicity, assume that this potential licensor cannot produce the product itself. For instance, in the chemical industry, many process technologies are licensed by specialized engineering firms, known as SEFs, that do not have any stake in the product market and focus their business model around the design, engineering, licensing and, sometimes, construction of chemical plants (Arora et al., 2001). Now assume that a potential entrant exists, one who needs a license to enter the market. What is the most plausible scenario if the monopolist does not license its technology? The potential entrant might strike a deal with the other technology owner and ultimately start to compete with the monopolist in the product market. As a result the monopolist might suffer of both eroded market share and reduced price-cost margin. Moreover it does not collect any licensing payments since it has opted for not licensing its technology. Although this is an oversimplified example, it makes clear the point that the presence of competing technologies generates additional incentives to license. The monopolist would have suffered in any case from the profit dissipation effect, but at least it would have benefited from the revenue effect, had it licensed out its technology to the potential entrant.

When there exists a market for technology, as is typically the case for most chemical process technologies, a refusal to license by a technology holder will not blockade entry in the product market since the prospective licensee can obtain the technology from other potential licensors. Hence, the presence of multiple sources for a technology creates a strategic incentive to license.[6] However, we do not expect the relationship between the rate of licensing and the number of potential technology suppliers to be everywhere monotonic. There are at least two arguments that suggest that after a certain threshold the rate of licensing might actually decrease in the number of potential technology suppliers. First, the number of potential licensees for a given process technology is bounded. Indeed, in some cases, the search for suitable licensees turns out to be a long and costly process (Contractor, 1981). If the number of potential licensees is fixed (and bounded) and the number of potential licensors keeps increasing, then at a certain point the number of effective licenses per licensor will hit the constraint. After that, a further increase in the number of licensors produces a reduction in the average number of licenses. Second, a larger number of technology suppliers means stronger competition in the market for technology. Licensors have weaker bargaining power vis-à-vis the prospective licensees. In other words, the revenue effect tends to be competed away when the number of licensors increases. Putting together the different arguments we can formulate the following hypothesis:

HYPOTHESIS 1: *There exists an inverted-U shaped relationship between the rate of licensing and the number of potential technology suppliers.*

MARKET SHARE

To underscore the role of market share in conditioning licensing decisions let us assume that the revenue effect is independent of market share, and focus exclusively on the impact of market share on the profit dissipation effect.[7] As noted before, the profit dissipation effect is the erosion of profits due to additional competition in the product market. Hence, we claimed that a technology holder licenses if the net licensing revenues are greater than the loss in profits due to increased competition in the product market. Although all incumbent producers potentially lose from the increased competition, each licensor only internalizes the negative effect on its own profits. This negative effect is smaller, the smaller the profits the licensor obtains from direct production prior to licensing. In turn, this implies that, other things equal, firms with smaller market shares have stronger incentives to license since they suffer from a much smaller profit dissipation effect. A simple way to understand this argument is by fixing the quantity produced by each firm and assuming that entry simply reduces the price-cost margin. Firms that sell larger quantities, i.e. firms with larger market shares, would suffer the most from competition since the same reduction in the margin is multiplied by a higher volume of sales. Firms that center their business model on the pure supply of technology with no stakes in the product market, have therefore stronger incentives to license than established producers that enjoy large market shares. We can therefore state the following hypothesis:

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[6] Cesaroni (2003) has studied in details technology licensing by Himont, the joint-venture created in 1983 between the Italian Montedison and the American Hercules. In the view of Himont's management, the possibility of creating additional competitors in the polypropylene market, from where the firm was collecting the largest share of its turnover, was perceived as a clear threat. However, one of the determinants of its decision to become a worldwide licensor of its Spheripol process was the presence of other potential licensors – such as Union Carbide, Shell and BASF – for polypropylene technology. Himont's management estimated that its refusal to license would have not prevented entry of additional competitors, and would have simply reduced the firm's possibility to capture additional value from its R&D investments.

HYPOTHESIS 2: *The higher the licensor's share in the product market, the smaller its rate of licensing.*

This argument is exemplified by the different ways in which BP Chemicals has approached the acetic acid and polyethylene businesses. In acetic acid, BP has strong proprietary technology and a substantial market share. It licenses very selectively, typically only granting a license to get access to markets it would otherwise be unable to enter. In polyethylene, by contrast, BP's market share is small. Although it has good proprietary technology in polyethylene as well, there are many other sources of technology for making polyethylene. Thus, BP has licensed its polyethylene technology aggressively, competing with Union Carbide, the market leader in licensing polyethylene technology.

PRODUCT DIFFERENTIATION

The role of product differentiation is also better understood by focusing on the profit dissipation effect alone. Let us do the following thought experiment. Consider the market for polyethylene and assume that Mitsui, with its own proprietary technology, competes in the downstream market with several other producers. Assume that Mitsui has a 2% market share. Let us start with the case in which the final product, polyethylene, is perfectly homogenous across all producers. Mitsui is a small player and, as we argued above, would not suffer too much of a loss if an additional firm steps in and starts producing polyethylene. Hence, the profit dissipation effect for Mitsui is rather small and might well be smaller than the revenue effect. Mitsui might have strong incentives to license. Indeed, even if Mitsui has got a good proprietary technology, it might be difficult for the firm to gain a larger share of the polyethylene market. Licensing is a quick and rather riskless alternative for accomplishing this task. Now, consider the opposite

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[7] The relationship between market share and the revenue effect is ambiguous a priori. Bigger players, with larger market shares, might enjoy stronger bargaining power in licensing negotiations. However, prospective licensees might be reluctant to buy the technology from a large well established competitor. Indeed, the presence of a large competitor might reduce the licensees' expectations of future profits and, hence, their willingness to pay for the technology. However, we believe that these are second order effects that can be safely ignored.

situation in which each producer has a well-defined market niche. In other words, the polyethylene market is highly differentiated and each firm is producing its own no easily substitutable variety. Although Mitsui is a small player in the overall polyethylene market, it is almost a monopolist in its niche. Licensing would create much stronger competition now, since Mitsui would allow the entry of another firm producing exactly the same variety. In this case the profit dissipation effect is much larger and the firm might not find profitable to license. In addition, other technology suppliers are less of a threat since, even if they license, they would not allow direct entry into Mitsui's own market niche. An implicit assumption of this argument is that Mitsui's technology would produce indistinguishable varieties of polyethylene if exploited by other firms (licensees). So, product differentiation is due to differences in the process technology rather than to simple branding. This in turn fits quite well with most chemical products in our database – like ammonia, acetic acid, polypropylene – where the major source of differentiation is due to the technology (type of catalyst, temperature, feedstock, etc.) rather than the firm. This leads to the following hypothesis:

HYPOTHESIS 3: *The higher the degree of product differentiation, the smaller the firm's rate of licensing.*

4. METHODOLOGY AND DATA

We hypothesize that the rate of licensing is generated by the following function $y=f(x,\beta)$ where y is licensing counts, x is a vector of explanatory variables that includes the ones identified in our hypotheses above (plus all available control variables), and β is a vector of parameters to be estimated. Since the dependent variable is discrete, non-negative, with numerous zero entries, conventional linear regression models are, thus, inappropriate. The simplest model form to accommodate count data is the Poisson Regression Model. To guarantee non-negativity of λ, we model the single parameter of the Poisson distribution function, λ, as $E[y] = \lambda = \exp(x\beta)$. We estimate our parameters by maximum likelihood (Hausman, Hall, and Griliches, 1984).

The assumption that the dependent variable is distributed Poisson is quite strong. It implies that the mean of the distribution is equal to its variance. If such property is violated, although the parameters will be consistently estimated, their standard errors will typically be underestimated, leading to spuriously high levels of significance. Empirically, it is not uncommon to find that the conditional variance is larger than the conditional mean, implying over dispersion. For instance, this might be caused by the presence of unobserved heterogeneity. To address this problem we use a negative binomial regression, which provides more efficient estimators (Hausman et al., 1984).

Another econometric concern is the large number of zero observations (about 80%). These zero observations stand for cases in which a firm, that could potentially license its technology, has decided not to do it. This implies that we should be concerned about the censored distribution of the dependent variable. As a robustness check we estimate an equation using a Tobit regression. A brief discussion of an alternative, more sophisticated methodology is also provided.

Our data on licensing come from Chemintell (1997), a commercial data base compiled by Chemical Intelligence Services (Chem-Intell), a division of Reed Telepublishing Ltd, a member of the Reed Elsevier Plc Group.[8] Chemintell provides information on over 36,000 plants announced or constructed all over the world in the broadly defined chemical sector during 1980-1996. Although incomplete, it also reports information on plants built prior to 1980. The database is organized by plants. It reports the name of the company that ordered the plant, the name of the licensor for that plant (or 'staff' for in-house licensing), the location of the plant (city and country), the name of the chemical process or of the product being produced, the date in which the investment was first reported in the specialized trade press, along with other information. For about 40% of the plants, Chemintell also reports the total cost of investment in the plant in US million dollars, and for a larger share of the plants it shows the actual or planned capacity.

To test our hypotheses, we will focus on a sample of large chemical firms. These firms are all chemical firms from developed countries (Western Europe, USA and Canada, and Japan) that had, by the year 1988, more than $1 billion in aggregate sales (Aftalion, 1991). Of this set of firms only 153 had at least one plant scored in Chemintell. These are the firms we used in our study. By nationality, we have 67 US firms, 1 Canadian firm, 32 Japanese and 53 European firms. (The whole list of firms is available upon request.) We restricted our attention to this sample of large firms because we had to collect firm-specific variables that our database did not provide. Moreover, the focus of this paper is on the licensing strategies of large corporations, which more strongly face the tradeoff between revenue effect and profit dissipation effect. Therefore, the licensing activity of specialized technology suppliers, small firms and start-ups is left out from our study.

Among all possible chemical products in our database (about 3,000) we have selected a sample of 139 products for which we could reasonably collect additional information (notably, patents). This sample includes all the most important products in our data set (in terms of worldwide investment) and accounts for more than half of all plants in Chemintell. For instance, "ammonia" and "acetic acid" are two examples of such products. A full list of products along with their classification in chemical sub-sectors is available upon request.

As a first step we need to identify the firms that possess technological capabilities in a given product, and that can therefore license to others. Then, we look at the licensing behavior of these firms. Obviously, these firms change across different products. The set of potential licensors of ammonia process

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[8] Full access to the Chemintell database was bought in November 1997 with financial support of the European Union through the TSER Programme Contract SOE1-CT97-1059. Chem-Intell maintains the database by regularly monitoring a comprehensive range of publications worldwide in most European languages.

technology is different from the set of potential licensors of acetic acid process technology, although the two sets might overlap.

To address this issue we exploited the richness of our data set. We split the data in two time periods: 1980-85 and 1986-1996. We used the first time period to identify which of our 153 firms possessed technological capabilities in any of our 139 products. As a criterion we used the fact that the firm in question had either licensed the technology or built in-house a plant using its own technology. As a sensitive check we have also considered a different time break: 1980-87 and 1988-96. We have also experimented with a more demanding criterion: two plants instead of just one. Qualitative results do not change. For some products we have identified no potential licensors, so we have dropped them from our sample (about 20%). For other we have identified a fairly large group of potential licensors, confirming that the threat of competition in the market for technology is a real one in the chemical industry. It is important to remind the reader that we are looking at the licensors for the process technology used to fabricate a given chemical product. Finally, we used our second time period to look at the licensing behavior of these potential licensors.

Since our data set covers investment in chemical plants worldwide we have divided the world in seven geographical areas: Africa, Western Europe, Eastern Europe, North America, South America, Middle East and South East Asia. It is quite clear that licensing in France would create a much stronger competitive pressure in Western Europe than in North America or South East Asia. A firm with a large stake in the downstream market in North America, but a smaller one in Western Europe would suffer from a larger profit dissipation effect if it licenses in the former geographical area rather than in the latter. To summarize, we will look at the rate of licensing of large chemical firms (indexed by i), in a set of product markets that are defined around chemical products (indexed by j) and geographical areas (indexed by k).

VARIABLES

Rate of licensing. The number of licensed plants by firm i, in product j, and geographical area k. The count is done over the period 1986-1996. As discussed above only a small subset of our 153 firms have technological competencies in any given product j. Moreover this subset tends to change for each product.

Potential licensors. We want to capture the presence of other sources of technological competencies. In other words, we would like to know how many other firms are capable to supply the process for producing product j. We do so by counting the number of firms (excluding firm i) that have licensed a given process technology for producing product j in the period 1980-1985. This is a good proxy for the number of potential licensors of that technology in the period 1986-1996. It is plausible that this measure varies across geographical areas. The set of potential technology suppliers for polyethylene process technology in North America might differ from the set of potential technology suppliers in South East Asia. For instance, there might exist geographic idiosyncrasies that make a technology suitable for the economic, legal and environmental conditions of one area, but unsuitable for another. We have estimated our regressions with the number of potential licensors varying both across j and across jk (although, to save space, we only show the latter). Qualitative results do not change.

Market share. We compute the market share of firm i, in product j and geographical area k as the ratio between the capacity built by firm i in jk and the total capacity in jk. Unfortunately, Chemintell is silent about the extent of capacity utilization.

Product differentiation. Chemintell does not provide any direct measure of product differentiation at the level of the product j. To operationalize this variable we use three different proxies. The first one is a measure of product differentiation computed at the sub-sector level. Chemintell classifies all products in 23 sub-sectors. Hence, our first measure of product differentiation only varies across these 23 sub-sectors. We use plant counts at the product level to compute an equidistribution index at the sub-sector level (Sutton, 1991). Our index of product differentiation takes the value of 0 if the sub-sector has homogenous products and the value of 100 if the products are totally differentiated. Our second measure of product differentiation is computed at the product level by using patents accounts. We counted the total number of patents reported for a given product (for instance, polyethylene) at the US Patent Office during the 1976-1995 period. This number includes all patents concerning different uses, product and end-use applications, multiple inputs, and components for any given product j. It is both a measure of the technological complexity of a given product j and of the extent of potential applications and uses. This is our second proxy for product differentiation. The larger is this number the more differentiated is the product. Our third proxy of product differentiation is the average cost in US dollars per unit of capacity installed in each product j. We expect that more homogeneous and basic products are produced in large scale plants whose cost per unit of capacity installed is lower. By contrast, more differentiated and sophisticated products are produced in small size plants and tend to have, on average, a larger cost per unit of capacity installed. Hence, the higher the cost per unit of capacity installed the more differentiated is the product.

CONTROL VARIABLES

Demand growth. This variable measures the growth potential in the demand for chemical plants in product j and geographical area k. We use the ratio between the total number of plants constructed in technology j and geographical area k during the period 1986-1991 and the period 1980-1985. We expect to observe a positive relationship between the rate of licensing and demand growth since a rising demand relaxes the negative effect on the licensor's profits due to increased competition.

Potential licensees. The larger the number of potential licensees, the stronger the bargaining power of the licensor and, hence, the larger the revenue effect from licensing. Indeed, Contractor (1981) points out that, in some cases, the search for suitable licensees turns out to be a long and costly process. Hence, we posit a positive relationship between the rate of licensing and the number of potential licensees. The number of potential licensees is computed as the number of downstream chemical producers active in product j and geographical market k.

Aggregate sales. We include this variable to control for the effect of firm size on the rate of licensing. For instance, larger firms might have stronger bargaining power in the licensing negotiations or they might have better options to profit from their technological competences. We use the aggregate sales of firm i in 1988 (Aftalion, 1991).

R&D. For each firm i, R&D captures total R&D expenditures in 1988 (Aftalion, 1991). The sign of this variable is not theoretically clear a priori. Higher R&D intensity means that the firm is more likely to possess valuable technological assets to license out. On the other hand, firms tend to avoid giving away their state-of-the-art technology and typically prefer to license older vintage technologies. However, the reason for including this variable, as well as aggregate sales, is to control for firm-specific sources of variation that might affect the rate of licensing.

Japanese. A dummy variable that takes the value of 1 if the licensor is a Japanese firm. Japanese firms have a long tradition of being quite skeptical about licensing out their technology.

American. A dummy variable that takes the value of 1 if the licensor is an American firm. American firms have been traditionally active licensors of technology.

Core competence. For each firm i, this variable measures the amount of the investment in product j relative to the firm's overall investment. It is a proxy for how relevant or core is product j for firm i. We want to see if firms tend to license core or peripheral technologies.

Experience. This is a dummy variable that takes the value of 1 if firm i has already experience in technology licensing in product j and geographical area k. Experience in gathering information about prospective licensees, negotiating, writing contracts and enforcing them lowers the cost of licensing. Experience is therefore a good proxy for the transaction costs of licensing. We posit that experience, by reducing transaction costs, makes licensing a more appealing strategy.

Dummy variables for geographical areas. This set of dummy variables is meant to control for sources of heterogeneity across locations. For instance, some areas might have better conditions for technology licensing like stronger intellectual property rights or better access to related technological services that make easier the transaction.

Table 1 reports the means, standard deviations, and correlations between the dependent, independent, and control variables.

[TABLE 1 ABOUT HERE]

5. RESULTS

Table 2 shows the results of our estimations. Our preferred model is the Negative Binomial estimation, but, as one can see, the sign of the parameters is stable across all different regressions. The only difference between Model 1, Model 2 and Model 3 is that in the first we use our proxy of product differentiation computed at the sub-sector level, in the second we use our proxy of product differentiation based on patents accounts and in the third we use our proxy of product differentiation based on the average cost per unit of capacity installed.

The number of observations is 1754. Hypothesis 1 predicts that the rate of licensing is first increasing and then decreasing in the number of potential technology suppliers. To test this hypothesis we add a square term to the number of potential licensors. If our hypothesis is correct, then one should obtain a positive coefficient for the number of potential licensor and a negative coefficient for the square term. The parameter estimate for the number of potential licensors is positive and highly significant in all specifications reported in Table 2. We also find a negative and significant coefficient for the square term, suggesting that the relationship between the rate of licensing and the number of technology suppliers displays an inverted-U shape. For instance, by using Model 1 of the Negative Binomial estimation one can show that the inflection point is around 6 (notice that the number of potential licensors varies between 0 and 17 with an average of about 3). If all other variables are kept at their mean value, a standard deviation increase in the number of potential licensors would imply an increment in the rate of licensing of about 13%. Figure 1 shows the predicted rate of licensing as a function of the number of potential licensors.

Hypothesis 2 predicts that firms license more in product markets where they have smaller market shares. Indeed, as we argued above, the profit dissipation effect is positively correlated to market share. The sign of the parameter estimate for market share is negative in all regressions and highly significant. If all other variables are kept at their mean value, a standard deviation increase in market share would reduce the rate of licensing by more than 40%.

As an additional extension of our theory, one can conjecture that the importance of market share might depend on the presence of other potential licensors. Indeed, even if a firm with a large market share decides not to license in order to restrict entry, its effort would not produce the desired result if the prospective investors/licensees can resort to other providers for the technology. So, the impact of market share on the rate of licensing might depend on the existence or not of a well-established market for that given technology. For instance, BP, one of the major producer and licensor of polyethylene, had initially tried not to license its polyethylene technology in Western Europe, where it had a substantial share of polyethylene capacity. However, other licensors continued to supply technology to firms that wished to produce polyethylene in Western Europe, with the result that BP found it was losing potential licensing revenues without any benefits in the form of restraining entry. As a response, the firm started to actively license its technology to potential entrants. We have explored this possibility by separating the effect of market share between the case in which there were no other potential licensors and the case in which there were alternative sources for the technology. As expected the coefficient of market share is larger in the former case than in the latter, but the difference is not statistically significant. Results of these regressions are reported in Table 3. We have also experimented with an interaction term between the number of potential licensors and market share. Although the coefficient of the interaction term had a positive sign it was not statistically significant.

Hypothesis 3 suggests that firms show a higher rate of licensing when the product market is sufficiently homogenous. We used three different proxies to capture the degree of product differentiation. All are consistently negative in our estimations suggesting that licensing is less likely to occur in differentiated product market. These findings seem to support Hypothesis 3. Keeping all other variables at their mean value, a standard deviation increase in the degree of product differentiation would reduce the rate of licensing by between 35% and 48% (depending on the proxy we use).

The signs of the other variables are reasonable. Particularly interesting is the positive and highly significant coefficient of the number of potential licensees in a given product market jk. A larger number of licensees means greater bargaining power for the licensor. It also means that it is much more likely to find a licensee who better suits the idiosyncrasies of the licensor's technology. In turn, this implies that the value generated from the transaction is higher making licensing a more appealing option. Concerning transaction costs, the findings seem to support the idea that higher transaction costs reduce the rate of licensing. Indeed, our dummy for experience in licensing in product j and geographical area k is positive and highly significant. Demand growth has the positive expected sign, significant in all regressions. Our measure of firm size is positive, whereas R&D is negative, implying that larger firms with less R&D intensity have a higher rate of licensing. Japanese firms and American firms are respectively less and more active licensors than their European counterparts, although these findings are not statistically significant. Finally, firms tend to license more technologies that are core to their overall product portfolio. It is less likely that they license peripheral or orphan technologies.

As we discussed in the previous section, one important econometric concern is the presence of a large number of zeros in our dependent variable (about 80%). We have controlled for this potential problem through a Tobit specification. An alternative, more sophisticated methodology is a zero-inflated negative binomial regression (Greene, 2000). A zero-inflated negative binomial model, also known as hurdle model, assumes that the zeros are generated by a different process than the remaining counts. A binary probability model determines whether a zero or a nonzero outcome occurs, then, in the latter case, a (truncated) negative binomial distribution describes the positive outcomes. All our explanatory variables have been used in the regression. Results, available from the author upon request, remain qualitatively unchanged. A positive Vuong test shows that the inflated model performs slightly better than the standard negative binomial model.

[TABLE 2 AND 3 ABOUT HERE]

6. CONCLUSION, DISCUSSION AND IMPLICATIONS

There is increasing evidence that firms in some sectors are looking to profit from their intellectual property not just by embodying it in their own output but also by licensing their intellectual property to others, including potential competitors. Licensing does, however, entail a trade-off: licensing revenues have to be balanced against the lower price-cost margin and/or reduced market share that the increased competition from the licensees implies. In this paper we argued that competition in the market for technology might trigger a more aggressive behavior by potential licensors. The tradeoff between profit dissipation effect and revenue effect that normally guides licensing decisions should be adjusted for the presence of rival licensors. In particular, when there are multiple technology holders, not only do they compete in the product market, they also compete in the market for technology. Since licensing partially substitutes for production, firms lacking adequate downstream commercialization (production and marketing) capabilities are naturally more aggressive licensors. Moreover, we have argued that increasing product differentiation not only softens price competition in the product market, it also reduces the rate of licensing in the technology market.

We tested this framework using an extensive dataset on worldwide investment in chemical plants. We looked at licensing strategies by a sample of large chemical producers in more than 100 products. Our results suggest that the presence of a market for technology plays a crucial role in creating incentives for a more proactive licensing behavior. Firms, that normally would have not licensed their intellectual property, might be forced to do so, because of the competitive pressure in the market for technology.

Two contributions are particularly worth emphasizing here. First, this research underscores the crucial role played by the presence of a market for technology in shaping firms' licensing strategy. This has implications both for the literature that has addressed the rationales behind firms' licensing (Gallini, 1984; Rockett, 1990; Anand and Khanna, 2000) and for the literature on innovation and technology exploitation (Teece, 1986; Hsu, et al., 2002). In the former case our paper suggests that in some industries it might be problematic, if not wrong, to analyze firms' licensing strategy in isolation, abstracting from product and technology market dynamics. Indeed, most of this literature has assumed that the licensor is a monopolist technology holder, and this implies setting apart the analysis of all potential interesting interactions in the market for technology. In the latter case our paper offers an approach that is better suited to understand firm's rate of licensing than the extant transaction costs framework. Second, our paper provides one of the few large scale study of the determinants of the rate of licensing. This is particularly valuable in light of the recent trend towards a more widespread use of licensing agreements for the exploitation of the firm's intellectual property.

Our study has several limitations. From an empirical point of view, since we did not have firms' market shares back in the mid 80s we had to reconstruct them using the information on capacity investment provided by our database. Although correlated, installed capacity might not always be a good proxy for market share. More serious is the lack of an appropriate measure of product differentiation. Ideally, this measure should capture how different is the product produced with the process technology of a firm vis-à-vis those produced with the technologies of other potential licensors. In this case, our empirical analysis could benefit from additional data collection, which might require an in-depth analysis of all process technologies available for each of our 139 products. From a theoretically point of view our framework would clearly benefit from a deeper integration of our strategic positioning approach with the transaction costs approach. Ideally, one should be able to predict simultaneously the choice of the governance structure and the extent to which each governance structure is used. We are confident that we will be able to uncover most of these shortcomings in future developments of this line of research. Finally, as far as it concerns the generality of our findings one could easily contend that they are idiosyncratic to the chemical industry. As a partial defense to our work, we could point to the empirical evidence that has shown that industries with large licensing activity, i.e. electronics, biotechnology, semiconductors, are also those that have sufficiently well functioning markets for technology (Arora, et al., 2001). However, only future research would be able to prove whether our findings are industry specific or more generally applicable.

From a more applied point of view, our study suggests that firms that wish to exploit licensing opportunities have to ensure that the tradeoff between licensing revenues and rent dissipation is well managed. This requires educating business managers about the net value added from sale of products versus that from licensing. Licensing revenues are rarely comparable to the revenues from sales of products, but the cost of generating a dollar of licensing revenues is significantly lower than the cost of generating a dollar of product sales. Further, it requires that managers have incentives consistent with those of the firm as a whole. Managers who are rewarded for sales growth or market share will tend to overlook licensing opportunities.

A final cautionary remark is needed. The recent enthusiasm by many industry practitioners and independent consultants about the virtue of licensing might, in some cases, be misplaced. Licensing, especially when triggered by the presence of a market for technology, is a double-edged sword. Although some firms might benefit from aggressive licensing, the final outcome is likely to be increased competition in the product market and less overall industry profits. Attempts to implicitly or explicitly collude in the licensing market, which are relatively common in the chemical industry, confirm the relevance of this remark.

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TABLE 1: DESCRIPTIVE STATISTICS

VARIABLE	**Mean**	**s.d.**	**1**	**2**	**3**	**4a**	**4b**	**4c**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1. Rate of licensing	0.323	1.123													
2. Potential licensors	3.139	3.292	0.24												
3. Market share	0.029	0.085	-0.01	-0.08											
4a. Prod. Diff.: Sub-sector Index	21.046	7.241	-0.09	-0.18	-0.02										
4b. Prod. Diff.: Patents	813.9	1642	0.00	0.03	-0.02	0.18									
4c. Prod. Diff.: Cost per unit of capacity	12.42	36.94	-0.05	-0.07	-0.02	0.61	0.45								
5. Demand growth	1.532	1.737	0.09	0.13	0.01	-0.01	-0.05	-0.04							
6. Potential licensees	12.94	13.52	0.27	0.74	-0.03	0.05	0.26	0.27	0.08						
7. Aggregate sales	10011*	6430	-0.02	-0.02	0.11	0.01	0.05	-0.05	-0.02	-0.03					
8. R&D	555.8*	390.7	-0.06	-0.03	0.12	0.04	0.06	0.03	-0.02	-0.01	0.89				
9. Japanese	0.078	0.268	-0.02	-0.07	-0.07	0.06	-0.05	-0.03	0.06	0.03	-0.24	-0.22			
10. American	0.378	0.485	0.04	-0.02	0.03	-0.01	-0.04	0.05	-0.01	-0.02	-0.15	-0.13	-0.23		
11. Core competence	0.039	0.088	0.10	0.01	0.08	0.17	0.39	0.47	-0.01	0.28	-0.21	-0.14	-0.04	-0.01	
12. Experience	0.343	0.475	0.39	0.30	0.31	-0.07	-0.03	-0.06	0.08	0.27	0.06	0.03	-0.02	0.00	0.05

* In millions of US dollars.

TABLE 2: RATE OF LICENSING BY FIRM I IN PRODUCT J AND GEOGRAPHICAL AREA K

	Negative Binomial			**Poisson**			**Tobit**		
VARIABLE	**Model 1**	**Model 2**	**Model 3**				**Model 2**	**Model 1**	**Model 2**
Constant	-4.685***	-5.630***	-5.546***	-4.866***	-5.557***	-5.491***	-7.654***	-9.265***	-9.098***
Potential licensors	0.137**	0.137**	0.123**	0.154***	0.134**	0.130***	0.211*	0.197*	0.157
Square term	-0.011***	-0.009***	-0.011***	-0.012***	-0.011***	-0.012***	-0.018**	-0.016**	-0.018**
Market share	-7.064***	-6.604***	-7.226***	-6.288***	-5.791***	-6.468***	-13.551***	-12.853***	-14.063***
Product Differentiation									
Sub-sector Index	-0.047***			-0.038***			-0.084***		
Patents		-0.0002***			-0.0004***			-0.0008***	
Cost unit of capacity			-0.018***			-0.017***			-0.037***
Controls:									
Demand growth	0.103***	0.090**	0.091**	0.089***	0.079***	0.084***	0.217***	0.197***	0.197***
Potential licensees	0.025***	0.026***	0.031***	0.026***	0.034***	0.034***	0.043***	0.062**	0.069***
Aggregate sales	0.000**	0.000**	0.000**	0.000***	0.000***	0.000***	0.000**	0.000**	0.000**
R&D	-0.001**	-0.001**	-0.001**	-0.001***	-0.001***	-0.001***	-0.001**	-0.001****	-0.001*
Japanese	-0.180	-0.338	-0.273	-0.388*	-0.489**	-0.453**	0.022	-0.294	-0.134
American	0.263*	0.193	0.248*	0.271***	0.224**	0.267**	0.574*	0.487	0.632**
Core competence	1.430*	3.629***	2.612***	1.075**	3.348***	1.766***	3.382**	7.542	5.807***
Experience	4.352***	4.372***	4.307***	4.341***	4.371***	4.300***	6.594***	6.580***	6.414***
Dummy variables for geographical areas	yes	yes	yes	yes	yes	yes	yes	yes	yes
Number of obs.	1754	1754	1754	1754	1754	1754	1754	1754	1754
Log Likelihood	-774	-776	-769	-874	-869	-858	-862	-860	-854
Chi-squared	656	652	666	1432	1442	1466	633	637	650

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

TABLE 3: RATE OF LICENSING BY FIRM I IN PRODUCT J AND GEOGRAPHICAL AREA K

Variables	**Negative Binomial**		
	Model 1	**Model 2**	**Model 2**
Constant	-4.682^{***}	-5.612^{***}	-5.531^{***}
Potential licensors	0.133^{**}	0.129^{**}	0.115^{**}
Square term	-0.011^{***}	-0.009^{***}	-0.010^{***}
Market share*(1 – DUMjk)	$-8,027^{***}$	-8.220^{***}	-8.789^{***}
Market share*DUMjk	-6.855^{***}	-6.253^{***}	-6.885^{***}
Product Differentiation			
Sub-sector Index	-0.047^{***}		
Patents		-0.0003^{***}	
Cost unit of capacity			-0.018^{***}
Controls:			
Demand growth	0.102^{***}	0.089^{**}	0.090^{**}
Potential licensees	0.025^{***}	0.026^{***}	0.031^{***}
Aggregate sales	0.000^{**}	0.000^{**}	0.000^{**}
R&D	-0.001^{**}	-0.001^{**}	-0.001^{**}
Japanese	-0.175	-0.329	-0.264
American	0.268^{*}	0.202	0.256^{*}
Core competence	1.399^{*}	3.573^{***}	2.543^{***}
Experience	4.353^{***}	4.372^{***}	4.310^{***}
Dummy variables for geographical areas	yes	yes	yes
Number of obs.	1754	1754	1754
Log Likelihood	-774	-776	-769
Chi-squared	656	652	666

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. DUMjk is a dummy variable that takes the value of 1 if the number of potential licensors is positive and zero otherwise.

FIGURE 1: PREDICTED RATE OF LICENSING AND THE NUMBER OF POTENTIAL LICENSORS